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Renal Laboratory Abnormalities in Hospitalized Children with COVID-19: A Cross-Sectional Study from a Tertiary Center in Iran

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Running Title: Renal Laboratory Abnormalities in Pediatric COVID-19

Abstract

Background: Although COVID-19 is primarily considered a respiratory infection, accumulating evidence indicates that the kidneys may also be vulnerable to injury, particularly in pediatric patients. Renal dysfunction in children with COVID-19 is often overlooked but may carry important long-term consequences. This study aimed to evaluate kidney function abnormalities in hospitalized children with confirmed COVID-19.
Methods: In this retrospective cross-sectional study, 191 children diagnosed with COVID-19 admitted to Shahid Sadoughi Hospital, Yazd, Iran, were evaluated. Key renal function indicators, including serum creatinine, blood urea nitrogen (BUN), and urinalysis findings, were extracted and compared across age groups and disease severity categories.
Results: Elevated serum creatinine was observed in 13.1% (25 out of 191) of children, with a significantly higher prevalence among children aged ≤3 years (26.1%, 24 out of 92) than in older children (1.0%, 1/99; p<0.001). Among 111 patients with documented disease severity (58.1%), elevated creatinine was more common in non-severe cases (25.3%, 24 out of 95) than in severe/critical cases (6.3%, 1 out of 16), although this difference was not statistically significant (p = 0.114). This severity analysis is exploratory because severity data were missing for 80 patients.
Conclusion: Elevated serum creatinine was common in hospitalized children with COVID-19, even in non-severe cases, especially among children ≤3 years-old. Routine kidney function assessment may help identify children who require monitoring. However, this cross-sectional study cannot determine whether early detection prevents long-term renal sequelae; prospective studies with follow-up are needed.

Keywords: COVID-19; Pediatrics; Blood Urea Nitrogen; Urinalysis; Creatinine

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Introduction

Concurrent with COVID-19 pandemic, it became evident that the virus is not limited to the respiratory system and can significantly affect various organs, including the kidneys [1]. Although children generally experience milder acute symptoms compared to adults, recent findings indicate that the risk of renal outcomes following infection in this age group is considerable [2, 3].

A large cohort study in the United States (n=1,900,146) demonstrated that SARS-CoV-2 infection can increase the risk of developing chronic kidney disease (CKD) and declining kidney function (CKD, stage 2+, HR: 1.17; stage 3+, HR: 1.35), particularly in children who experienced acute kidney injury (AKI) during the acute phase [1]. Such risks persist during long-term follow-up, with elevated hazard ratios (HR) for complex kidney outcomes (≥50% decrease in eGFR, need for dialysis, or end-stage kidney disease) observed at 22-180 days (HR: 1.15) and 181-540 days (HR: 1.14) post-infection [1].

The mechanisms of injury remain under investigation, but may include direct viral cytotoxicity through angiotensin-converting enzyme 2 (ACE2) receptor-mediated damage to renal cells, systemic inflammatory responses that disrupt glomerular hemodynamics, and iatrogenic factors from intensive care interventions [4, 5]. The importance of these findings is amplified in children, as renal disorders at this age are often asymptomatic, and delayed diagnosis can lead to serious consequences

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[1]. Emerging studies suggest that kidney involvement in children with COVID-19 may arise not only from direct viral effects, but also from underlying immunological susceptibility. For instance, certain immunological backgrounds such as inborn errors of immunity (IEIs) or syndromes such as autoimmune polyendocrinopathy-candidiasis-ectodermal dystrophy (APECED) have been associated with nephrocalcinosis, tubulointerstitial nephritis (TIN), and glomerulonephritis, which can predispose children to kidney injury even in the absence of severe systemic disease [6, 7].

Despite numerous studies in adults, data on children, particularly in middle-income countries, such as Iran, remain limited. To address this gap, this study assessed kidney function parameters in children under 12 years old with COVID-19 and analyzed age-related patterns, associations with disease severity, and the occurrence of urinalysis abnormalities.

Materials and Methods

Study Design

This retrospective cross-sectional study was conducted on pediatric patients diagnosed with COVID-19.

Study Setting and Population

The study included 191 children under 12 years old hospitalized at Shahid Sadoughi Hospital, Yazd, Iran, between March 2020 and December 2021. Eligible participants were admitted to pediatric wards, infectious disease wards, or pediatric intensive care units (PICU).

Inclusion and Exclusion Criteria

Inclusion criteria were: (1) age under 12 years, (2) COVID-19 confirmed by PCR or clinical evaluation, and (3) hospitalization during the study period. No exclusion criteria were applied.

Data Collection

Clinical and laboratory data were retrospectively extracted from hospital medical records using a standardized questionnaire. Collected data included demographic information, clinical symptoms, disease severity, serum creatinine, blood urea nitrogen (BUN), and urinalysis findings. COVID-19 severity was classified according to World Health Organization guidelines. COVID-19 diagnosis was based on a positive SARS-CoV-2 PCR or clinical diagnosis by a pediatric infectious disease specialist following national guidelines. eGFR was not analyzed because height was not consistently available in the medical records. AKI was determined according to kidney disease: Improving Global Outcomes (KDIGO) criteria only when a baseline creatinine measurement was available. Because baseline creatinine before admission was often unavailable, elevated creatinine was primarily reported as a laboratory abnormality rather than as confirmed AKI. Therefore, AKI staging was limited and is not reported as a definitive outcome.

Elevated BUN was defined as a value above the source laboratory's upper reference limit (>12 mg/dL). Because age-specific pediatric reference ranges were not uniformly available in the retrospective records, this threshold was used as an operational laboratory definition, and BUN findings are interpreted descriptively.

Statistical Analysis

All statistical analyses were performed using SPSS software (version 26). Categorical variables were summarized as frequencies and percentages. Comparisons of categorical variables were performed using the chi-square test or Fisher's exact test, as appropriate. Fisher's exact test was used when expected cell counts were small. Continuous variables were summarized using mean ± standard deviation for normally distributed variables and median with interquartile range for skewed variables. Categorical variables are reported as frequencies and percentages with 95% confidence intervals where appropriate. Missing data were handled using available-case analysis without imputation. Denominators are explicitly reported for all variables with missing observations. Because disease severity was missing for 80 out of 191 patients (41.9%), severity comparisons were restricted to the 111 patients with documented severity and were considered exploratory. No adjustment for multiple comparisons was made; therefore, subgroup analyses should be interpreted as hypothesis-generating. No sensitivity analysis using imputation was performed.

Results

Serum creatinine level was available for all 191 patients. Elevated serum creatinine was observed in 25 out of 191 patients (13.1%), including 24 children ≤3 years (26.1%) and 1 child in children >3

years (1.0%) (Table 1). Because creatinine values were skewed, mean ± SD is not reported as the primary descriptive measure.

Table 1. Frequency of Elevated Serum Creatinine by Age Group

Age Group	ULN* Creatinine	N	Elevated Creatinine, n (%)
≤3 years	>0.9 mg/dL	92	24 (26.1%)
>3 years	>1.3 mg/dL	99	1 (1.0%)
Total	—	191	25 (13.1%)

* ULN = upper limit of normal.

Serum Creatinine Abnormalities

Elevated serum creatinine was observed in 13.1% of patients (25 out of 191), with a significantly higher prevalence in children ≤3 years (26.1%, 24 out of 92) compared with children >3 years (1.0%, 1 out of 99; $p < 0.001$). Of 25 children with elevated creatinine, 24 (96%) were ≤3 years. This may reflect age-specific thresholds, higher susceptibility in younger children, or both; therefore, age-stratified reporting is essential for interpretation. Among 111 patients with documented disease severity (58.1%), elevated creatinine was observed in 25.3% of non-severe cases (24 out of 95) versus 6.3% of severe/critical cases (1 out of 16); this difference was not statistically significant by Fisher's exact test ($p = 0.114$). Severity data were missing for 80 patients, and the severe/critical subgroup was small (n=16); therefore, this comparison was exploratory and likely underpowered to detect a statistically significant difference.

Table 2. Frequency of Elevated Serum Creatinine by Age Group and Disease Severity*

Category	Normal Creatinine, n (%)	Elevated Creatinine, n (%)	Total, N
Age Group			
≤3 years	68 (73.9%)	24 (26.1%)	92
>3 years	98 (99.0%)	1 (1.0%)	99
Total	166 (86.9%)	25 (13.1%)	**191**
Disease Severity (available cases)			
Non-severe	71 (74.7%)	24 (25.3%)	95
Severe/Critical	15 (93.8%)	1 (6.3%)	16
Total	86 (77.5%)	25 (22.5%)	**111**

*Severity data were available for only 111/191 patients (58.1%); missing severity data were not imputed. Severity comparisons are restricted to this subgroup and should be interpreted as exploratory.

Urinalysis Findings

Among 185 children with available urinalysis (185/191; 96.9%), hematuria was present in 29/185 (15.7%; predominantly mild, 1–10 RBCs/HPF), leukocyturia in 33/185 (17.8%; majority 1–10 WBCs/HPF), and proteinuria in 7/185 (3.8%).

Blood Urea Nitrogen (BUN)

BUN was available for 131 of 191 children (68.6%). Using the source laboratory's pediatric threshold of >12 mg/dL, the only upper reference limit consistently available in the retrospective records, 88/131 children (67.2%) had BUN above this threshold. Because this is not an age-specific ULN and may misclassify BUN status across the pediatric age range, this finding is reported descriptively. Because BUN and disease-severity data were incomplete, no formal analysis of the association between BUN and disease severity was performed.

Chronic Kidney Disease and Mortality

Among 112 children with documented CKD history, 8 had pre-existing CKD. The mortality rate was 25.0% in children with pre-existing CKD versus 3.8% in children without documented CKD. CKD history was missing for 41.4% of children; mortality data for these children were not included in this comparison. Because CKD history was missing for 41.4% of patients and the CKD subgroup was very small, no formal statistical hypothesis testing was performed. This finding is descriptive and should be interpreted cautiously, because of the small number of children with pre-existing CKD and the substantial amount of missing CKD data.

Data Availability

Data availability varied significantly: creatinine was recorded in 100% of patients, BUN in 68.6%, urinalysis in 96.9%, CKD history in 58.6%, and disease severity classification in 58.1%. Missing values were primarily due to incomplete referral records or lack of testing in patients with stable clinical status. All analyses were performed on available cases, and the specific denominators (N) for each subgroup are explicitly reported in the footnotes of Table 2 and Table 3. Severity analyses were restricted to 111 patients with documented severity and are exploratory due to missing data.

Table 3. Summary of Available Data for Key Clinical Variables

Variable	Available Samples	Total Samples	Missing Data
Creatinine	191	191	0%
BUN	131	191	31.4%
Urinalysis	185	191	3.1%
CKD Status	112	191	41.4%
Disease Severity	111	191	41.9%

Discussion

The mechanisms of kidney involvement in COVID-19 are likely multifactorial. Hypothesized pathways include direct viral cytotoxicity through ACE2 receptors on tubular cells and podocytes, immune-mediated cytokine injury, thrombotic microangiopathy, hemodynamic instability, and exposure to nephrotoxic drugs [4, 8]. However, these mechanisms were not directly assessed. Histopathological data in children are limited, as renal biopsy is rarely performed during acute infection, but case series in adults have reported acute tubular injury, endothelial damage, and immune-mediated lesions [4, 5].

This study highlights a considerable prevalence of renal abnormalities among hospitalized pediatric patients with COVID-19, even in those classified as non-severe. Notably, younger children (≤3 years) demonstrated higher rates of abnormal serum creatinine compared to older children. These findings are consistent with recent large-scale studies showing that SARS-CoV-2 infection can negatively impact kidney function in children regardless of initial disease severity.

A comprehensive retrospective cohort study including approximately 1.9 million children and adolescents in the United States showed that COVID-19 is associated with an increased risk of developing CKD and progression of existing CKD. Specifically, children with pre-existing CKD or those who experienced acute kidney injury during the acute phase were more likely to develop adverse kidney outcomes in the post-acute period [1].

Furthermore, a study from South Korea during the Omicron variant wave reported increased kidney involvement among pediatric COVID-19 patients, including those with mild respiratory symptoms [2]. This suggests that even milder COVID-19 cases may have renal implications in children.

Our study also observed elevated BUN levels in a substantial proportion of patients. However, because BUN measurements were unavailable for approximately one-third of the cohort, the clinical significance of this finding requires further investigation.

These findings are consistent with a large pediatric and adolescent cohort in the United States, which reported that SARS-CoV-2 infection was associated with an increased risk of chronic kidney disease and kidney-function decline, particularly in children who experienced acute kidney injury during the acute phase [1]. They also align with pediatric studies from the Omicron era showing kidney involvement even in children with mild respiratory symptoms [2]. Adult data on post-acute kidney sequelae exist, but the present comparison is restricted to pediatric evidence.

Collectively, these results support vigilant renal monitoring in children with COVID-19, regardless of disease severity. Early detection may help identify children who require follow-up. However, because this study was cross-sectional and lacks post-discharge follow-up, it cannot determine whether early detection or management mitigates long-term renal complications.

Clinical Implications

Our findings suggest that serum creatinine, BUN, and urinalysis may be considered at admission in all hospitalized pediatric COVID-19 patients, particularly children ≤3 years and those with pre-

existing kidney disease, irrespective of symptom severity. If abnormalities are detected, repeat testing and early nephrology consultation may be reasonable. However, whether this strategy improves patient outcomes or reduces long-term complications is not established by this cross-sectional study.

Future Research Directions

Future research should focus on prospective multicenter studies including matched non-COVID-19 hospitalized control groups, standardized kidney testing protocols, baseline creatinine measurements to allow KDIGO AKI staging, and tubular injury biomarkers such as NGAL and KIM-1. Long-term follow-up at 1, 3, 6, and 12 months would clarify the persistence of renal dysfunction. Inclusion of renal histopathology when clinically indicated would further elucidate injury mechanisms. Such studies are needed to confirm and extend these findings.

Limitations

This study had several limitations. First, it was a single-center retrospective cross-sectional study, limiting generalizability. Second, BUN values were missing in 31.4% of patients, pre-existing CKD history in 41.4%, and disease severity in 41.9%, largely due to incomplete referral documentation or lack of testing in children with stable clinical status. In addition, BUN was not analyzed with age-specific reference ranges because these were not uniformly available; the single threshold used may misclassify BUN status, particularly in older children. Third, we lacked baseline creatinine measurements before admission in many patients, which limited KDIGO AKI staging; therefore, elevated creatinine was reported as a laboratory abnormality rather than confirmed AKI. Fourth, we lacked systematic post-discharge follow-up data to assess the persistence of renal abnormalities. Fifth, renal biopsy data were unavailable, as renal biopsy is rarely performed during acute systemic infection in children. Finally, the absence of a matched control group of non-COVID-19 hospitalized children limits our ability to attribute these renal findings solely to SARS-CoV-2 infection, rather than to general hospitalization, systemic illness, or other confounding factors. Therefore, our findings should be interpreted as descriptive and hypothesis-generating.

Conclusion

The results of this study demonstrate a relatively high prevalence of elevated serum creatinine in children hospitalized with COVID-19, even in non-severe cases and in those under three years of age. Routine renal screening may be reasonable to identify children who require monitoring. However, this cross-sectional study cannot determine whether screening prevents long-term renal sequelae. Larger multicenter studies with long-term follow-up, baseline creatinine measurements, and novel biomarkers are needed to confirm and extend these findings.

Abbreviations

Abbreviation	Full Form
AKI	Acute Kidney Injury
APECED	Autoimmune Polyendocrinopathy-Candidiasis-Ectodermal Dystrophy
BUN	Blood Urea Nitrogen
CKD	Chronic Kidney Disease
COVID-19	Coronavirus Disease 2019
eGFR	Estimated Glomerular Filtration Rate
HR	Hazard Ratio
IEIs	Inborn Errors of Immunity
KDIGO	Kidney Disease: Improving Global Outcomes
KIM-1	Kidney Injury Molecule-1
NGAL	Neutrophil Gelatinase-Associated Lipocalin
PCR	Polymerase Chain Reaction
PICU	Pediatric Intensive Care Unit
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
TIN	Tubulointerstitial Nephritis
WHO	World Health Organization

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Declaration

Conflict of Interest:
The authors declare no competing interests.

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Availability of Data and Materials:
The data supporting the findings of this study are not publicly available due to ethical and confidentiality restrictions related to retrospective hospital medical records. De-identified data are available from the corresponding authors upon reasonable request and with permission from the Ethics Committee of Ali-Ebne-Abitaleb University of Medical Sciences, Yazd, Iran.

Consent for Publication:
Not applicable. No identifiable personal information is presented in this article.

Ethics Approval and Consent to Participate:
The study protocol was approved by the Ethics Committee of Ali-Ebne-Abitaleb University of Medical Sciences, Yazd, Iran (ethics code: IR.IAU.KHUISF.REC.1401.263). Patient confidentiality was maintained by anonymizing all collected data.

AI Disclosure:
During the preparation of this manuscript, the authors used DeepSeek (version DeepSeek V3) for language editing and to improve the clarity, conciseness, and overall readability of the text. The AI tool was employed solely to refine the writing; no scientific content, data analysis, or interpretation was generated by the AI. All suggestions were critically reviewed and edited by the authors, who take full responsibility for the accuracy, integrity, and originality of the content presented in this publication.

Author Contributions:
AS, AZ, and MK contributed to study conception and design. AZ and MK contributed to data collection and analysis. AS and AZ drafted the manuscript. All authors reviewed and approved the final manuscript.

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