

Original article

Post-COVID Trajectory and Outcomes of Chronic Kidney Disease

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Abstract

Introduction. COVID-19 is a multisystem disease with frequent renal involvement. Acute SARS-CoV-2 infection can precipitate acute kidney injury (AKI) and accelerate chronic kidney disease (CKD), while pre-existing CKD worsens COVID-19 outcomes. We evaluated post-COVID CKD trajectory and key risk factors for CKD progression and adverse outcomes in survivors.

Methods. We performed a retrospective observational study of 1,000 adults hospitalized with COVID-19 at *Timofei Moșneaga* Republican Clinical Hospital (2020-2022). Clinical data and inflammatory, renal and hepatic parameters were collected during acute illness. CKD stage was defined by estimated glomerular filtration rate (eGFR) according to KDIGO. "CKD progression" was defined as transition to a more advanced CKD stage or new-onset CKD stage ≥ 3 during follow-up. Patients with versus without CKD progression was compared, and multivariate models identified independent predictors of CKD progression and mortality.

Results. CKD progression occurred in 30% of patients during a median 12-month follow-up. Progressors were older (median 71 vs 62 years, $p < 0.001$) and more frequently had hypertension (74% vs 62%, $p = 0.005$), type 2 diabetes (27% vs 21%, $p = 0.017$) and cardiovascular disease (31% vs 23%, $p = 0.04$). Comorbidity burden was higher (Charlson index 5 vs 3, $p < 0.0001$). Baseline CKD conferred >2.5 -fold higher risks of mortality and further renal decline than absence of CKD.

Conclusions. COVID-19 was associated with accelerated CKD progression in survivors, especially in older, comorbid patients. Advanced age, hypertension, cardiovascular disease, type 2 diabetes and Charlson index >4 independently predicted poor renal and survival outcomes, supporting close nephrological follow-up and nephroprotective strategies in high-risk post-COVID patients.

Keywords: COVID-19; chronic kidney disease; acute

kidney injury; CKD progression; risk factors; outcomes

Introduction

COVID-19, initially viewed as a respiratory illness, is now recognized as a multisystem disease with long-term organ sequelae [1]. Renal involvement is significant: acute COVID-19 frequently causes acute kidney injury (AKI), reported in ~ 30 -50% of hospitalized patients [1,2], and AKI markedly increases the risk of chronic kidney disease (CKD) development or progression [2,3]. Patients with pre-existing CKD are particularly vulnerable, with COVID-19 mortality more than double that of individuals without kidney disease [3]. Thus, the relationship between COVID-19 and CKD is bidirectional-acute infection may cause persistent renal damage, while underlying CKD worsens COVID-19 outcomes.

Evidence also shows increased long-term renal impairment among COVID-19 survivors, even in the absence of AKI [4,5]. Large cohort studies indicate higher rates of incident CKD and accelerated eGFR decline after COVID-19 compared with other pneumonias [6], especially in older patients and those with hypertension or diabetes [6,7]. These comorbidities further exacerbate kidney injury through inflammatory, hemodynamic, and metabolic mechanisms [3,7].

The concept of "renal long COVID", encompassing new or progressive CKD following SARS-CoV-2 infection, has gained prominence [4,5], though true incidence remains uncertain due to small cohorts, short follow-up periods, and heterogeneous CKD definitions [4,5]. Data from Eastern Europe are particularly limited, despite the global burden of CKD and its major public health implications [1,3,5].

The present study investigated a large cohort of hospitalized COVID-19 survivors with the following objectives: (1) to determine the frequency of AKI occurring during acute COVID-19 and the progression or worsening of pre-existing CKD after recovery, acknow-

ledging that de novo CKD cannot be diagnosed in patients without prior kidney disease within a short post-infectious timeframe; (2) to identify clinical and laboratory predictors associated with AKI development during COVID-19 and subsequent renal function deterioration; and (3) to assess the impact of baseline CKD on COVID-19-related in-hospital mortality. We hypothesized that older patients with multiple comorbidities are at increased risk of AKI during acute infection, accelerated CKD progression after recovery, and poorer clinical outcomes.

Material and methods

Study design and population: We conducted a retrospective observational study of 1,000 adults hospitalized with RT-PCR-confirmed COVID-19 at Timofei Moșneaga Republican Clinical Hospital (Chișinău, Moldova) between March 2020 and December 2022. Inclusion criteria were age ≥ 18 years and availability of post-COVID renal follow-up. Patients on chronic dialysis or kidney transplant recipients were excluded. Pre-existing CKD (stages 1-4) was identified from medical records; CKD was defined as eGFR < 60 mL/min/1.73 m² or structural kidney disease > 3 months per KDIGO.

Data collection: Demographics, comorbidities (hypertension, diabetes, cardiovascular disease, obesity), and Charlson Comorbidity Index were recorded. CVD was defined as coronary artery disease, heart failure, or stroke; obesity as BMI ≥ 30 kg/m². Laboratory data during acute illness included inflammatory markers, renal and hepatic tests. AKI was defined by KDIGO criteria with highest AKI stage was noted. Severity was assessed by ICU admission or mechanical ventilation. After discharge, patients underwent scheduled renal follow-up (creatinine, eGFR, urine tests) at ~3, 6, and 12 months. CKD progression was defined as transition to a more advanced KDIGO stage or new-onset CKD $\geq$ stage 3 in previously healthy patients, and for those with CKD, any stage that increases or $\geq 25\%$ eGFR decline constituted progression. Mortality and

initiation of dialysis were recorded. Median follow-up was ~12 months (IQR 9-15).

Statistical analysis: Patients were stratified into progression vs. non-progression groups. Group comparisons used t-tests or Mann-Whitney U tests for continuous variables and chi-square or Fisher's exact tests for categorical variables (significance $p < 0.05$). Multivariate logistic regression identified independent predictors of CKD progression (age, sex, baseline CKD, hypertension, diabetes, obesity, CVD, Charlson index, AKI). Cox models assessed predictors of mortality, including baseline CKD and CKD progression. Proportional hazards assumptions were met. Results are expressed as ORs or HRs with 95% CIs. Analyses were performed using STATISTICA 9.0 and SPSS 26. **Ethical considerations:** The study was approved by the Nicolae Testemițanu SUMPh Ethics Committee (favorable opinion of the Committee for Research Ethics at no.6 of 18.05.2023). Informed consent was waived due to the retrospective design. All data were de-identified and handled according to the Declaration of Helsinki of 1975, as revised in 2000.

Results

Patient characteristics: Among the 1,000 COVID-19 survivors, the median age was 66 years (22-89; IQR 58-74), and 58% were male. Comorbidities were common: 64% had hypertension, 24% diabetes, and 26% cardiovascular disease. The median Charlson Index was 4 (IQR 3-5). Pre-existing CKD (stages 1-4) was present in 200 patients (20%)-mainly stage 3 ($n=142$) and stage 4 ($n=40$). The remaining 800 patients (80%) had no known CKD ($\text{eGFR} \geq 60$). AKI occurred in 310 patients (31%), and 55 (5.5%) required acute dialysis. In-hospital mortality during acute COVID-19 was 12.3%, and the 1,000 survivors entered follow-up.

AKI and CKD progression after COVID-19: During a median 12-month follow-up, 180/800 (22.5%) patients without prior developed new CKD stage ≥ 3 , and 120/200 (60%) patients with pre-existing worsened CKD by at least one stage. Conversely, 700 patients (70%) showed no progression. Among those without

Table 1. Baseline characteristics of COVID-19 survivors with vs. without CKD progression

Characteristic	AKI Onset+ (n=300)	No AKI Onset+ (n=700)	p-value
Age, years (median, IQR)	71 (65-78)	62 (55-70)	$< 0.001^1$
Male sex, %	60%	57%	0.48
Hypertension, %	74%	62%	0.005
Type 2 Diabetes Mellitus, %	27%	21%	0.017
Cardiovascular Disease, %	31%	23%	0.040
Obesity (BMI ≥ 30), %	29%	26%	0.34
Charlson Comorbidity Index (median)	5 (4-7)	3 (2-5)	< 0.0001
Acute COVID-19 AKI, %	45%	25%	< 0.0001
ICU care for COVID-19, %	22%	15%	0.008
Baseline CKD present, %	40%	11%	< 0.0001

Note: ¹ $p < 0.001$ by Mann-Whitney U test for age (non-normal distribution). Other p-values by chi-square test or t-test as appropriate.

prior CKD, 77.5% maintained normal renal function, while 40% of patients with CKD remained stable.

The comparison between AKI onset and progressors vs non-progressors (Table 1) summarizes the baseline characteristics and acute illness features of patients who developed CKD and who progressed in CKD status versus those who did not. Patients who experienced post-COVID AKI and CKD progression were significantly older than those who did not progress (median age 71 vs 62 years, $p<0.001$). The progression group also had a higher prevalence of key chronic conditions: hypertension was present in 74% of progressors vs 62% of non-progressors ($p=0.005$), diabetes in 27% vs 21% ($p=0.017$), and cardiovascular disease in 31% vs 23% ($p=0.04$). The rate of obesity was slightly higher in the progression group (29% vs 26%) but this difference was not statistically significant ($p=0.34$). Comorbidity burden, as quantified by the Charlson index, was markedly greater in those with CKD progression (median CCI 5 vs 3, $p<0.0001$). A Charlson index >4 (approximately corresponding to having 2 or more significant comorbid conditions) was observed in 58% of progressors, compared to 30% of non-progressors.

Acute COVID-19 course. Severity of the acute illness strongly influenced long-term renal outcomes. AKI occurred in 45% of patients who later developed CKD progression versus 25% of non-progressors ($p<0.0001$). ICU admission was also more common among progressors (22% vs 15%, $p=0.008$). These findings indicate that severe acute disease—particularly AKI—predisposes patients to chronic renal impairment, with older and more comorbid individuals being most affected.

Outcomes: mortality and renal replacement therapy. Overall mortality during follow-up was 8.6% (86/1000), but differed sharply by renal trajectory. Patients with CKD progression had 15.0% mortality (45/300) versus 5.9% (41/700) in non-progressors ($p<0.001$). Baseline CKD was an even stronger determinant: mortality was 20% (40/200) in those with pre-existing CKD vs 5.8% (46/800) without it ($p<0.0001$), representing a ~3.5-fold higher risk. After adjustment, baseline CKD remained an independent predictor (HR ~2.5, 95% CI 1.8–3.5). Most deaths in CKD patients were due to renal failure, cardiovascular events, or infections.

Chronic dialysis was initiated in 27 patients (2.7%), all from the progression group (15 with advanced baseline CKD; 12 with new ESKD after severe AKI). No non-progressors required dialysis. Renal survival curves confirmed significantly worse outcomes in progressors ($p<0.0001$).

Independent predictors of CKD progression. Multivariate analysis identified baseline CKD as the strongest predictor (OR ≈ 3.8 ; 95% CI 2.7–5.4; $p<0.0001$). Age increased risk (OR ~1.5 per decade). Significant comorbidity predictors included hypertension (OR ~1.6; $p=0.01$), cardiovascular disease (OR ~1.4; $p=0.04$), and

poorly controlled diabetes (OR ~1.5; $p=0.03$), particularly with obesity (OR ~2.0). A Charlson index >4 increased risk (OR ~2.2; $p<0.001$). Sex was not predictive. AKI independently increased the odds of CKD progression (OR ~1.9; 95% CI 1.4–2.6; $p<0.001$).

Independent predictors of mortality. In Cox models, CKD progression predicted mortality (HR ~1.88; $p=0.004$), but baseline CKD (HR ~2.5; $p<0.001$) and Charlson index (HR ~1.2 per point; $p<0.001$) remained dominant when analyzed together. Advanced age (HR ~1.5 per decade; $p<0.001$) and cardiovascular disease (HR ~1.7; $p=0.01$) also increased mortality risk. Patients with baseline CKD who subsequently worsened had the poorest overall prognosis.

Discussion

In this cohort of 1,000 survivors hospitalized for COVID-19, CKD progression emerged as a frequent long-term outcome, affecting nearly one-third of patients and supporting the concept of "renal long COVID" [5,10]. Older age, hypertension, diabetes, cardiovascular disease, and higher comorbidity burden were strongly associated with renal deterioration, consistent with risk factors described in prior studies [12,18]. These conditions likely exacerbate SARS-CoV-2-induced inflammatory and hemodynamic injury. Younger patients without comorbidities rarely developed CKD [12,22].

Pre-existing CKD had the strongest impact on outcomes: such patients were over 2–3 times more likely to progress and had significantly higher mortality, aligning with evidence that CKD is a major predictor of severe COVID-19 and death [17,18,23]. CKD may reduce physiological reserve and amplify systemic inflammation, contributing to poor recovery.

The high incidence of CKD progression in our study (30% overall; 22.5% new CKD; 60% CKD worsening) fits within the broad range reported in the literature, though somewhat higher than in studies including milder infections. A scoping review noted new CKD in 0.4–45% and progression in 8–49% of post-COVID cohorts [7,10,22]. Our findings likely reflect the severity of illness, as AKI-present in 31%—is a well-known driver of long-term CKD [10,16,23]. AKI nearly doubled the risk of progression.

Importantly, most patients without traditional risk factors remained free of CKD, suggesting that long-term renal injury is concentrated in vulnerable subgroups [7,15]. Some reports found no CKD development in healthier populations [8,11,19], emphasizing the need for targeted follow-up.

Mortality patterns further illustrate this vulnerability: CKD progression correlated with death, but baseline CKD was the dominant predictor, consistent with large epidemiologic studies [8,12,21]. This highlights CKD as both a consequence and a marker of systemic frailty.

Clinically, all hospitalized COVID-19 survivors-especially older, comorbid patients or those with AKI-should undergo post-COVID renal monitoring, as recommended by expert consensus [13,19,20]. Early nephrology referral and optimization of reno-protective strategies (blood pressure and glycemic control, ACEi/ARB use, avoidance of nephrotoxins, consideration of SGLT2 inhibitors) may mitigate progression. Cardiovascular risk reduction is also essential, given shared pathophysiology.

At a public health level, even small increases in CKD incidence after COVID-19 translate into substantial population-level burden. Estimates suggest hundreds of thousands of new CKD cases globally linked to COVID-19. Health systems must prepare through expanded renal care capacity and structured follow-up programs. *Limitations:* This single-center retrospective study may be limited for its generalizability. Residual confounding is possible, including effects of treatments, viral variants, or vaccination (not stratified). CKD progression was defined by stage or eGFR decline, potentially missing subtle changes, though sensitivity analysis was consistent. Median follow-up was 12 months, so late-onset CKD may be underdetected. Lack of complete proteinuria data limits assessment of full renal involvement.

Conclusions

COVID-19 can have a profound and lasting impact on the kidneys. In our cohort of the survivors from severe COVID-19, nearly one-third experienced new or worsening CKD in the year following their illness. Older age and high comorbidity burden (notably hypertension, diabetes, and cardiovascular disease) were identified as key risk factors for post-COVID CKD progression, and these patients should be targeted for careful renal follow-up. Pre-existing CKD emerged as a critical determinant of outcomes-patients with baseline kidney impairment are not only more prone to further renal decline after COVID-19 but also suffer higher mortality. COVID-19 survivors with these risk factors represent a vulnerable group in whom early nephrological intervention and risk factor optimization may be lifesaving. Our findings reinforce the need for an integrated post-COVID care strategy that includes monitoring of kidney function, in line with recent recommendations. By recognizing those at greatest risk and managing their kidney health proactively, we can hopefully mitigate the long-term toll of the COVID-19 pandemic on CKD and overall patient well-being.

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