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Timing of Kidney Replacement Therapy and Clinical Outcomes in Severe Acute Kidney Injury in Kinshasa

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ABSTRACT

Introduction
Severe acute kidney injury (AKI) requiring kidney replacement therapy (KRT) carries high mortality in resource-limited intensive care units (ICUs). Where care relies largely on out-of-pocket payments, intervals between KRT indication and initiation are often prolonged, yet empirical evidence from Central Africa remains scarce.

Purpose
To evaluate the association between time from KRT indication to initiation and both ICU mortality and renal recovery among critically ill adults with severe AKI in a referral hospital in Kinshasa, Democratic Republic of the Congo.

Methods
We conducted a retrospective, single-centre pilot study in the ICU of Centre Hospitalier Mère et Enfant (CHME) Monkole (January 2024–May 2026). Adults with Kidney Disease: Improving Global Outcomes (KDIGO) stage 2 or 3 AKI and a documented KRT indication were eligible. Time zero (T_0) was the recorded indication timestamp, excluding immediate life-threatening dialysis emergencies lacking a discrete decision-to-treatment interval. Patients were categorized as early (≤ 24 hr), delayed (> 24–48 hr), very delayed (> 48 hr), or no KRT. The primary outcome was ICU mortality; renal recovery among survivors was secondary. Prior to analysis, a record-linkage audit was performed on the extraction database. Given sample constraints, analyses were descriptive using exact 95% confidence intervals (CIs) and nonparametric tests.

Results
Across 160 database records, linkage identified 14 unique patients (median age 60.5 yr; median APACHE II score 16.0): seven early, two delayed, one very delayed, and four no KRT. Overall ICU mortality was 5/14 (35.7%; 95% CI [12.8, 64.9]): 3/7 (42.9%) early, 0/2 (0.0%) delayed, 1/1 (100.0%) very delayed, and 1/4 (25.0%) no-KRT (p = .55). Renal recovery occurred in 4/4 (100.0%) early survivors and 3/3 (100.0%) no-KRT survivors; in the delayed group, 1/2 (50.0%) recovered and one lacked assessment (1/1 assessed). The very delayed patient died. Non-survivors had higher APACHE II scores than survivors (median 19.0 vs. 13.0; p = .032), whereas age did not differ (median 63.0 vs. 55.0 yr; p = .46). Five deaths precluded multivariable modelling.

Conclusion
In this small single-centre pilot series, a link between KRT timing and mortality could neither be confirmed nor excluded; baseline illness severity appeared more closely related to death than timing. Time-stamped bedside triage protocols and pre-financing mechanisms should be implemented and tested in prospective multicentre studies.

INTRODUCTION

Acute kidney injury (AKI) is one of the most frequent and life-threatening complications encountered in the intensive care unit (ICU) and, in its most severe forms requiring kidney replacement therapy (KRT), carries a substantial risk of death (Bellomo et al., 2012; Kellum et al., 2021). According to the Kidney Disease: Improving Global Outcomes (KDIGO) clinical practice guidelines, AKI is defined by an increase in serum creatinine of at least 0.3 mg/dL (⩾ 26.5 µmol/L) within 48 hr, an increase to at least 1.5 times baseline within 7 days, or a urine output below 0.5 mL/kg/hr for at least 6 hr, and is staged from 1 to 3 by increasing severity (KDIGO Acute Kidney Injury Work Group, 2012).

The optimal timing of KRT initiation in severe AKI remains a subject of active clinical debate. The Artificial Kidney Initiation in Kidney Injury (AKIKI) trial found no significant difference in 60-day mortality between early and delayed initiation strategies, noting that nearly half of the patients in the delayed arm recovered spontaneously without ever requiring dialysis (Gaudry et al., 2016). While the single-centre Early Versus Late Initiation of Renal Replacement Therapy in Critically Ill Patients With Acute Kidney Injury (ELAIN) trial reported lower 90-day mortality with early initiation (Zarbock et al., 2016), both the Initiation of Dialysis Early Versus Delayed in the Intensive Care Unit (IDEAL-ICU) trial in patients with septic shock (Barbar et al., 2018) and the multinational Standard Versus Accelerated Initiation of Renal-Replacement Therapy in Acute Kidney Injury (STARRT-AKI) trial (STARRT-AKI Investigators, 2020) demonstrated no survival advantage for an accelerated strategy; notably, the STARRT-AKI trial observed greater dialysis dependence at 90 days in the accelerated arm. An individual-patient-data meta-analysis further confirmed the absence of a survival benefit with early initiation (Gaudry et al., 2020). However, the subsequent AKIKI 2 trial demonstrated that postponing KRT well beyond standard delayed-strategy criteria was associated with an increased hazard of death (Gaudry et al., 2021). Taken together, these findings indicate that once an unambiguous clinical indication exists, prolonged deferral of KRT may be deleterious.

Crucially, these landmark trials were conducted in high-income health systems where dialysis is available on demand, meaning treatment timing reflects clinical judgement rather than material constraints. In low- and lower-middle-income countries, publicly funded KRT that is free at the point of care is the exception: in a multinational survey, only 28.0% of such countries reported publicly funded haemodialysis, and the annual cost of treatment substantially exceeded average per capita income (Nkunu et al., 2024). Access to acute dialysis is therefore inequitable and heavily dependent on a patient's immediate ability to pay (Mehta et al., 2015). Across sub-Saharan Africa, reported outcomes of AKI vary markedly by setting (Olowu et al., 2016). Recent hospital-based cohorts documented in-hospital mortality rates of 56.6% among adults with dialysis-requiring AKI in Johannesburg, South Africa (Naidu et al., 2025), 26.1% among patients dialysed for AKI in western Kenya (Demba & Aradi, 2025), and 46.7% at 3 months among critically ill adults with AKI in Dodoma, Tanzania (Danda et al., 2026). In Cameroon, access to dialysis among patients with an indication ranged from 23.3% to 73.1% depending on institutional resources (Teuwafeu et al., 2022).

In the Democratic Republic of the Congo (DRC), AKI is an established independent predictor of mortality among critically ill patients in Kinshasa (Masewu et al., 2016). Cohort studies have reported mortality rates of 52.5% in a Kinshasa ICU during the COVID-19 pandemic (Nlandu et al., 2023) and 25.2% among patients receiving haemodialysis for AKI in Goma (Kahindo et al., 2022). Because the Congolese health system is financed predominantly through direct out-of-pocket payments without universal health coverage, the interval between KRT indication and initiation is largely governed by non-clinical barriers. Once the ICU team records an indication for KRT, the patient's family must mobilize funds to purchase a dialysis catheter, consumables (dialyser, bloodlines, and dialysate concentrate), and individual sessions—a process that can take from several hours to several days. Concurrently, consumables are not consistently stocked on site and often require external procurement, while the number of dialysis machines available for ICU deployment is limited. Consequently, the indication-to-initiation interval reflects a sequence of

financial and logistical bottlenecks rather than an intentional watchful-waiting strategy.

Empirical data examining the relationship between time to KRT and clinical outcomes in resource-limited African ICUs remain scarce, and, to our knowledge, no study has investigated this question in Kinshasa. Therefore, we aimed to evaluate the association between the interval from KRT indication to treatment initiation and both ICU mortality and renal recovery among critically ill adults with severe AKI in a referral ICU in Kinshasa. We hypothesized that a longer interval between KRT indication and initiation would be associated with higher ICU mortality, independent of baseline illness severity.

METHODS

Study Design, Setting, and Reporting

We conducted a retrospective, single-centre, observational study in the ICU of the Centre Hospitalier Mère et Enfant (CHME) Monkole, a tertiary referral hospital in Kinshasa, DRC, equipped with an on-site haemodialysis unit and an electronic medical record (EMR) system. This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (von Elm et al., 2007). Because of the small final sample size (see *Sample Size and Power*), the investigation is presented as a descriptive pilot study.

Study Period and Data Extraction

The study period encompassed all ICU admissions from January 1, 2024, to May 31, 2026. Data were retrospectively extracted from archived CHME Monkole ICU medical records between June and July 2026, following institutional ethics approval (May 15, 2026) and the conclusion of the clinical observation window. All endpoints (ICU mortality or discharge and renal recovery assessments) were ascertained from completed medical records at the time of extraction; no prospective patient follow-up was conducted.

Study Population and Sampling

All ICU records meeting eligibility criteria during the 29-month study period were screened via exhaustive, consecutive sampling. Inclusion criteria were age ≥18 yr, admission to the CHME Monkole ICU during the study period, KDIGO stage 2 or 3 AKI, and a formally documented medical indication for KRT. Exclusion criteria were pre-existing end-stage kidney disease requiring chronic maintenance dialysis prior to admission and incomplete records in which the interval between time zero (T_0) and the first KRT session could not be determined. Non-inclusion criterion: KRT initiated for an immediately life-threatening emergency (e.g., refractory hyperkalaemia accompanied by malignant arrhythmia) in which no discrete decision-to-treatment interval existed. Only patients with an interpretable KRT status (documented modality and session count, or explicit confirmation that KRT was not performed) were included in the final analysis.

Sample Size and Power

The original study protocol was designed as a multicentre investigation across six ICUs in Kinshasa. The target sample size was calculated using the formula for comparing two independent proportions, assuming an ICU mortality rate of 55.0% in the delayed-initiation reference group and 41.0% in the early-initiation comparison group, with a two-sided $\alpha = .05$ ($Z = 1.96$) and 90% statistical power ($Z = 1.28$). This yielded 273 patients per group (546 total), which was inflated by 10% to account for incomplete records, resulting in a target of approximately 620 records. Re-computation under identical parameters yields 262 to 280 patients per group depending on the application of pooled variance and continuity correction, confirming the accuracy of the initial protocol estimate.

The final achieved sample of 14 unique patients fell substantially short of this target for three primary reasons. First, due to logistical feasibility constraints (unequal administrative access to records, heterogeneous documentation systems across hospitals, and the timeline of a medical specialization thesis), data collection was restricted to the CHME Monkole ICU, whose EMR system permitted reliable timestamp and outcome extraction. Second, the absolute volume of critically ill adults presenting with a documented KRT indication at a single centre over 29 months was inherently low. Third, a rigorous record-linkage audit revealed that the 160 raw entries in the extraction database represented only 14 unique patients. Consequently, the study lacks statistical power for formal hypothesis testing; with 14 patients, the exact 95% CI around an observed mortality rate of 35.7%

spans 12.8% to 64.9%. All findings are therefore reported descriptively, and all p values are strictly exploratory.

Definition of Acute Kidney Injury

AKI was defined and staged according to the 2012 KDIGO clinical practice guideline based on serum creatinine trajectories and urine output criteria (KDIGO Acute Kidney Injury Work Group, 2012). Only patients with KDIGO stage 2 or 3 AKI—the clinical stages at which KRT is standardly evaluated—were eligible for inclusion.

Indications for Kidney Replacement Therapy

The clinical decision to prescribe KRT was made at the bedside by the attending ICU physician; systematic nephrology co-assessment was not uniformly documented across all cases. Indications were recorded according to one or more prespecified clinical or biochemical criteria: refractory hyperkalaemia (> 6.5 mmol/L), refractory pulmonary oedema, severe metabolic acidosis, overt uraemic complications (e.g., encephalopathy, pericarditis), severe azotaemia (serum urea > 40.0 mmol/L), or prolonged anuria/oliguria unresponsive to initial haemodynamic resuscitation (KDIGO Acute Kidney Injury Work Group, 2012). Indication categories were not mutually exclusive.

Exposure: Time to Kidney Replacement Therapy

Time zero (T_0) was defined per protocol as the exact date and clock time at which the treating ICU team formally documented the indication for KRT, excluding immediately life-threatening emergencies lacking a discrete decision-to-treatment interval. Time to KRT was calculated in hours as the elapsed interval between T_0 and the initiation timestamp of the first KRT session, with both timestamps extracted directly from clinical records. Patients were categorized into four exposure groups: early KRT (≤ 24.0 hr), delayed KRT (> 24.0 to ≤ 48.0 hr), very delayed KRT (> 48.0 hr), or no KRT despite a documented medical indication.

Outcomes

The primary outcome was all-cause ICU mortality. Secondary outcomes included renal recovery, ICU length of stay, total number of KRT sessions, and KRT-related complications. In accordance with Acute Disease Quality Initiative (ADQI) 16 consensus recommendations (Chawla et al., 2017), renal recovery was defined as sustained cessation of KRT for ≥ 28 days without resumption, accompanied by at least one of the following biochemical or clinical criteria: serum creatinine ≤ 125% of baseline, estimated glomerular filtration rate ≥ 60 mL/min/1.73 m^2, urine output > 500 mL/24 hr} without diuretics or > 1,000 mL/24 hr with diuretics, normalized serum potassium, serum bicarbonate > 18.0 mmol/L, or stable serum urea and creatinine concentrations. Because renal recovery cannot be evaluated in decedents, it is reported using (a) all ICU survivors per group as the denominator (primary presentation) and (b) survivors with a documented follow-up renal assessment as the denominator (secondary presentation). Intradialytic hypotension was defined as a nadir systolic blood pressure < 90 mmHg when pre-dialysis systolic blood pressure was < 160 mmHg, or < 100 mmHg when pre-dialysis systolic blood pressure was ≥ 160 mmHg. Catheter-related bloodstream infection was defined per 2019 Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines as clinical signs of infection paired with at least one positive blood culture and no alternative identifiable source (Lok et al., 2020).

Data Collection

Trained physician investigators extracted data from anonymized medical files using a standardized electronic case-report form deployed on smartphones and synchronized directly to a central database. The instrument comprised eight structured modules: (1) anonymized patient identifiers; (2) admission demographics, comorbidities, and Acute Physiology and Chronic Health Evaluation (APACHE) II severity scores (Knaus et al., 1985); (3) serial laboratory parameters at T_0, T_0 + 24 hr, T_0 + 48 hr, T_0 + 72 hr, and T_0 + 96 hr; (4) T_0 date and clock time; (5) KRT parameters (first-session date and clock time, modality, and session count); (6) treatment-related complications; (7) renal recovery status (at ICU discharge, Day 28, and Day 90); and (8) direct healthcare costs. Date and clock-time fields for T_0 and KRT initiation were captured separately and programmatically concatenated into unified timestamps prior to analysis.

Data Cleaning, Timestamp Verification, and Record Linkage

Data curation followed a prespecified five-step protocol:

1. **Timestamp verification:** For every database entry, T_0 and first-session timestamps were combined to compute the elapsed interval. Negative intervals or

intervals exceeding 30 days were flagged and cross-checked against free-text delay notes on the original case-report form; first-session timestamps were verified against dedicated dialysis-unit session logs because automated dialysis-machine connection logs were unavailable. Two entries exhibiting negative intervals due to calendar-year transcription errors were identified and corrected using the verified interval from linked copies of the same patient.

2. **Biological plausibility checks:** Physiologically implausible laboratory entries (serum potassium > 10.0 mmol/L}; serum creatinine < 44.0 or > 3,000.0 µmol/L) were recoded as missing, affecting eight potassium and seven creatinine values.
3. **Record linkage and deduplication:** Because the extraction form lacked a unique patient key, entries were linked hierarchically: exact duplicate rows were purged; entries sharing an identical T_0 date and clock time (to the exact minute) were merged as a single patient; and entries sharing an identical T_0 clock time alongside an identical T_0 biochemical profile (serum potassium, haemoglobin, and arterial pH) but differing solely in the recorded calendar date were merged as single patients with date-entry errors.
4. **Resolution of discordant fields:** Across linked duplicate entries for a given patient, discrepancies in categorical variables were resolved by majority vote, whereas discrepancies in continuous variables were resolved using the median of plausible values. Time to KRT was assigned using the modal non-negative interval.
5. **Sensitivity analysis:** All statistical analyses were repeated without the date-error merging step, treating each distinct T_0 timestamp record (n = 18) as an independent patient.

Statistical Analysis

Distributional normality of continuous variables was evaluated using the Shapiro–Wilk test (Shapiro & Wilk, 1965). Because key variables deviated significantly from normality (time to KRT, $p = .008$; number of KRT sessions, $p < .001$) and subgroup sizes were small, continuous data are summarized as median and interquartile range (IQR) alongside full range (minimum–maximum). For subgroups containing only one or two patients, raw individual values are reported in place of summary statistics, as measures of dispersion are not statistically meaningful. Continuous variables were compared across the four exposure groups using the Kruskal–Wallis test and between ICU survivors and non-survivors using the Mann–Whitney U test. Categorical variables are expressed as n/N (%) and compared using the Fisher–Freeman–Halton exact test, approximated via Monte Carlo simulation (10,000 permutations); comparisons of KRT-related complications were restricted to the 10 patients who received KRT. Proportions are accompanied by exact Clopper–Pearson 95% CIs. A two-sided $p < .05$ was used to denote nominal statistical significance, with all inferential tests interpreted as exploratory.

A multivariable logistic regression model adjusting for age, APACHE II score, and KRT timing group had been planned a priori. However, with only five mortality events, the events-per-variable ratio fell well below the established minimum threshold of 10 events per covariate required to prevent overfitting and unstable parameter estimation (Peduzzi et al., 1996); accordingly, multivariable modelling was omitted and no adjusted odds ratios are reported. Similarly, time-dependent survival analyses were evaluated but deemed unfeasible. Although a Cox proportional hazards model incorporating KRT initiation as a time-varying covariate or a landmark analysis at 24 and 48 hr post-T_0 represents the gold standard for mitigating immortal-time bias—the artefactual survival advantage accrued by patients while awaiting assignment to delayed treatment categories (Suissa, 2008)—these techniques require exact timestamps of death and adequate event counts within each risk set. With only five deaths, a 48-hr landmark analysis would have retained a single patient in the very delayed risk set. Immortal-time bias is therefore addressed qualitatively as a methodological limitation. All statistical computations were performed in Python 3.13 using the pandas, SciPy, and statsmodels libraries; analytical scripts are available from the corresponding author upon request.

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Ethics

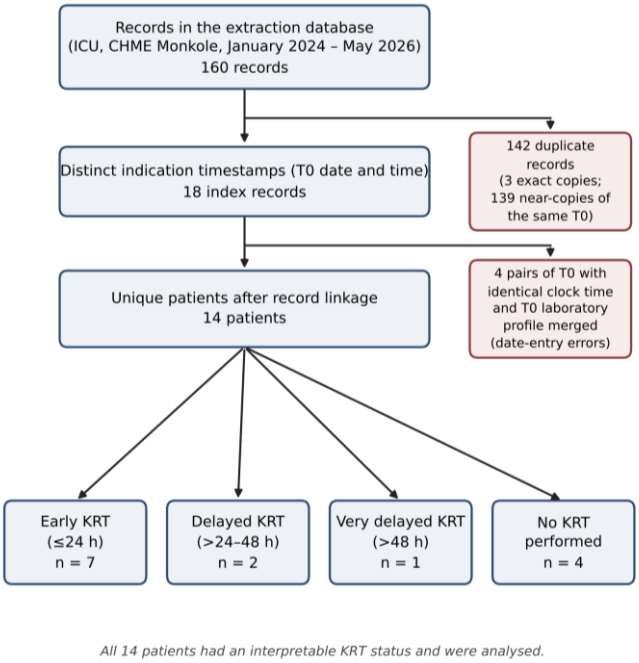
The study protocol was reviewed and approved by the Ethics Committee of the School of Public Health, University of Kinshasa (Approval No. ESP/CE/74/2026, granted May 15, 2026; valid through May 14, 2027). The study adhered strictly to the ethical principles of the Declaration of Helsinki. All patient records were de-identified prior to analysis, and routine clinical management was unaltered. Given the retrospective design and complete anonymization of archival data, the requirement for individual written informed consent was waived by the Ethics Committee.

RESULTS

Study Population and Record Linkage

The raw extraction database contained 160 records documenting a KRT indication. Deterministic record linkage identified three exact duplicate entries and 139 near-duplicate entries sharing the exact T_0 date and clock time of an index record, yielding 18 distinct T_0 records. Subsequent biochemical profile matching identified four pairs of records with identical T_0 clock times and identical T_0 laboratory panels (potassium, haemoglobin, arterial pH) that differed only by calendar date, resolving the cohort into 14 unique patients **(Figure 1)**. Each unique patient was represented by a median of 13 database entries (range, 5–17), and every patient exhibited at least one discordant field across duplicate entries. All 14 unique patients possessed an interpretable KRT status and were included in the analysis: seven (50.0%) received early KRT, two (14.3%) received delayed KRT, one (7.1%) received very delayed KRT, and four (28.6%) received no KRT despite a documented indication.

Figure 1:
Flow diagram of database record linkage and patient stratification. AKI = acute kidney injury; CHME = Centre Hospitalier Mère et Enfant; ICU = intensive care unit; KRT = kidney replacement therapy; T_0 = time of KRT indication.



Baseline Characteristics

Across the entire cohort (N = 14), the median age was 60.5 yr (IQR, 36.8–67.5), 10 patients (71.4%) were male, and the median admission APACHE II score was 16.0 (IQR, 11.5–18.8). Median age was 48.0 yr in the early group, 55.0 and 69.0 yr in the two delayed-group patients, 76.5 yr in the very delayed patient, and 67.0 yr in the no-KRT group (p = .22). Median APACHE II scores were 14.0 in the early group, 11.0 and 17.0 in the delayed group, 24.0 in the very delayed patient, and 16.5 in the no-KRT group (p = .63). No baseline demographic, clinical, or biochemical variable differed significantly across exposure groups **(Table 1)**.

Table 1:
Baseline Demographic, Clinical, and Biochemical Characteristics Stratified by Timing of Kidney Replacement Therapy (N = 14)

Characteristic	Early (≤ 24 hr) (n=7)	Delayed (> 24–48 hr)(n=2)[a]	Very delayed (> 48 hr)(n=1)[a]	No KRT(n=4)	p value[b]
Age, yr	48.0 [30.0–60.5] (19.0–63.0)	55.0; 69.0	76.5	67.0 [54.3–71.0] (19.0–80.0)	.22
Male sex, n (%)	6 (85.7)	1 (50.0)	1 (100.0)	2 (50.0)	.57
APACHE II score	14.0 [10.5–18.5] (8.0–35.0)	11.0; 17.0	24.0	16.5 [13.0–19.5] (7.0–24.0)	.63
KDIGO stage 3 AKI, n (%)	6 (85.7)	1 (50.0)	1 (100.0)	3 (75.0)	.77
Hypertension, n (%)	3 (42.9)	1 (50.0)	1 (100.0)	3 (75.0)	.86
Diabetes mellitus, n (%)	1 (14.3)	0 (0.0)	1 (100.0)	2 (50.0)	.24
Serum urea at T_0, mmol/L	48.0 [32.8–62.5] (18.2–74.0)	48.3; 31.7	52.3	44.5 [35.5–50.8] (24.0–58.0)	.87
Serum creatinine at T_0,µmol/L	811.5 [478.0–951.3]	671.8; 1,349.0	926.4	338.5 [309.3–350.9]	.29

	(289.0–1,410.0)			(265.0–412.0)	
Serum potassium at T_0, mmol/L[c]	5.0 [4.3–5.5] (3.8–6.1)	4.4; 5.5	4.9	5.5 [4.6–5.9] (4.1–6.3)	.97

Note. Continuous variables are presented as median [interquartile range] and (range). AKI = acute kidney injury; APACHE = Acute Physiology and Chronic Health Evaluation; KDIGO = Kidney Disease: Improving Global Outcomes; KRT = kidney replacement therapy; T_0 = time of KRT indication. [a]For subgroups with n ≤ 2, individual patient values are displayed (ordered consistently by patient across rows) because measures of dispersion are not interpretable. [b]Calculated using the Kruskal–Wallis test for continuous variables and the Fisher–Freeman–Halton exact test (Monte Carlo simulation, 10,000 permutations) for categorical variables. [c]Evaluated in n = 6 patients in the early group (one physiologically implausible value was excluded as missing).

Kidney Replacement Therapy Characteristics

Among the 10 patients who initiated KRT, nine (90.0%) received intermittent haemodialysis and one patient (10.0%, early group) received acute peritoneal dialysis. The median time from indication to KRT initiation was 4.9 hr (IQR, 2.8–16.5; range, 0.0–24.0) in the early group, compared with 25.7 and 27.8 hr in the two delayed-group patients and 76.9 hr in the very delayed patient. Patients received a median of 2 KRT sessions (IQR, 1–2; range, 1–2) in the early group, 2 sessions each in the delayed group, and 1 session in the very delayed group **(Table 2)**.

Table 2:
Kidney Replacement Therapy Modalities, Timing, and Clinical Indications Among KRT Recipients (n = 10)

Characteristic	Early (≤ 24 hr)(n=7)	Delayed (> 24–48 hr)(n=2)[a]	Very delayed (> 48 hr)(n=1)[a]
KRT modality, n (%)			
Intermittent haemodialysis	6 (85.7)	2 (100.0)	1 (100.0)
Peritoneal dialysis	1 (14.3)	0 (0.0)	0 (0.0)
Treatment delivery			
Time from T_0 to first KRT session, hr	4.9 [2.8–16.5] (0.0–24.0)	25.7; 27.8	76.9
Total KRT sessions completed	2 [1–2] (1–2)	2; 2	1
Documented KRT indications, n (%)[b]			
Uraemic complications	5 (71.4)	2 (100.0)	1 (100.0)
Severe metabolic acidosis	3 (42.9)	0 (0.0)	0 (0.0)
Prolonged anuria/oliguria	2 (28.6)	0 (0.0)	0 (0.0)
Severe azotaemia (serum urea > 40.0 mmol/L)	1 (14.3)	1 (50.0)	0 (0.0)

Note. Continuous variables are presented as median [interquartile range] and (range). KRT = kidney replacement therapy; T_0 = time of KRT indication. [a]For subgroups with n ≤ 2, individual patient values are presented (ordered consistently by patient across rows). [b]Indication categories were not mutually exclusive. Refractory hyperkalaemia (> 6.5 mmol/L) and refractory pulmonary oedema were not documented as primary indications in any KRT recipient.

Clinical Outcomes

Overall all-cause ICU mortality was 5/14 (35.7%; 95% CI [12.8, 64.9]). Group-specific mortality was 3/7 (42.9%; 95% CI [9.9, 81.6]) in the early group, 0/2 (0.0%; 95% CI [0.0, 84.2]) in the delayed group, 1/1 (100.0%; 95% CI [2.5, 100.0]) in the very delayed group, and 1/4 (25.0%; 95% CI [0.6, 80.6]) in the no-KRT group (p = .55; **Table 3, Figure 2**). When restricted to KRT recipients (n = 10), mortality did not differ significantly between early KRT (3/7; 42.9%) and combined delayed/very delayed KRT (1/3; 33.3%; Fisher's exact test, p = 1.00). Median ICU length of stay was 20.0 days (IQR, 9.3–25.0) in the early group, 3.0 and 15.0 days in the delayed-group patients, 6.0 days in the very delayed patient, and 7.0 days (IQR, 5.8–12.3) in the no-KRT group (p = .67).

Renal recovery was achieved in 4/4 (100.0%) survivors in the early group and 3/3 (100.0%) survivors in the no-KRT group. In the delayed group, both patients survived to ICU discharge; complete renal recovery was documented in one patient (1/2 survivors; 50.0%), whereas the second survivor lacked a documented follow-up renal assessment (1/1 [100.0%] among assessed survivors). Because the sole patient in the very delayed group died in the ICU, renal recovery was not applicable. Given the small subgroup denominators and missing follow-up data, formal hypothesis testing was not performed for renal recovery.

Across the entire cohort, ICU non-survivors presented with significantly higher admission APACHE II scores than survivors (median 19.0 [IQR, 18.0–24.0] vs. 13.0 [IQR, 8.0–17.0]; Mann–Whitney U test, p = .032), whereas

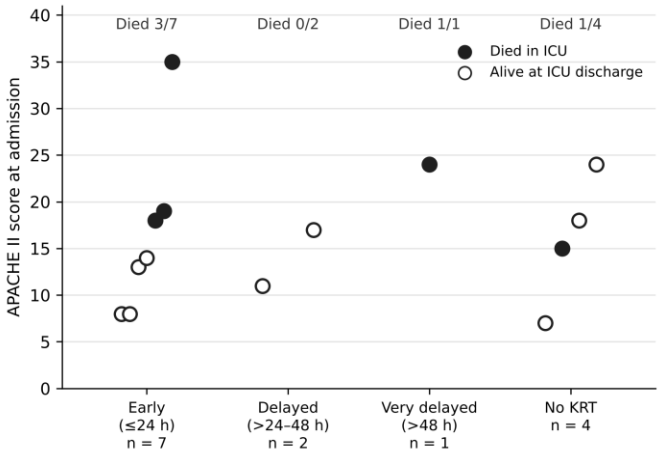
chronological age did not differ significantly between non-survivors and survivors (median 63.0 yr [IQR, 58.0–68.0] vs. 55.0 yr [IQR, 27.0–66.0]; p = .46; **Figure 2**).

Table 3:
Primary and Secondary Clinical Outcomes Stratified by Timing of Kidney Replacement Therapy (N = 14)

Outcome	Early (≤ 24 hr)(n=7)	Delayed (> 24–48 hr)(n=2)	Very delayed (> 48 hr)(n=1)	No KRT (n=4)	p value[a]
Primary outcome					
ICU mortality, n/N (%) [exact 95% CI]	3/7 (42.9) [9.9, 81.6]	0/2 (0.0) [0.0, 84.2]	1/1 (100.0) [2.5, 100.0]	1/4 (25.0) [0.6, 80.6]	.55
Secondary outcomes					
ICU survivors, n/N (%)	4/7 (57.1)	2/2 (100.0)	0/1 (0.0)	3/4 (75.0)	—
Renal recovery among all survivors, n/N (%) (primary)	4/4 (100.0)	1/2 (50.0)	n/a	3/3 (100.0)	Not tested
Survivors lacking renal assessment, n/N (%)	0/4 (0.0)	1/2 (50.0)	n/a	0/3 (0.0)	—
Renal recovery among assessed survivors, n/N (%) (secondary)	4/4 (100.0)	1/1 (100.0)	n/a	3/3 (100.0)	—
ICU length of stay, days	20.0 [9.3–25.0] (3.0–30.0)	3.0; 15.0	6.0	7.0 [5.8–12.3] (5.0–25.0)	.67
KRT-related complications[b]					
Intradialytic hypotension, n/N (%)	4/7 (57.1)	1/2 (50.0)	1/1 (100.0)	n/a	1.00
Coagulopathy, n/N (%)	1/7 (14.3)	1/2 (50.0)	0/1 (0.0)	n/a	.53
Catheter-related bloodstream infection, n/N (%)	1/7 (14.3)	0/2 (0.0)	0/1 (0.0)	n/a	1.00

Note. Continuous variables are presented as median [interquartile range] and (range), with raw individual values shown for subgroups of n ≤ 2. CI = confidence interval; ICU = intensive care unit; KRT = kidney replacement therapy; n/a = not applicable. [a]Calculated using the Fisher–Freeman–Halton exact test (Monte Carlo simulation, 10,000 permutations) for categorical variables and the Kruskal–Wallis test for continuous variables. [b]Complication rates were evaluated exclusively among the 10 patients who received KRT.

Figure 2:
Distribution of individual patients by timing of kidney replacement therapy, admission APACHE II score, and ICU survival status at CHME Monkole. Filled circles represent ICU non-survivors; open circles represent patients discharged alive from the ICU. APACHE = Acute Physiology and Chronic Health Evaluation; CHME = Centre Hospitalier Mère et Enfant; ICU = intensive care unit; KRT = kidney replacement therapy.



Complications

Among the 10 patients who underwent KRT, intradialytic hypotension was the most frequent adverse event, occurring in 6/10 patients (60.0%): 4/7 (57.1%) in the early group, 1/2 (50.0%) in the delayed group, and 1/1 (100.0%) in the very delayed group (p = 1.00). Coagulopathy was documented in 2/10 patients (20.0%) and catheter-related bloodstream infection in 1/10 patients (10.0%; **Table 3**).

Sensitivity and Multivariable Analyses

In the prespecified sensitivity analysis treating each of the 18 distinct T_0 timestamp records as an independent patient without date-error linkage, one record lacked KRT treatment documentation, leaving 17 analyzable records: eight early, four delayed, one very delayed, and four no KRT. Corresponding ICU mortality rates were 3/8 (37.5%), 0/4 (0.0%), 1/1 (100.0%), and 1/4 (25.0%), respectively (p = .33). Consistent with the primary analysis, ICU non-survivors exhibited significantly higher admission APACHE II scores than survivors (p = .015), confirming the robustness of the primary findings. As detailed in the *Statistical Analysis* section, multivariable logistic regression was not performed due to insufficient mortality events (n = 5).

DISCUSSION

In this retrospective, single-centre pilot cohort of 14 critically ill adults with severe AKI in Kinshasa, overall ICU mortality was 35.7%. Deaths occurred across all exposure strata except the two-patient delayed group, and the sole patient in the very delayed group died. Because of the small sample size, the study was underpowered to confirm or

exclude an association between KRT initiation timing and ICU survival. The sole nominally significant finding was a higher baseline APACHE II score among non-survivors, suggesting that acute physiological derangement at admission, rather than treatment delay per se, was the primary determinant of mortality in this series.

Our findings align broadly with the international randomized clinical trial literature. Major multicentre trials and an individual-patient-data meta-analysis have consistently demonstrated no survival advantage for systematic early KRT initiation over a watchful-waiting strategy (Barbar et al., 2018; Gaudry et al., 2016, 2020; STARRT-AKI Investigators, 2020), whereas the AKIKI 2 trial indicated that excessive postponement once a definitive indication arises increases mortality risk (Gaudry et al., 2021). Crucially, however, the mechanisms driving treatment timing in Kinshasa differ fundamentally from those in high-income trial settings. In our ICU, treatment delays were dictated by out-of-pocket financial mobilization and consumable supply bottlenecks rather than clinical judgement. Moreover, the single patient in the very delayed group was both the oldest individual in the cohort (76.5 yr) and among the most severely ill (APACHE II score 24.0). Consistent with previous sub-Saharan African cohorts, treatment timing and baseline disease severity were tightly confounded (Kahindo et al., 2022; Olowu et al., 2016).

The relatively high mortality observed in the early KRT group (3/7; 42.9%) warrants cautious interpretation. Although our protocol excluded immediately life-threatening dialysis emergencies from the T_0 definition, retrospective chart review cannot always reliably separate hyper-acute clinical deteriorations from planned urgent initiations; notably, one early death occurred in the most critically ill patient in the entire cohort (APACHE II score 35.0). Conversely, the survival of both patients in the delayed group (25.7 and 27.8 hr) likely reflects selection of haemodynamically more stable individuals (APACHE II scores 11.0 and 17.0) who tolerated a brief window for pre-dialysis medical optimization. Similarly, in the no-KRT group, specific reasons for non-initiation—such as rapid clinical demise prior to catheter placement, family inability to fund treatment, equipment unavailability, or spontaneous renal recovery under conservative therapy—were not systematically documented. Survival in the no-KRT stratum (3/4; 75.0%) must therefore be interpreted in light of potential selection bias and immortal-time bias (Suissa, 2008).

Intradialytic hypotension affected 60.0% of KRT recipients, falling within the broad incidence range reported among critically ill patients undergoing acute dialysis, where haemodynamic instability is driven by rapid ultrafiltration, osmotic fluid shifts, and sepsis-induced vasoplegia (Douvris et al., 2019). Prior cohort data indicate that intradialytic hypotension is closely linked to net positive fluid balance and increased mortality in critical illness (Silversides et al., 2014). As is typical in resource-constrained tropical ICUs, continuous KRT modalities were unavailable at our centre, necessitating reliance on intermittent haemodialysis, which is inherently less well tolerated by vasopressor-dependent or haemodynamically labile patients. These findings underscore the need for enhanced peri-dialytic haemodynamic monitoring, conservative ultrafiltration targets, and prolonged, lower-efficiency intermittent dialysis protocols (e.g., sustained low-efficiency dialysis) for unstable patients.

Beyond clinical management, our observations highlight actionable targets for bedside workflow optimization. We propose three institutional interventions: (1) implementing a standardized bedside KRT indication checklist that automatically time-stamps T_0, distinguishes immediate life-threatening emergencies from urgent planned indications, and mandates documentation of specific causes of delay (clinical, financial, or logistical); (2) instituting an automated or paper-based parallel triage alert that simultaneously notifies the haemodialysis unit and hospital social/financial services upon KRT prescription, enabling concurrent rather than sequential vascular access placement, consumable procurement, and financial clearance; and (3) tracking the indication-to-initiation interval as a core quality-of-care metric during routine ICU morbidity and mortality audits. At the health-system level, establishing pre-financing mechanisms—such as dedicated hospital emergency dialysis funds, community-based mutual health insurance schemes, or inclusion of acute KRT within public universal health coverage packages—is essential to decouple life-saving

critical care from immediate household liquidity (Mehta et al., 2015; Nkunu et al., 2024).

Finally, this investigation underscores the critical necessity of rigorous data governance in retrospective research conducted in resource-limited environments. Because the initial extraction instrument lacked a unique patient identifier, multiple duplicate and near-duplicate entries for single patients accumulated in the raw database. Uncorrected, these duplicates generated severe statistical artefacts, including zero-width interquartile ranges, zero standard deviations, and an artificially inflated sample size. Future clinical registries in similar settings must incorporate mandatory unique patient keys, automated front-end duplicate alerts within electronic data-capture tools, and independent double data entry. Furthermore, future prospective multicentre studies should integrate health-economic evaluations quantifying direct out-of-pocket expenditures, time required for family fund mobilization, and the incidence of catastrophic health expenditure.

Limitations

Design-related limitations. This retrospective, single-centre, non-randomized study is inherently susceptible to selection bias and confounding by indication, limiting the generalizability of our findings to other ICUs in Kinshasa or across the DRC. Within the early KRT group, hyper-acute emergency indications could not be retrospectively differentiated from urgent planned indications with complete certainty. Among patients who did not receive KRT, medical records did not consistently clarify whether death occurred before dialysis could be arranged or whether patients improved conservatively, exposing group comparisons to immortal-time bias that could not be analytically corrected via time-varying Cox models or landmark analyses due to low event counts (Suissa, 2008).

Sample-related limitations. The final analytical cohort of 14 unique patients (five deaths) fell substantially below the protocol target of 273 patients per arm, reflecting the restriction from six planned study sites to a single centre and the high rate of record duplication uncovered during data auditing. Consequently, the study lacks statistical power, two exposure strata contained only one or two patients, exact confidence intervals are wide, and multivariable adjustment for confounders was statistically unfeasible. All comparative analyses must therefore be viewed as exploratory and hypothesis-generating.

Data-quality limitations. The primary methodological limitation involves extensive record duplication in the raw extraction database, wherein 160 records corresponded to 14 unique patients due to the absence of a unique patient identifier. Duplicate entries for the same individual occasionally contained discrepant values for age, sex, APACHE II score, comorbidities, or calendar dates. Although all analyses presented here were rigorously recomputed at the verified patient level following hierarchical record linkage—and corroborated by an 18-record sensitivity analysis—the linkage algorithm itself relied on timestamp and biochemical matching assumptions rather than complete re-abstraction of primary paper charts. Additionally, physiologically implausible laboratory values were excluded as missing, renal recovery follow-up was missing for one survivor in the delayed group, systematic 90-day post-discharge follow-up was unavailable, and direct out-of-pocket KRT costs could not be quantified as originally planned.

CONCLUSION

Among 14 critically ill adults with severe AKI admitted to a tertiary referral ICU in Kinshasa, overall mortality was 35.7%, and death was more strongly associated with baseline illness severity than with the measured interval from KRT indication to initiation. While this underpowered pilot series cannot establish whether delays in KRT initiation independently worsen survival, it demonstrates that treatment intervals in this setting are heavily governed by financial and logistical barriers and that rigorous patient-level data curation is indispensable for clinical research. Implementing time-stamped bedside KRT triage protocols, establishing pre-financing mechanisms for acute dialysis, and conducting an adequately powered, prospective multicentre study utilizing unique patient identifiers represent essential next steps.

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Authors' Contributions

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- **John Nsiala Makunza:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.
- **Alphonse Mosolo:** Methodology, Supervision, Validation, Writing – review & editing.
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- **Benjamin Longo-Mbenza:** Investigation, Supervision, Writing – review & editing.
- **Rais Nsinabau:** Validation, Writing – review & editing. All authors read and approved the final version of the manuscript.

Data Availability Statement: The de-identified patient-level dataset, record-linkage key, and Python analytical scripts are available from the corresponding author upon reasonable request.

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Informed Consent: The requirement for individual informed consent was waived due to the retrospective design and use of fully anonymized archival data, in accordance with the approved protocol.

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