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Estimating baseline creatinine values to define acute kidney injury in critically ill pediatric patients

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Background: Acute kidney injury (AKI) is a common complication in critically ill children. However, the common lack of baseline serum creatinine values affects AKI diagnosis and staging. Several approaches for estimating baseline creatinine values in those patients were evaluated.

Methods: This single-center retrospective study enrolled pediatric patients with documented serum creatinine measurements within 3 months before admission and more than two serum creatinine measurements within 7 days after admission to the pediatric intensive care unit of a tertiary care children's hospital between January 2016 and April 2020. Four different approaches for estimating AKI using serum creatinine measurements were compared: 1) back-calculation using age-adjusted normal reference glomerular filtration rates, 2) age-adjusted normal reference serum creatinine values, 3) minimum values measured within 7 days after admission, and 4) initial values upon admission.

Results: The approach using minimum values showed the best agreement with the measured baseline value, with the largest intraclass correlation coefficient (0.623), smallest bias (–0.04), and narrowest limit of agreement interval (1.032). For AKI diagnosis and staging, the minimum values were 80.8% and 76.1% accurate, respectively. The other estimated baseline values underestimated AKI and showed poor agreement with baseline values before admission, with a misclassification rate of up to 42% ($p < 0.001$).

Conclusion: Minimum values of serum creatinine measured within 7 days after hospital admission showed the best agreement with creatinine measured within 3 months before admission, indicating the possibility of using it as a baseline when baseline data are unavailable. Further large-scale studies are required to accurately diagnose AKI in critically ill children.

Keywords: Acute kidney injury, Creatinine, Critical illness, Pediatrics

Introduction

Acute kidney injury (AKI) is a common problem associated with increased adverse outcomes and high mortality in critically ill pediatric patients [1–4]. AKI in children is currently diagnosed using standardized diagnostic criteria derived from those for adults [5–10], most of which use changes in baseline serum creatinine values (SCr-base) or the glomerular filtration rate (GFR) for diagnosing and staging AKI. Ideally, SCr-base accurately reflects a patient's steady-state kidney function before the onset of AKI [11]. However, many patients do not have preadmission SCr-base values in

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their records, which complicates AKI diagnosis and staging [12–14].

In the absence of consensus-based standardized methods for replacing missing SCr-base data, several values have been suggested for estimating a surrogate SCr-base value, including the initial admission SCr values, minimum SCr values during hospitalization, dynamic SCr values during a 7-day or 48-hour window, or back-calculation by imputing an estimated GFR (eGFR) of 75 mL/min/1.73 m^2 with the Modification of Diet in Renal Disease (MDRD) equation or the Chronic Kidney Disease Epidemiology Collaboration formula [13,15–20]. However, those substitutes have mainly been studied and validated in adult populations. Few studies have evaluated the various estimation approaches in critically ill children. Therefore, it is difficult to determine which SCr-base surrogate should be used to evaluate AKI and related clinical outcomes in critically ill pediatric patients.

This study evaluated several approaches for calculating an estimated SCr-base (eSCr-base) value, including methods commonly used in adult patients and those specified and adjusted for use in pediatric patients. The eSCr-base values calculated using different approaches were compared with a reference SCr-base value measured 3 months or less before admission (mSCr-base). The value of the different estimations in diagnosing and staging AKI was also compared.

Methods

Study subjects

This study was a single-center, retrospective cohort study. All critically ill children consecutively admitted to a 14-bed multidisciplinary pediatric intensive care unit (PICU) in Asan Medical Center Children's Hospital, Seoul, Korea between January 2016 and April 2020 were screened. Patients aged 1 month to 18 years with available mSCr-base data, defined as the lowest value measured 3 months or less before PICU admission, and at least two documented SCr measurements within the first 7 days of PICU admission were enrolled. Exclusion criteria were as follows: age of <1 month or >18 years, no available mSCr-base value, known kidney anomalies, preexisting chronic renal failure, dialysis used before PICU admission, PICU stay of <24 hours, and do-not-resuscitate orders (Fig. 1).

This study was approved by the Institutional Review Board of Asan Medical Center (No. 2020-0878), which waived the requirement for informed consent because the study was retrospective. This study was conducted in accordance with the principles of the 1964 Declaration of Helsin-

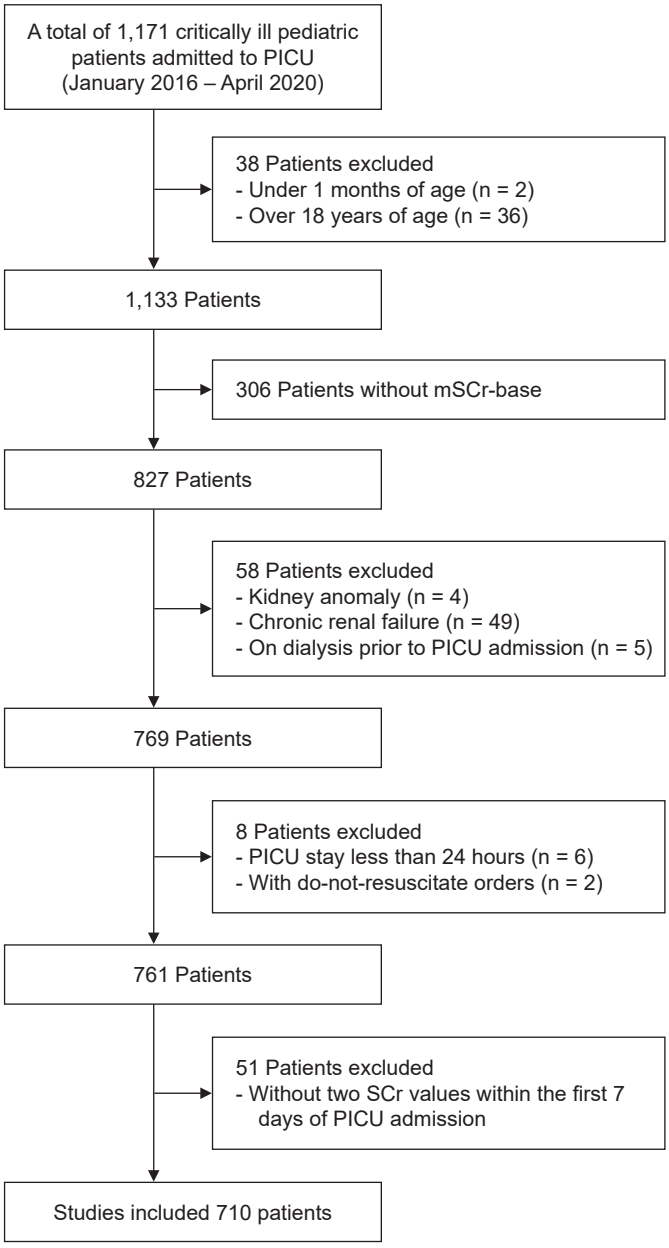

Figure 1. Flow chart for inclusion and exclusion of the study population.
mSCr-base, measured SCr-base (within 3 months prior to admission); PICU, pediatric intensive care unit; SCr, serum creatinine.

ki and later amendments. It also conforms to the Strengthening the Reporting of Observational Guidelines statement for reporting observational studies.

Data collection

We retrospectively reviewed the electronic medical records of all included patients and collected data on their baseline demographic characteristics, underlying disorders, reasons for PICU admission, initiation of continuous renal replacement therapy (CRRT), duration of PICU stay, 28-day mortality rate, and laboratory findings, including SCr values. We evaluated four different methods for calculating an eSCr-base value: 1) back-calculation of SCr values using the age-adjusted normal reference value for eGFR (SCr-eGFR) [21–23] (Supplementary Table 1, available online 2) normal reference values adopted from the pediatric Sequential Organ Dysfunction Assessment (pSOFA) (SCr-ref) [24] (Supplementary Table 1); 3) minimum SCr value measured within 7 days after PICU admission (SCr-min); and 4) initial SCr values measured at PICU admission (SCr-adm). Imputation of SCr-base by back-calculation was performed using the original Schwartz formula because it was derived from SCr measured using the Jaffe method, which is used in our institution [22,25–28]. To evaluate disease severity and organ dysfunction, the Pediatric Risk of Mortality III and pSOFA scores were calculated using the worst documented values within the first 24 hours of PICU admission [24,29].

Study design

The primary outcome was agreement between mSCr-base and the eSCr-base values calculated using the different methods. For this purpose, reliability analyses were performed to assess the intraclass correlation coefficients (ICCs). In addition, descriptive statistics were used to calculate the bias (mean difference) and limit of agreement (LOA), and the results are depicted as scatterplots. The secondary outcome was the performance of the various eSCr-base values in AKI diagnosis and staging. For that purpose, we compared the AKI diagnoses and stages determined using the various eSCr-base values with those made using mSCr-base.

Definitions

AKI was defined as an absolute increase in SCr of 0.3 mg/dL within 48 hours or a > 50% relative increase in SCr compared with "SCr-base" during the first 7 days of PICU admission (higher than stage 1 of the Kidney Disease: Improving Global Outcomes [KDIGO] 2012 criteria) [10]. AKI was diagnosed and classified according to the definition of the KDIGO workgroup, which considers the maximum increase in SCr during the first 7 days of PICU admission. The urine output criteria were not used because of data uncertainty.

Statistical analyses

The data were analyzed using IBM SPSS for Windows, version 21.0 (IBM Corp., Armonk, NY, USA). Continuous variables with a normal distribution are reported as means and standard deviations (SDs), and those with skewed distributions are reported as medians and interquartile ranges (IQRs). Normality was determined using the Kolmogorov-Smirnov test. Categorical variables are expressed as numbers and proportions. The agreement between eSCr-base and mSCr-base was assessed using a reliability analysis with ICCs. The bias and LOA (defined as the bias ± 1.96 × SD), were calculated using descriptive statistics. The performance of the various eSCr-base values in AKI diagnosis and staging was compared with the results with mSCr-base using chi-square testing in a trend analysis. Based on crosstables of the mSCr-base and eSCr-base results, we calculated and report the sensitivity, specificity, positive predictive value (PPV = true positive/[true positive + false positive]), negative predictive value (NPV = true negative/[true negative + false negative]), positive likelihood ratio (PLR = sensitivity/1 – specificity), negative likelihood ratio (NLR = 1 – sensitivity/specificity), misclassification rate, and percent positive agreement. Kappa statistics with 95% confidence intervals (CIs) are used to report the agreement levels. The misclassification rate was evaluated using McNemar test. For all analyses, variables with a two-sided p-value of <0.05 were considered statistically significant.

Table 1. Baseline characteristics of the study population

Variable	Data
No. of patients	710
Male sex	383 (53.9)
Age (mo)	23.0 (7.0–88.0)
Weight (kg)	10.0 (5.7–21.0)
Height (cm)	81.0 (63.0–118.2)
Duration of PICU stay (day)	7 (3–16)
Hospital stay (day)	37 (19–82)
Underlying disease	
Cardiac	200 (28.2)
Hemato-oncologic	158 (22.3)
Gastrointestinal/hepatic	121 (17.1)
Respiratory	83 (11.7)
Neurologic	49 (6.9)
Genetic	44 (6.2)
Endocrinologic	24 (3.4)
Nephrology	11 (1.6)
None	19 (2.7)
Cause of PICU admission	
Respiratory problems	281 (39.6)
Gastrointestinal/hepatic problems	133 (18.7)
Cardiac problems	103 (14.5)
Shock	64 (9.0)
Neurological problems	48 (6.8)
Hemato-oncologic problems	30 (4.2)
Nephrological problems	24 (3.4)
Post-cardiopulmonary arrest	12 (1.7)
Others	15 (2.1)
CRRT within 7 days of PICU admission	48 (6.8)
Presence of AKI	417 (58.7)
Stage 1	166 (39.8)
Stage 2	112 (26.9)
Stage 3	139 (33.3)
Malnutrition	192 (27.0)
28-Day mortality	49 (6.9)
mSCr-base	0.19 (0.17–0.31)
SCr-eGFR	0.49 (0.40–0.66)
SCr-ref	0.40 (0.30–0.70)
SCr-min	0.21 (0.17–0.34)
SCr-adm	0.32 (0.22–0.53)
PRISM III score	9.0 (5.3–14.0)
pSOFA score	6.0 (4.0–8.0)

Data are expressed as number only, number (%), or median (interquartile range).
AKI, acute kidney injury; CRRT, continuous renal replacement therapy; eGFR, estimated glomerular filtration rate; mSCr-base, measured SCr-base (within 3 months prior to admission); PICU, pediatric intensive care unit; PRISM, Pediatric Risk of Mortality; pSOFA, pediatric Sequential Organ Failure Assessment; SCr, serum creatinine; SCr-adm, initial SCr value measured at PICU admission; SCr-eGFR, back-calculation of SCr values using the age-adjusted normal reference value of eGFR; SCr-min, minimum SCr value measured within 7 days after PICU admission; SCr-ref, normal reference SCr values adopted from pSOFA.

Table 2. The ICCs, bias (mean difference), and LOAs between mSCr-base and SCr-eGFR, SCr-ref, SCr-min, and SCr-adm

Estimation method	ICC	Bias	LOA
SCr-eGFR	0.35	−0.27	1.13
SCr-ref	0.34	−0.25	1.19
SCr-min	0.62	−0.04	1.03
SCr-adm	0.57	−0.22	1.68

eGFR, estimated glomerular filtration rate; ICC, intraclass correlation coefficients; LOA, limits of agreement; SCr, serum creatinine; SCr-adm, initial SCr value measured at pediatric intensive care unit admission; SCr-eGFR, back-calculation of SCr values using age-adjusted normal reference value of eGFR; SCr-min, minimum SCr value measured within 7 days after pediatric intensive care unit admission; SCr-ref, normal reference SCr values adopted from the pediatric Sequential Organ Dysfunction Assessment score.

Results

Baseline characteristics of the study population

A total of 710 patients were included. The median (IQR) age and body weight were 23.0 months (7.0–88.0 months) and 10.0 kg (5.7–21.0 kg), respectively. Cardiac (28.2%) and hemato-oncological disorders (22.3%) were the most frequently encountered underlying disorders. Respiratory problems (39.6%) were the most common indication for PICU admission (Table 1). Forty-eight patients (6.8%) required CRRT within the first 7 days of PICU admission. The overall 28-day mortality rate was 6.9%. Of all patients, 27% were malnourished.

Comparison of mSCr-base and eSCr-base

The ICCs between mSCr-base and SCr-eGFR, SCr-ref, SCr-min, and SCr-adm were 0.351, 0.337, 0.623, and 0.571, respectively (Table 2). Fig. 2 shows the degree of agreement between mSCr-base and each eSCr-base value. According to the corresponding measurements of agreement, the largest bias was found between mSCr-base and SCr-eGFR (–0.21). SCr-adm showed the worst agreement with mSCr-base and the widest LOA interval (1.683), whereas SCr-min showed the best agreement, with the smallest bias (–0.04) and narrowest LOA interval (1.032) (Table 2).

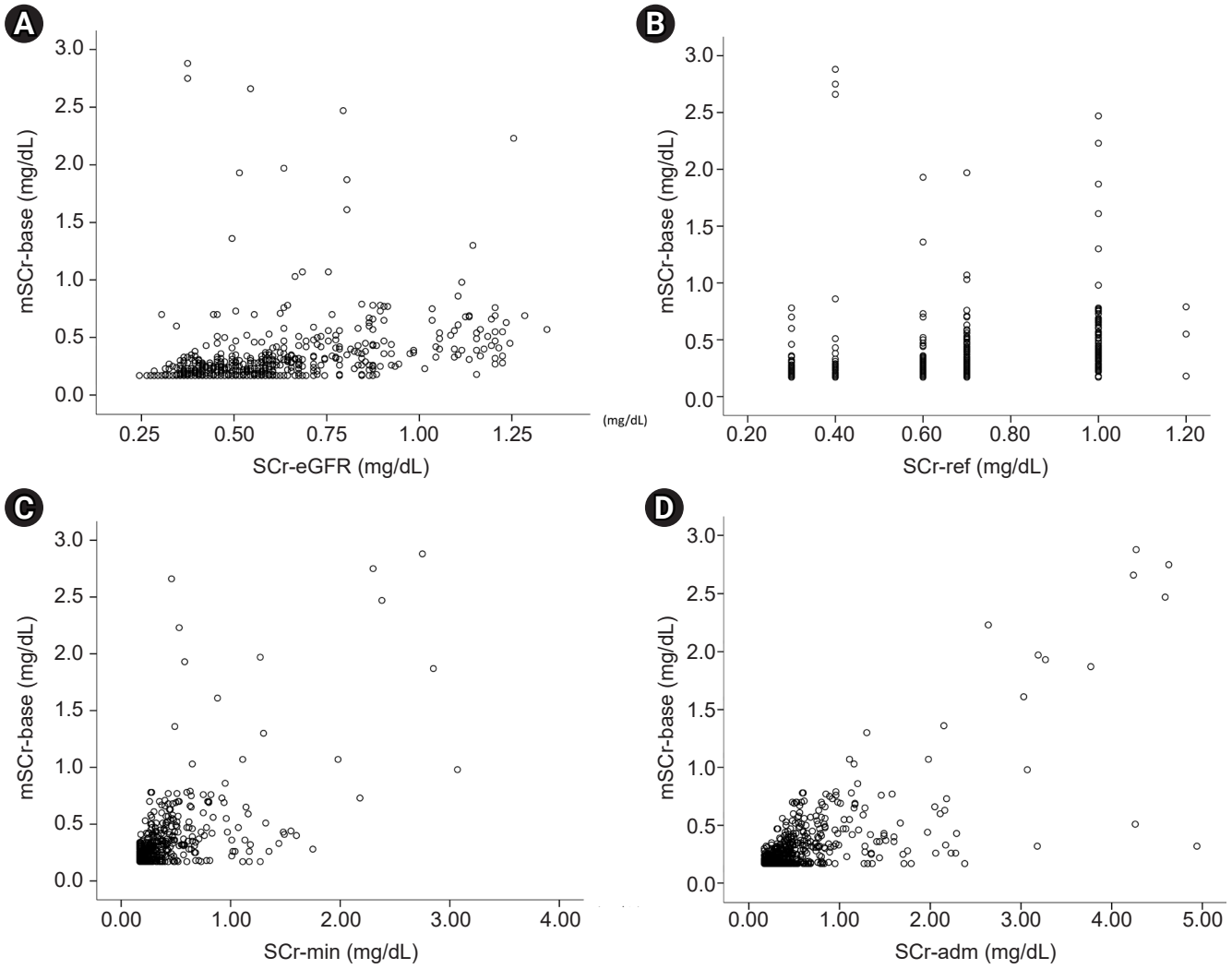

Figure 2. Scatterplots comparing mSCr-base and estimated SCr-base values derived using four different estimating approaches. (A) Back-calculation of SCr values using age-adjusted normal reference values for the eGFR (SCr-eGFR). (B) Normal reference SCr values adopted from the pediatric Sequential Organ Dysfunction Assessment score (SCr-ref). (C) Minimum SCr value measured within 7 days after PICU admission (SCr-min). (D) Initial SCr value at PICU admission (SCr-adm).
eGFR, estimated glomerular filtration rate; mSCr-base, measured SCr-base (within 3 months prior to admission); PICU, pediatric intensive care unit; SCr, serum creatinine.

Evaluation of estimated serum creatinine-based performance

Acute kidney injury diagnosis based on different estimated serum creatinine-based values

The incidence of AKI calculated using mSCr-base was 58.7%, whereas it was overestimated as 63.5% by SCr-min. All other eSCr-base values (SCr-eGFR, SCr-ref, and SCr-adm) underestimated the incidence of AKI (as 19.1%, 22.1%, and 23.8%, respectively). Table 3 presents the sensitivity, specificity, PPV, NPV, PLR, NLR, misclassification rate, percent positive agreement, McNemar test results, and kappa statistics of the various eSCr-base values compared with mSCr-base. Among the eSCr-base values, SCr-min showed the best agreement for AKI diagnosis, with a positive percent agreement of 80.8% and kappa statistic of 0.598 (95% CI, 0.537–0.659).

Table 3. Performance of the tested estimation methods in diagnosing and staging AKI relative to the use of baseline SCr levels measured preadmission

Estimation method	Diagnosis of AKI (%)	Sensitivity (%)	Specificity (%)	PPV	NPV	PLR	NLR	Misclassification rate (%)	Percent agreement (%)	McNemar test (p-value)	Kappa statistics (95% CI)
mSCr-base	58.7										
SCr-eGFR	19.1	31.5	98.3	0.962	0.506	18.437	0.697	40.3	58.7	<0.001	0.26 (0.22–0.31)
SCr-ref	22.1	36.5	98.3	0.968	0.521	21.360	0.647	38.0	62.0	<0.001	0.31 (0.26–0.36)
SCr-min	63.5	87.8	71.0	0.812	0.803	3.025	0.172	19.2	80.8	<0.001	0.60 (0.54–0.66)
SCr-adm	23.8	37.9	96.2	0.935	0.521	10.092	0.645	38.0	62.0	<0.001	0.30 (0.25–0.35)

AKI, acute kidney injury; CI, confidence interval; mSCr-base, measured SCr-base (within 3 months prior to admission); NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value; SCr, serum creatinine; SCr-adm, initial SCr value measured at pediatric intensive care unit admission.; SCr-eGFR, back-calculation of SCr values using age-adjusted normal reference value of eGFR; SCr-min, minimum SCr value measured within 7 days after pediatric intensive care unit admission; SCr-ref, normal reference SCr values adopted from the pediatric Sequential Organ Dysfunction Assessment score.

Table 4. Performance of the tested estimation methods in AKI staging and associated mortality relative to the use of baseline SCr levels measured preadmission

Estimation method	Category	AKI stage				Misclassification rate (%)	Percent agreement (%)	McNemar test	Kappa statistics (95% CI)
		0	1	2	3				
mSCr-base	Staging (%)	41.2	23.4	15.8	19.6				
	28-Day mortality (%)	0.7	1.2	7.1	26.6				
SCr-eGFR	Staging (%)	80.1	6.5	2.5	10.8	49.4	50.8	<0.001	0.22 (0.18–0.26)
	28-Day mortality (%)	2.8	13.0	27.8	28.6	49.3	50.7	<0.001	0.20 (0.16–0.23)
SCr-ref	Staging (%)	77.9	6.6	4.1	11.4	47.9	52.1	<0.001	0.25 (0.20–0.29)
	28-Day mortality (%)	2.9	14.9	13.8	27.2	48.0	52.0	<0.001	0.27 (0.23–0.31)
SCr-min	Staging (%)	36.5	32.8	17.2	13.5	23.9	76.1	<0.001	0.51 (0.46–0.56)
	28-Day mortality (%)	3.1	2.6	11.5	21.9	35.4	64.5	<0.001	0.52 (0.47–0.57)
SCr-adm	Staging (%)	76.2	10.1	4.1	9.6	43.9	56.1	<0.001	0.30 (0.25–0.34)
	28-Day mortality (%)	2.4	12.5	24.1	29.4	44.9	55.1	<0.001	0.32 (0.27–0.37)

AKI, acute kidney injury; CI, confidence interval; mSCr-base, measured SCr-base (within 3 months prior to admission); SCr, serum creatinine; SCr-adm, initial SCr value measured at pediatric intensive care unit admission; SCr-eGFR, back-calculation of SCr values using age-adjusted normal reference value of eGFR; SCr-min, minimum SCr value measured within 7 days after pediatric intensive care unit admission; SCr-ref, normal reference SCr values adopted from the pediatric Sequential Organ Dysfunction Assessment score.

Acute kidney injury staging and associated 28-day mortality rate

Using mSCr-base, 23.4%, 15.8%, and 19.6% of AKI cases were classified as stages 1, 2, and 3, respectively. In the comparison between mSCr-base and the various eSCr-base values, SCr-min showed the best positive percent agreement of 76.1%, with a kappa statistic of 0.510 (95% CI, 0.463–0.557) for AKI staging (Table 4). The 28-day mortality rate showed a statistically significant tendency to increase along with the AKI stage calculated using mSCr-base and all the eSCr-base values ($p < 0.001$). The 28-day mortality data sorted by AKI stage based on SCr-min showed the best agreement with those sorted by mSCr-base, with a positive percent agreement of 64.5% and a kappa statistic of 0.522 (95% CI, 0.474–0.569).

Discussion

In this study, we evaluated four different methods for calculating a surrogate SCr-base value for critically ill pediatric patients and found overall poor agreement with mSCr-base.

No definite consensus-based diagnostic criteria for AKI are available for children; several standardized criteria have been adopted from those used in adults, including the pediatric Risk Injury Failure Loss End-stage Renal Disease (pRIFLE) criteria, the Acute Kidney Injury Network criteria, and the KDIGO criteria [5,7,8,10,30]. Most of those criteria require a baseline kidney function, represented by mSCr-

base or GFR, to make an AKI diagnosis. However, mSCr-base is missing for up to 50% of patients, which makes the accurate evaluation of AKI and associated clinical outcomes difficult [12,13,31]. For patients without mSCr-base data, several previous studies in adults have evaluated different estimation methods [13,15,16,18,32], but the pediatric and adult populations differ in several important, relevant ways. The most widely used approach in the adult population is the imputation method with the MDRD equation, which assumes an eGFR of 75 mL/min/1.73 m^2 [13,16,33]. However, the MDRD equation is inappropriate in children because the normal reference eGFR differs by age, and the age- and growth-dependent reference ranges for SCr and eGFR values in pediatric patients are wide [21,23,34,35]. In this study, we used the age-adjusted normal reference values for eGFR and SCr [21–24] in our SCr-eGFR and SCr-ref, calculations, respectively. Nonetheless, SCr-eGFR and SCr-ref showed poor agreement with mSCr-base. The finding that mSCr-base was smaller than both SCr-eGFR and SCr-ref can be explained using various factors that depend on the conditions of individual patients. Most of the patients included in this study had underlying disorders, most commonly cardiac problems. In addition, 27.0% had severe malnourishment, which could be related to decreased muscle mass. Consequently, assuming that the renal function of critically ill pediatric patients admitted to a PICU is equivalent to that of "normal healthy" children may be inappropriate.

Although the definition of mSCr-base used here, an SCr value measured within 3 months before hospitalization, is the most widely accepted, the use of mean, most recent, or nadir outpatient SCr values at time intervals of up to 730 days before hospitalization has been suggested in adult population studies [11,15,36]. However, in children, the normal reference values can change significantly over time, so using older data could lead to AKI evaluation inaccuracies. Furthermore, the use of data from >3 months of hospitalization could mistakenly suggest chronic renal failure. Therefore, we used SCr values measured within 3 months before hospitalization as mSCr-base.

SCr-min was another eSCr-base method used in this study. Although a strong consensus exists that the lowest SCr value should be used for the SCr-min calculation, the duration within which the lowest SCr value is determined varies among the relevant studies, ranging from the whole hospitalization period to 2 weeks or 3 days after PICU admission [11,13,16,17,31,32,37]. In this study, SCr-min was defined as the lowest SCr value measured within 7 days after PICU admission for the following reasons. First, that time period is consistent with the diagnostic criteria provided by pRIFLE and KDIGO. Second, from a clinical standpoint, a longer time window could impede the prompt evaluation and management of AKI. Third, the condition of pediatric patients admitted to a PICU with temporary AKI caused by dehydration or acute deterioration, often improves dramatically with treatment.

Among the eSCr-base calculation methods tested here, SCr-min showed the best agreement with mSCr-base (i.e., the actual SCr-based value), with the largest ICC, smallest bias, and best percent agreement in AKI diagnosis, staging, and the associated 28-day mortality rate. However, it slightly overestimated the incidence of AKI. The eSCr-base values calculated using the other methods underestimated the incidence of AKI; thus, the diagnosis and staging of AKI based on those calculations were inaccurate, with large misclassification rates.

In adult populations, researchers have suggested several approaches for SCr-base imputation and reported various degrees of agreement between mSCr-base and their eSCr-base calculations. However, the best technique to use remains controversial; no definite universal baseline SCr or eSCr-base method has reached consensus-level support. In addition, some investigators have expressed significant disagreement consistent with our results and suggested the use of recorded SCr values whenever possible [15,32,38].

Critically ill patients in intensive care unit settings differ from the normal healthy population in many important ways that can affect their SCr values, renal function, and AKI evaluation, such as chronic illness, impaired nutritional status, decreased muscle mass, fluid imbalance, and the use of various medications [31]. Likewise, individual characteristics and clinical situations might need to be considered to accurately estimate SCr-base and achieve good agreement with the actual mSCr-base. In this study, SCr-min showed the best agreement with mSCr-base, which suggests that considering individual traits might provide a better estimate of a patient's steady-state than using a value assumed to represent "normal healthy" children.

On the other hand, SCr itself has several drawbacks as a marker of renal function. It is affected by age, sex, ethnicity, dietary factors, and muscle mass. In addition, it is actively

secreted by the proximal tubule, leading to an overestimation of GFR. There is also a time lag between significant renal injury and the elevation of SCr levels. Cystatin C was recently introduced as an alternative endogenous marker of renal function because it is freely filtered by the renal glomerulus, does not have non-renal elimination or glomerular secretion, and is independent of muscle mass. Consequently, cystatin C measurement could provide some advantages in evaluating AKI, especially in critically ill children [39,40]. Large-scale, well-designed studies of pediatric patients are needed to develop pediatric-specific definitions, diagnostic tools, and staging criteria for AKI that use proper markers, including cystatin C.

This study has some limitations. First, it was a single-center retrospective study. Due to the characteristics of the study population, the results might have limited generalizability. Second, in back calculating SCr from eGFR, we used the original Schwartz equation (instead of the revised bedside Schwartz equation) because it was derived from SCr measured using the Jaffe method, which is used to measure SCr in our institution. However, the kinetic Jaffe assay can be affected by factors such as albumin, glucose, and bilirubin in ways that can result in the overestimation of SCr [25,27,41].

Third, mSCr-base was defined as the lowest value within 3 months before PICU admission. All the SCr values included were measured regardless of the patients' status and whether they were drawn in the emergency room or at outpatient clinics. Those values might not fully represent the patients' best normal condition. Fourth, only SCr-based criteria were used for AKI diagnosis and classification. However, a recent report emphasizes that changes in urine output can be helpful for detecting AKI that might be missed when using only SCr criteria [2].

Despite those limitations, this study has several strengths. Its main advantage is that, to the best of our knowledge, it is the first to evaluate different eSCr-base methods in critically ill pediatric patients. In addition to considering methods widely studied and used in adult populations, we examined the characteristics of the children and used age-adjusted normal reference SCr and eGFR values. We further evaluated not only the agreement between each eSCr-base and mSCr-base, but also the clinical performance of each eSCr-base and mSCr-base in AKI diagnosis and staging to determine which method could be most useful in clinical practice. Because this was a single-center study, unified diagnosis and staging using the same criteria and general intensive care were applied consistently throughout the study period, which reduced the number of confounding factors.

In conclusion, the diagnosis and staging of AKI are greatly affected by the SCr-base value used; therefore, the careful selection of an appropriate SCr-base is important. In this study, SCr-min showed the best agreement with mSCr-base in both the actual SCr value calculated and the diagnosis and staging of AKI. However, further large-scale studies are required to establish definite, accurate diagnostic and staging criteria for AKI in critically ill pediatric patients.

Conflicts of interest

No potential conflicts of interest relevant to this article are reported.

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Authors' contributions

Conceptualization: SJP, WKJ
Data curation: YJL, WKJ
Formal analysis: WKJ
Intellectual contributions: YSP
Writing–original draft: YJL, WKJ
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