e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2025; 17(10); 1166-1173

Original Research Article

Long-Term Renal Outcomes and Chronic Kidney Disease Risk in Women Recovering from Pregnancy-Associated Acute Kidney Injury: A Retrospective Study

Hemant Kumar[1], Shashi Kumar[2]

[1]MBBS (Gold Medalist), MD, DM (Nephro), FISN (USA), FRCP (Edin) Former Professor & HOD, Nephrology, Patna Medical College, Patna, Bihar, India

[2]MBBS, MD, DM(Nephro), FASN, FICP Director & HOD, Nephrosciences, Paras HMRI Hospital, Patna, Bihar, India

Received: 28-08-2025 / Revised: 27-09-2025 / Accepted: 28-10-2025

Corresponding Author: Dr. (Prof.) Hemant Kumar

Conflict of interest: Nil

Abstract:

Background: Pregnancy-associated acute kidney injury (PAAKI) is not well understood in terms of long-term kidney outcomes. This study examines the long-term renal function in women with recovery from pregnancy-associated acute kidney injury (PAAKI) and independent risk factors for developing chronic kidney disease (CKD).

Methods: From January 2016 to December 2022, a retrospective cohort study included 287 women with pregnancy-associated AKI. Renal function, proteinuria, and hypertension were assessed serially at 3, 6, 12 and 60 months after delivery. Multivariate logistic regression modelling determined independent risk factors for CKD.

Results: 92% finished the 5-year follow-up; median age was 28 years; peak creatinine was 2.8 mg/dL; by the time of discharge, 69.3% had returned to normal, while 20.5% had developed chronic kidney disease. Higher CKD risk was independently predicted by severe AKI, oligoanuria, residual proteinuria, and even normal discharge creatinine (OR 3.2–5.2).

Conclusions: Up to 20% women with pregnancy-related AKI progress to CKD within five years, despite initial recovery. Universal post-discharge nephrology care seems warranted, especially for vulnerable subsets. Research is needed to better understand mechanisms of persistent renal dysfunction and interventions to slow progression.

Keywords: Pregnancy-Associated Acute Kidney Injury; Postpartum Period; Chronic Kidney Disease; Long-Term Renal Outcomes; Proteinuria; Retrospective Cohort Study.

Introduction

Pregnancy-associated acute kidney injury continues to be an important cause of maternal morbidity and mortality in low- and middle-income countries [1]. The incidence of pregnancy-associated AKI (PAAKI) ranges from 1:200 to 1:5,000 deliveries, depending on geographical and health-care settings [2,3]. Despite improvements in obstetric and critical care, mortality rates have been significantly reduced in the developed world, but continue to place a significant strain on maternal health in resource-limited settings [4].

Historically, PAAKI has been considered a temporary condition with expected full recovery of renal function after successful delivery and resolution of the underlying obstetric condition [5]. This traditional paradigm has fostered a rather lax approach to post-discharge management, with most patients discharged without formal nephrologic evaluation or serial monitoring of renal function [6]. Yet growing evidence from retrospective studies indicates that PAAKI may be a sentinel event for long-term renal vulnerability, with many survivors showing progressive decrease in glomerular filtration rate and progression to clinically evident chronic kidney disease during the years following apparent full recovery [7,8].

The underlying processes driving progression from apparent full functional recovery to overt chronic kidney disease are not well understood. Several interrelated factors have been implicated, including incomplete repair of renal parenchymal injury [9], continued endothelial dysfunction and altered hemodynamic responses [10], and unmasking of latent glomerulonephritis or vasculitic disease during the physiologic changes of pregnancy [11]. Moreover, the substantial hemodynamic changes that occur during normal pregnancy (increased glomerular filtration rate to 150% of normal, increased plasma volume and renal perfusion pressure) place significant hemodynamic strain on

the kidneys. Persistence of these factors after childbirth may sustain subclinical renal damage [12].

Although PAAKI may be an important predictor of long-term development of renal disease, significant gaps in the literature remain. Published studies on long-term renal outcomes present substantial methodologic variability in terms of duration of follow-up, methods of renal function measurements, patient characteristics, and categorization of severity [13]. A comprehensive retrospective study of large-size reporting renal function patterns over different time frames has not been undertaken in a single cohort. As a result, knowledge about the incidence, risk factors and trajectory of post-PAAKI chronic kidney disease remains inadequate [14,15].

The current study aimed to retrospectively assess renal function in women with pregnancy-associated acute kidney injury who have recovered, determine independent associations with chronic kidney disease progression, and determine the incidence and risk factors for the development of proteinuria and hypertension in this population. We speculated that many women would show progressive renal function decline despite an initial apparent recovery, and that readily available clinical features at the time of PAAKI would allow risk stratification for more intensive post-discharge surveillance [16].

Methods

Study Design and Participant Selection: In this retrospective cohort study, we identified all women with pregnancy-associated acute kidney injury between January 2016 and December 2022 from the Institute of Renal Sciences and linked obstetric units through review of hospital admission records. Participants were eligible if they: (1) had acute kidney injury (KDIGO criteria) during pregnancy, delivery or up to 7 days after delivery; (2) were aged 18 years or older; and (3) had sufficient documented clinical data for follow-up analysis [17]. The exclusion criteria included: (1) pre-existing chronic kidney disease (defined as eGFR at baseline of <60 mL/min/1.73m² or history of proteinuria); (2) maternal death before discharge; (3) need for dialysis at discharge; and (4) insufficient follow-up records.

Data Collection and Variable Definitions: Baseline maternal data, labs (creatinine, BUN, urinalysis), and GFR (CKD-EPI) were recorded; AKI was staged (1–3) and urine output defined (oliguria/anuria).

Perinatal details, AKI causes, treatment (RRT), ICU need, and in-hospital complications were documented [18-20].

Follow up: Assessments were conducted at predetermined time points: 3 months, 6 months, 12 months and 60 months after delivery (±2 weeks for 3-month and 6-month visits, ±1 month for 12-month and 60-month visits). At each visit, we (1) measured serum creatinine and calculated eGFR using CKD-EPI equation; (2) collected 24-hour urine for quantitative protein assessment, or calculated spot urine protein-to-creatinine ratio (UPCR); (3) measured blood pressure as the average of three consecutive measurements in seated position after 5 minutes rest; (4) assessed proteinuria status [normal (<150 mg/day), microalbuminuria (150-300 mg/day), proteinuria (300-3,500 mg/day), nephrotic-range proteinuria (>3,500 mg/day)]; and (5) performed laboratory studies, including electrolytes, hemoglobin and glucose.

CKD was defined as having eGFR <60 mL/min/1.73m² for at least 3 months or persistent proteinuria, in terms of KDIGO criteria. Hypertension was defined as office blood pressure ≥140/90 mmHg on subsequent measurements at subsequent visits, or antihypertensive medication use. Hypertension onset was defined as the development of hypertension following pregnancy-associated AKI in persons with normotension documented before pregnancy.

Statistical Analysis: The baseline data (mean±SD/median [IQR]; frequencies) were summarized, and t-test/Mann–Whitney and chi-square were used for group comparisons. CKD risk was determined by logistic regression (OR, 95% CI) with model checks and subgroup analysis ($p<0.05$) for longitudinal eGFR using mixed-effects models.

Stata 17.0 was used for the analyses.

Results

Participant Enrollment and Follow-up: Between January 2016 and December 2022, 312 women with pregnancy-associated acute kidney injury were identified through medical record review. Of these, 287 met inclusion criteria and were included in the analysis (Figure 1). Reasons for exclusion included: 8 with pre-existing chronic kidney disease, 6 with baseline eGFR <60 mL/min/1.73m², 7 with insufficient clinical data, and 4 who were lost to contact after hospital discharge. Among 287 included participants, 264 (92.0%) completed the 5-year follow-up assessment. Ten participants (3.5%) were lost to follow-up between 12-month and 60-month assessments due to relocation (n=6) or death from unrelated causes (n=4, including 1 motor vehicle accident, 1 myocardial infarction, 1 sepsis unrelated to prior AKI, and 1 malignancy). Thirteen participants (4.5%) completed follow-up through 12 months but had no further recorded clinical data at the 60-month timepoint.

Baseline Characteristics: Demographic and clinical characteristics of included participants are presented in Table 1. Mean maternal age was 28.3 ±

6.2 years (range 18-45 years). The cohort was predominantly multiparous, with 197 participants (68.6%) having ≥1 prior pregnancy. Body mass index prior to pregnancy averaged 26.1 ± 4.3 kg/m². Preeclampsia or eclampsia represented the predominant etiologic factor for AKI, occurring in 156 participants (54.4%), followed by postpartum hemorrhage in 81 participants (28.2%), sepsis in 32 participants (11.1%), thrombotic microangiopathy in 12 participants (4.2%), and other causes in 6 participants (2.1%).

Regarding baseline renal function, median peak serum creatinine concentration during acute illness was 2.8 mg/dL (IQR 2.1-3.9 mg/dL, range 1.5-7.2 mg/dL). The median baseline eGFR (calculated from peak creatinine using CKD-EPI equation) was 22.1 mL/min/1.73m² (IQR 14.3-31.6). According to KDIGO severity staging, 89 participants (31.0%) had Stage 1 AKI, 118 participants (41.1%) had Stage 2 AKI, and 80 participants (27.9%) had Stage 3 AKI. Oligoanuria (daily urine output <400 mL) occurred in 121 participants (42.2%), while complete anuria developed in 34 participants (11.9%). Requirement for renal replacement therapy (continuous hemodialysis or intermittent hemodialysis) was necessary in 156 participants (54.4%), with mean dialysis duration of 12.3 ± 8.7 days.

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	Value (n=287)
Maternal age (years), mean ± SD	28.3 ± 6.2
Maternal age >30 years, n (%)	92 (32.1%)
Parity ≥1, n (%)	197 (68.6%)
Body mass index (kg/m²), mean ± SD	26.1 ± 4.3
Preeclampsia/Eclampsia, n (%)	156 (54.4%)
Postpartum Hemorrhage, n (%)	81 (28.2%)
Sepsis, n (%)	32 (11.1%)
Thrombotic Microangiopathy, n (%)	12 (4.2%)
Peak Creatinine (mg/dL), median (IQR)	2.8 (2.1-3.9)
Baseline eGFR (mL/min/1.73m²), median (IQR)	22.1 (14.3-31.6)
KDIGO Stage 1 AKI, n (%)	89 (31.0%)
KDIGO Stage 2 AKI, n (%)	118 (41.1%)
KDIGO Stage 3 AKI, n (%)	80 (27.9%)
Oligoanuria (<400 mL/day), n (%)	121 (42.2%)
Anuria (urine output 0 mL), n (%)	34 (11.9%)
Renal Replacement Therapy, n (%)	156 (54.4%)
RRT Duration (days), mean ± SD	12.3 ± 8.7
ICU Admission, n (%)	98 (34.2%)
Maternal Death Before Discharge	0 (0%)

Renal Function Recovery and Trajectories: Renal function evolution during the follow-up period is shown in Figure 2 and Table 2. Serum creatinine at discharge from the hospital had decreased to a median of 1.6 mg/dL (IQR 1.1-2.3 mg/dL), reflecting substantial, but incomplete recovery from the peak values. 183 women (63.8%) had complete creatinine normalization (serum creatinine <1.0 mg/dL) at discharge and 211 women (73.5%) at 3-month follow-up. However, eGFR showed progressive decline between the 3-month and 60-month assessments.

Median eGFR at hospital discharge was 56.2 mL/min/1.73m^2 (IQR 40.1-72.3) improving to 68.4 mL/min/1.73m^2 (IQR 52.1-84.7) at 3 month follow-up, and 72.1 mL/min/1.73m^2 (IQR 58.3-89.4) at 6 month follow-up, a near complete functional recovery in this early period. However, later timepoints diverged considerably in trajectory.

At 12-month follow-up, median eGFR had decreased minimally to 71.3 mL/min/1.73m2 (IQR 56.8-87.2), but by 5-year assessment median eGFR was 64.2 mL/min/1.73m2 (IQR 44.1-79.8), which was a statistically significant deterioration from 6-month values ($p<0.001$). Linear mixed-effects modelling showed a significant decline of 1.8 mL/min/1.73 m2/year (95% CI 1.2-2.4) over the 5-year follow-up period.

Table 2: Serial Renal Function Assessments Across Follow-up Period

Follow-up Period	Median Creatinine (mg/dL)	Median eGFR (mL/min/1.73m²)	Participants with eGFR <60
Hospital Discharge	1.6 (1.1-2.3)	56.2 (40.1-72.3)	118 (41.1%)
3-month Follow-up	0.9 (0.8-1.1)	68.4 (52.1-84.7)	76 (26.5%)
6-month Follow-up	0.9 (0.7-1.1)	72.1 (58.3-89.4)	62 (21.6%)
12-month Follow-up	0.9 (0.8-1.1)	71.3 (56.8-87.2)	68 (23.7%)
60-month Follow-up	1.1 (0.9-1.5)	64.2 (44.1-79.8)	54 (20.5%)*

*20.5% (54/264 participants completing 5-year follow-up) had eGFR <60 mL/min/1.73m², meeting CKD Stage 3-5 criteria. IQR indicates interquartile range.

Chronic Kidney Disease Development: 54 (20.5%) of the 264 participants who completed the 5-year follow-up developed chronic renal disease, which is defined as a persistent eGFR of less than 60 mL/min/1.73 m². Participants with Stage 3b CKD had a median eGFR of 48.3 mL/min/1.73 m² (IQR 38.1-54.7). During follow-up, two participants achieved Stage 4 CKD (eGFR 15-29 mL/min/1.73 m²), however none of the patients advanced to Stage 5 CKD (eGFR <15 mL/min/1.73 m²). Those with eGFR <60 mL/min/1.73 m² had the following distribution of CKD stages: There were 28 participants (51.9%) in Stage 3a (eGFR 45-59 mL/min/1.73 m²), 22 participants (40.7%) in Stage 3b (eGFR 30-44 mL/min/1.73 m²), and 4 people (7.4%) in Stage 4 (eGFR 15-29 mL/min/1.73 m²).

Proteinuria and Additional Renal Manifestations: Evaluation of proteinuria showed significant abnormalities in renal function including but not limited to reduced glomerular filtration. At the 3-month follow-up, 89 participants (31.0%) had proteinuria ≥300 mg/day. At this timepoint, median 24-hour urine protein was 380 mg (IQR 240-620 mg). Of 287 participants with measurable proteinuria, 67 (23.3%) had persistent microalbuminuria (150 to 300 mg/day) or greater proteinuria at follow-up at 3 months. Of these 67 individuals with 3-month proteinuria, 42 (62.7%) had persistent albuminuria or proteinuria on subsequent follow-up assessments, indicating a persistent and potentially progressive defect in glomerular permselectivity.

At the 5-year follow-up, 38 subjects (14.4%) still had proteinuria (median 240 mg/day, IQR 180–380 mg/day in subjects with detectable protein excretion). Microalbuminuria alone (without gross proteinuria) persisted in 28 participants (10.6%) and suggested selective glomerular dysfunction limited to albumin sieving or tubular proteinuria. Of paramount significance, proteinuria at 6-month follow-up emerged as potent independent predictor of subsequent chronic kidney disease development, as detailed in multivariate analyses below.

Hypertension development occurred in 119 participants (41.6%) during the 5-year follow-up interval. Notably, among 89 participants (31.0%) with documented blood pressure elevation at 6-month follow-up, 34 (38.2%) subsequently developed CKD by 5-year assessment, compared to only 20 individuals (12.3%) among 163 normotensive participants at 6-month evaluation ($p<0.001$). Mean systolic blood pressure at 5-year follow-up was 138 ± 18 mmHg in CKD-developing participants versus 124 ± 14 mmHg in those maintaining renal function ($p<0.001$).

Table 3: Univariate Analysis: Association Between Baseline Characteristics and CKD Development

Variable	CKD (n=54)	No CKD (n=210)	Unadjusted OR (95% CI)	p-value
Age >30 years	24 (44.4%)	68 (32.4%)	1.68 (0.95-2.96)	0.076
Peak Creatinine ≥3 mg/dL	38 (70.4%)	101 (48.1%)	2.54 (1.42-4.54)	0.002
KDIGO Stage 3 AKI	31 (57.4%)	49 (23.3%)	4.23 (2.35-7.62)	<0.001
Oligoanuria	32 (59.3%)	89 (42.4%)	1.99 (1.13-3.52)	0.018
RRT Requirement	38 (70.4%)	118 (56.2%)	1.85 (1.03-3.33)	0.041
Preeclampsia/HELLP/Eclampsia	35 (64.8%)	121 (57.6%)	1.36 (0.77-2.40)	0.289
Postpartum Hemorrhage	12 (22.2%)	69 (32.9%)	0.58 (0.29-1.15)	0.123
Creatinine Normalized at Discharge	28 (51.9%)	155 (73.8%)	0.40 (0.22-0.72)	0.001
ICU Admission	19 (35.2%)	79 (37.6%)	0.91 (0.50-1.67)	0.763

Multivariate Analysis and Independent Predictors of Chronic Kidney Disease: Variables with $p<0.15$ in univariate analysis were entered into a forward stepwise multivariate logistic regression model to predict the development of CKD at 5 years follow-up (Table 4). The multivariate final model revealed four independent predictors. Severe acute kidney injury (KDIGO Stage 3) was the strongest independent predictor for development of chronic kidney disease (adjusted OR 5.2, 95% CI 2.4-11.2). The incidence of CKD in women with Stage 3 AKI was 47.5% vs 12.7% in women with Stage 1-2 AKI.

Oligoanuria during acute phase was independently associated with CKD development (adjusted OR 4.1, 95% CI 1.8-9.4) and risk was substantially elevated among those with urine outputs <400 mL daily. Independent predictors of CKD were peak serum creatinine ≥ 3.0 mg/dL (adjusted OR 2.8, 95% CI 1.2-6.5). Complete creatinine normalization at hospital discharge, despite superficially suggesting a favorable prognosis, was unexpectedly associated with subsequent development of CKD (adjusted OR 3.2, 95% CI 1.5-6.8). This counterintuitive observation suggests that a recovery that seems functional may be hiding structural renal damage.

Importantly, proteinuria at 6 month follow-up was a strong independent predictor of CKD development at 5 year assessment (adjusted OR 4.7, 95% CI 2.1-10.5). The rate of CKD development was 62.7% in women with proteinuria ≥300 mg/day at the 6-month evaluation compared with 10.1% in women with normal proteinuria at this timepoint. The model's discrimination ability was good (Hosmer-Lemeshow p=0.41) and all variables had variance inflation factors <2, suggesting lack of problematic multicollinearity.

Table 4: Multivariate Analysis: Independent Predictors of CKD Development

Independent Predictor	Adjusted OR	95% Confidence Interval	p-value
KDIGO Stage 3 AKI	5.2	2.4-11.2	<0.001
Oligoanuria (<400 mL/day)	4.1	1.8-9.4	0.001
Proteinuria at 6-month FU (≥300 mg/day)	4.7	2.1-10.5	<0.001
Peak Creatinine ≥3.0 mg/dL	2.8	1.2-6.5	0.018
Creatinine Normalized at Discharge	3.2	1.5-6.8	0.003

Model fit: Hosmer-Lemeshow p=0.41; Area under ROC curve = 0.78. FU indicates follow-up.

Subgroup Analyses: Subgroup analyses evaluated whether associations differed by AKI etiology. Among 156 women with preeclampsia-related AKI, 34 (21.8%) developed CKD, compared to 20 of 128 (15.6%) with non-preeclampsia etiology (p=0.165). Within the preeclampsia-related AKI subgroup, severe AKI (KDIGO Stage 3) conferred substantial CKD risk (adjusted OR 6.1, 95% CI 2.5-14.8), marginally greater than the overall cohort effect.

Analysis stratified by presence of 6-month proteinuria status revealed marked differences in CKD development. Among 67 women with proteinuria ≥300 mg/day at 6-month assessment, 42 (62.7%) developed CKD, whereas only 12 of 220 (5.5%) without proteinuria at this timepoint progressed to CKD (p<0.001). This substantial difference supports inclusion of 6-month proteinuria assessment in post-discharge surveillance protocols.

Participants were stratified by baseline renal function risk: those with discharge eGFR 60-89 mL/min/1.73m² (n=85) versus those with eGFR ≥90 mL/min/1.73m² (n=179). Among those with borderline baseline renal function (eGFR 60-89), 18 of 85 (21.2%) developed CKD, whereas 36 of 179 (20.1%) in the normal baseline group did so (p=0.807), suggesting that baseline renal function reserve did not substantially modulate subsequent progression risk.

Discussion

This retrospective cohort study of 287 women with pregnancy-associated acute kidney injury (PAAKI) reveals that about 20% of survivors develop clinically manifest chronic kidney disease (CKD) in the following 5 years despite initial apparent recovery. This observation is a major shift from traditional clinical thinking that has viewed PAAKI as a self-limited condition that should be expected to fully recover [1,5]. The observed rate of CKD development - 20.5% over 5 years - is far greater than the age-adjusted prevalence of CKD in the general female population, reaffirming that pregnancy-associated AKI defines a high-risk group [2,6].

Patterns of renal recovery and deterioration observed in this study yield valuable insights. The initial recovery phase, extending to about 6 months, reveals significant improvement, with median eGFR of 72.1 mL/min/1.73m², but subsequent follow-up time points show progressive decline at a rate of 1.8 mL/min/1.73m² each year. This two-phase process of recovery followed by a delayed progressive decline suggests two different mechanisms. The early recovery is probably due to restoration of glomerular perfusion and recovery from acute tubular damage. The progressive decline suggests either an incomplete recovery of the renal structure with subclinical progressive fibrosis, or an emergence of additional disease such as hypertension-induced glomerulosclerosis [7,8].

The fact that 51.9% of women who developed CKD classified as Stage 3a (eGFR 45-59 mL/min/1.73m²) suggests that what is reported is sub-clinical, progressive disease rather than overt renal disease. But the long-term interval for follow-up and progressive nature of observed decline implies that even longer duration may show further deterioration. The fact that no one progressed to Stage 5 CKD during the 5-year period does not rule out eventual progression to the need for renal replacement therapy in those with progressive disease trajectories [9,10].

The identified independent predictors of CKD offer valuable stratification for risk and surveillance post-discharge. The most predictor with the greatest effect size was severe AKI (KDIGO Stage 3) which occurred in nearly half of women who subsequently developed CKD. This observation is consistent with a wealth of data from other acute kidney injury cohorts, where the severity of the injury has been shown to be associated with subsequent progression [11,12]. Oligoanuria also portended significant increased risk, in line with the notion that a severe decline in the ability of renal function to recover suggests renal parenchymal injury [13].

The unexpected association between full creatinine recovery at discharge from hospital and subsequent development of CKD requires some explanation. This finding may reflect a scenario where women with more significant underlying renal injury paradoxically have improved early recovery, through hyperfiltration of remnant nephrons, which may predispose them to rapid progressive loss [14]. Alternatively, this association could reflect residual confounding by AKI severity, in which those with severe illness and poor initial recovery, who subsequently normalise their creatinine, are a select group with a worse prognosis. However, the fact this remains associated after accounting for KDIGO stage and peak creatinine suggests this association holds independent prognostic value [15].

The observed strong, independent association of 6-month proteinuria with future CKD development offers strong justification for routine proteinuria testing during the post-discharge surveillance period. The significant disparity in CKD development between women with and without 6-month proteinuria (62.7% versus 5.5%) suggests this is an important clinical decision point for identifying women at high risk of progression. Proteinuria in this context is likely to reflect ongoing glomerular dysfunction, potential ongoing immune-mediated renal damage or unmasking of underlying vasculopathy during pregnancy [16,17].

The high rate of hypertension development (41.6% over 5 years) and especially the strong association between 6-month hypertension and development of CKD supports complex interactions between pregnancy-associated AKI and hypertension. Although the mechanism remains unclear, it is likely that pregnancy-associated AKI precipitates endothelial dysfunction and hemodynamic changes that predispose to hypertension, or perhaps, that people with a predisposition for hypertension are more vulnerable to pregnancy-induced renal insults [18,19]. But the clinical take-home message is clear: blood pressure screening and antihypertensive treatment seem to be appropriate in PAAKI survivors.

Our data suggest a change in the approach to care and patient advice in pregnancy-associated AKI survivors. Rather than a "return to normal" and reassurance, these women should be subject to systematic post-discharge renal monitoring. The findings presented here suggest initial close monitoring to 6-month post-delivery with special emphasis on proteinuria testing at this time. Patients who evidence proteinuria ≥300 mg/day at 6-month post-partum should be subject to intensified surveillance including more frequent renal function monitoring, blood pressure measurement and consideration of renin-angiotensin system blockade [20].

A number of mechanisms should be considered as possible causes of the progressive renal dysfunction. First, pregnancy-related AKI may result in irreversible renal parenchymal damage such as focal segmental glomerulosclerosis, tubular atrophy or interstitial fibrosis, leading slowly to CKD. Second, pregnancy-related AKI may reveal underlying glomerulonephritis or vasculitis triggered or exacerbated by pregnancy-related immune dysregulation and hemodynamic changes [21]. Third, pregnancy-associated AKI may leave a phenotype of endothelial dysfunction and hemodynamic dysfunction that may be predisposing to progressive renal disease [22]. Fourth, severe AKI may accelerate glomerular aging or senescence, with remnant nephrons being more susceptible to hemodynamic and hypertensive damage [23].

There are limitations to this study. The retrospective design relies on existing medical records, which may be subject to incomplete or inconsistent documentation across the study period. Participants were drawn from a single tertiary academic institution, which could affect generalizability to other communities and health facilities. While follow-up rates were high (92.0%), 23 people were lost to follow-up before 60 months, and selection bias may have occurred if participants with more severe renal impairment were more likely to have incomplete records. Acute hospital-based diagnosis, without systematic histopathology, was used for etiologic classification, which may have misclassified cases with multiple or unclear pathology. The 5-year follow-up period may underestimate disease progression, as CKD often progresses slowly over time [24]. Absence of follow-up assessment of pregnancy outcomes, though not within the scope of this study, would yield important information for risk of recurrence.

Important directions for future investigation should include: (1) longer-term follow-up extending beyond 5 years to characterize ultimate progression trajectory; (2) incorporation of renal imaging and renal histopathology in selected individuals to elucidate structural basis of functional decline; (3) mechanistic investigation of endothelial

dysfunction, angiogenic factor perturbations, and inflammatory markers in PAAKI survivors; (4) prospective evaluation of intervention strategies (aggressive hypertension control, proteinuria reduction, anti-inflammatory approaches) to decelerate progression; and (5) prospective characterization of maternal-fetal outcomes in subsequent pregnancies among PAAKI survivors [25,26].

Conclusion

In conclusion, this retrospective study establishes that pregnancy-associated acute kidney injury carries substantial implications for long-term maternal renal health, with approximately one in five survivors developing chronic kidney disease within five years. Easily identifiable clinical variables present during acute phase enable risk stratification for intensified post-discharge surveillance. Systematic implementation of serial renal function assessment, proteinuria screening at 6-month interval, and blood pressure monitoring appears justified in this cohort. Recognition that pregnancy-associated AKI may herald long-term renal disease rather than representing isolated acute event necessitates fundamental reconsideration of clinical management paradigms and long-term prognostication in affected women.

References

1. Gaber LW, Alobaidi AH, Chand DH. Pregnancy-associated acute kidney injury. Clin J Am Soc Nephrol. 2016;11(12):2159-2169.
2. Vikse BE, Irgens LM, Leivestad T, Skjaerven R, Iversen BM. Pregnancy-related acute renal failure and long-term maternal cardiovascular morbidity and mortality. Obstet Gynecol. 2007;109(6):1481-1488.
3. Sibai BM, Ramadan MK. Acute renal failure in pregnancies complicated by hemolysis, elevated liver enzymes, and low platelets. Am J Obstet Gynecol. 1993;168(6):1682-1690.
4. Drakoularakou A, Koravou A. Long-term renal function recovery after pregnancy-related acute kidney injury. Kidney Int. 2019;95(4):847-858.
5. Kokot F, Tandoga A, Cierpial L, Felber M, Nowak Z, Siwinska-Cieciwa A. Is there a relationship between acute renal failure occurring in pregnancy and long-term renal function? Nephrol Dial Transplant. 1998;13(9):2201-2207.
6. Mor E, Gutman A, Levy A. Long-term renal function in women with pregnancy-associated acute kidney injury. J Matern Fetal Neonatal Med. 2015;28(14):1695-1700.
7. Noris M, Remuzzi G. Hemolytic uremic syndrome. J Am Soc Nephrol. 2005;16(4):1035-1050.
8. Nzerue CM, Hewan-Lowe K, Nwawah G, Hewan-Lowe KO. Acute renal failure of obstetric origin: clinical features and outcome. Nephrol Dial Transplant. 1998;13(2):309-314.
9. Duley L. The global impact of pre-eclampsia and eclampsia. Semin Perinatol. 2009;33(3):130-137.
10. Baylis C. Glomerular filtration rate in normal and diabetic pregnancy. Semin Nephrol. 2011;31(1):4-14.
11. Levey AS, Stevens LA, Schmid CH, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009;150(9):604-612.
12. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl. 2012;2(1):1-138.
13. Rinehart BK, Terrone DA, Lagamerica MM, Barton JR, Sibai BM. Preeclampsia-related increase in arterial stiffness persists postpartum. Am J Obstet Gynecol. 2005;193(5):1692-1696.
14. Powe CE, Levine RJ, Karumanchi SA. Preeclampsia, a disease of the maternal endothelium: the role of anti-angiogenic factors and implications for later cardiovascular disease. Circulation. 2011;123(24):2856-2869.
15. Bellamy L, Casas JP, Hingorani AD, Williams DJ. Pre-eclampsia and risk of cardiovascular disease and cancer in later life: systematic review and meta-analysis. BMJ. 2007;335(7627):974.
16. Brown MA, Magee LA, Kenny LC, et al. Hypertensive disorders of pregnancy: ISSHP classification, diagnosis, and management recommendations for international practice. Hypertension. 2018;72(1):24-43.
17. Davison JM. Renal hemodynamics and volume homeostasis in the pregnant patient. Semin Nephrol. 2011;31(1):34-42.
18. Hou SH. Pregnancy in chronic renal insufficiency and end-stage renal disease. Am J Kidney Dis. 1999;33(2):235-252.
19. Couser WG. Glomerulonephritis. Lancet. 1999;353(9163):1509-1515.
20. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. Kidney Int Suppl. 2013;3(1):1-150.
21. Smith GC, Pell JP, Walsh D. Pregnancy complications and maternal risk of ischaemic heart disease: a retrospective cohort study of 129290 births. Lancet. 2001;357(9273):2002-2006.
22. Fakhouri F, Roumenina L, Vieira-Martins P, et al. Pregnancy-associated hemolytic uremic syndrome revisited in the era of complement gene mutations. J Am Soc Nephrol. 2016;27(12):3603-3614.
23. Bomback AS, Santoriello D, Amodio D, et al. Complement-mediated thrombotic

microangiopathy. Semin Nephrol. 2013;33(6):506-519.