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Acute Renal Replacement Therapy in Intensive Care Units: A Retrospective Study of 594 Cases

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Abstract **Original Research Article**

***Background*:** Acute kidney injury (AKI) is a frequent and severe complication in intensive care units, associated with high morbidity and mortality. Its management often requires renal replacement therapy (RRT). ***Objectives*:** To describe the epidemiological profile of patients requiring RRT, the indications and modalities of dialysis, as well as the risk factors associated with mortality and non-recovery of renal function. ***Methods*:** We conducted a retrospective, descriptive, and analytical study including 594 patients who underwent urgent RRT in several intensive care units in Rabat between January 2022 and December 2024. Demographic, clinical, biological, therapeutic, and outcome data were collected and analyzed using JAMOVI software. AKI was defined according to the 2012 KDIGO guidelines. ***Results*:** The mean age was 43 ± 10.7 years, with a male predominance (61%). The most frequent comorbidities were hypertension (40.1%), diabetes mellitus (29.6%), and ischemic heart disease (20%). The main indications for RRT were oligo-anuria associated with acute pulmonary edema (63%), severe metabolic acidosis (57%), life-threatening hyperkalemia (36%), and severe uremia (40%). In-hospital mortality was 44.6%. Independent predictors of mortality included age >60 years, septic shock, invasive mechanical ventilation, and severe anemia. Complete recovery of renal function was observed in 60% of patients. Factors associated with non-recovery of renal function included hypertension, diabetes mellitus, ischemic heart disease, oligo-anuria, septic shock, hyperkalemia, and severe metabolic acidosis. ***Conclusion*:** AKI in critically ill patients remains frequent, complex, and associated with high mortality. Prompt and appropriate management may allow renal recovery in a substantial proportion of patients. Identification of risk factors for mortality and non-recovery of renal function is essential to guide therapeutic strategies and improve patient outcomes.

Keywords: Acute Kidney Injury, Renal Replacement Therapy, Dialysis, Intensive Care Unit, Risk Factors, Mortality, Renal Recovery.

I. INTRODUCTION

Acute kidney injury (AKI) is a frequent and life-threatening complication in intensive care units (ICUs). Its incidence has increased considerably over recent decades [1–3]. This rise is partly related to population aging, the growing complexity of critically ill patients, as well as improvements in diagnostic tools and a better understanding of the pathophysiology of AKI [4, 5].

AKI most commonly occurs in the setting of severe clinical conditions such as sepsis, shock states, multiorgan failure, or drug-induced toxicity, and is associated with a significant increase in hospital morbidity and mortality [6–8]. Approximately 20–50% of patients admitted to intensive care units develop AKI, and nearly 5% require renal replacement therapy (RRT), with reported mortality rates exceeding 50% [9–11].

Despite its high prevalence, clinical research in AKI has long been limited by the lack of a standardized definition [12]. More than 35 operational definitions have been described in the literature, making comparisons between studies difficult and sometimes unreliable. To overcome this heterogeneity, the Acute Dialysis Quality Initiative (ADQI) group proposed the RIFLE classification (Risk, Injury, Failure, Loss, and End-stage kidney disease) in 2004. This system categorizes AKI according to three increasing levels of severity and two functional outcome categories, thereby establishing a common framework for both clinical practice and research [12].

Furthermore, the term "acute kidney injury" (AKI) has progressively replaced the older terminology of "acute renal failure" (ARF), in order to better reflect the continuum of renal impairment ranging from subtle functional abnormalities to severe kidney failure requiring renal replacement therapy [3-9]. This conceptual evolution emphasizes a broader and more dynamic understanding of acute renal damage.

Three major elements remain central to modern definitions of AKI: an increase in serum creatinine concentration (or less commonly blood urea levels), a reduction in urine output (typically <0.5 mL/kg/h for 6 to 24 hours), and the exclusion of pre-existing chronic kidney disease (CKD) [7-11]. These well-established criteria allow improved patient stratification and guide therapeutic decisions, particularly the initiation of renal replacement therapy.

II. Study Objectives

The primary objectives of this study were to:

- Describe the epidemiological profile of patients with acute kidney injury (AKI) requiring renal replacement therapy (RRT) in intensive care settings and managed by the hemodialysis unit of Ibn Sina Hospital, Rabat.
- Describe the indications and modalities of renal replacement therapy in critically ill patients.
- Identify risk factors associated with in-hospital mortality.
- Identify risk factors associated with non-recovery of renal function.

III. MATERIALS AND METHODS

1. Study Design and Period

This was a retrospective, descriptive, and analytical study conducted over a three-year period from January 2022 to December 2024, including a total of 594 patients.

The study included all patients who underwent urgent renal replacement therapy (RRT) for acute kidney injury (AKI) in the intensive care units of Ibn Sina University Hospital, including Ibn Sina Hospital, Specialty Hospital of Rabat, Moulay Abdellah Oncology Hospital, Rabat Maternity Hospital, Moulay Youssef Hospital, and Lalla Aicha Hospital.

2. Inclusion and Exclusion Criteria

Inclusion Criteria:

All patients hospitalized in intensive care units for more than 24 hours and requiring urgent renal replacement therapy (RRT) were included in the study.

Exclusion Criteria: Patients with pre-existing chronic kidney disease (CKD) requiring chronic dialysis were excluded from the study.

Acute kidney injury (AKI) was defined according to the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) guidelines [22], by the presence of at least one of the following criteria:

- Increase in serum creatinine ≥ 0.3 mg/dL (26.5 µmol/L) within 48 hours.
- Increase in serum creatinine to ≥ 1.5 times the baseline value, known or presumed to have occurred within the previous 7 days.
- Reduction in urine output to < 0.5 mL/kg/h for at least 6 consecutive hours.

3. Data Collection

Retrospective data collection was performed using medical records of patients admitted to intensive care units, hemodialysis monitoring sheets, and the Green Cube hospital information system.

The following variables were collected:

- **Demographic data:** age and sex.
- **Medical history:** diabetes mellitus, hypertension, neoplastic disease, and known kidney disease.
- **Reason for admission to the intensive care unit.**
- **Clinical and biological parameters recorded at admission:**
  - Blood pressure and heart rate.
  - Neurological status, including level of consciousness and presence of seizures.
  - Respiratory status, including respiratory rate, peripheral oxygen saturation, and requirement for endotracheal intubation.
  - Laboratory parameters including serum creatinine, blood urea nitrogen, serum potassium, serum sodium, bicarbonate levels, and infectious workup parameters such as C-reactive protein (CRP), procalcitonin, white blood cell count, urine culture, and blood cultures.
- **Radiological investigations performed:** chest radiography, transthoracic echocardiography, computed tomography (CT), and magnetic resonance imaging (MRI).
- **Therapeutic interventions initiated in the ICU before or concomitantly with dialysis:** fluid resuscitation, blood transfusion, loop diuretics, and antibiotic therapy.

Regarding renal replacement therapy (RRT), the following data were collected:

- Indications for initiation of RRT, including anuria, acute pulmonary edema, severe uremia, hyperkalemia, and severe metabolic acidosis.
- Prescription modalities, including vascular access, blood pump flow rate, and anticoagulation protocol.
- Duration and number of RRT sessions per patient.

Complications Occurring During Hemodialysis Sessions:

- Hemodynamic complications: hypotension, cardiac arrest, and arrhythmias.
- Respiratory complications: chest pain, dyspnea, and tachypnea.
- Neurological complications: seizures.
- Mechanical complications: bleeding at the puncture site, hemodialysis catheter dysfunction, and extracorporeal circuit clotting.

- Patient survival and assessment of renal function at discharge and after one month of follow-up. Renal recovery was defined as an estimated glomerular filtration rate (eGFR) > 60 mL/min/1.73 m².

4. Statistical Analysis

Collected data were analyzed using JAMOVI software.

Qualitative variables were expressed as absolute numbers and percentages. Quantitative variables with a normal distribution were presented as mean ± standard deviation (SD). Variables with a non-normal distribution were described using the median and interquartile range (IQR).

Factors associated with mortality, as well as factors associated with renal recovery or non-recovery of normal renal function, were assessed using univariate and multivariate logistic regression analyses. Statistical significance was defined as a p-value < 0.05.

IV. RESULTS

1. Clinical Characteristics of the Study Population

During the study period, 594 critically ill patients underwent at least one urgent renal replacement therapy (RRT) session.

The mean age of the study population was 43 ± 10.7 years. The male-to-female ratio was 1.6, indicating a male predominance.

Cardiovascular and renal comorbidities were the most common underlying conditions, with hypertension reported in 238 patients (40.1%) and diabetes mellitus in 176 patients (29.6%). In addition, 72 patients (12.1%) had recently undergone surgery. Active or previously treated neoplastic disease was identified in 53 patients (8.9%). Recent exposure to iodinated contrast media was reported in 101 patients (17.0%), while recent use of nonsteroidal anti-inflammatory drugs (NSAIDs) was noted in 56 patients (9.4%) (Table 1).

Table 1: Clinical and Demographic Characteristics of the Study Population

Variables	Patients (n = 594)
Sex (M/F)	365 / 229
Mean age (years)	43 +/- 10.7
Comorbidities	
Hypertension	238 (40.1%)
Diabetes mellitus	176 (29.6%)
Ischemic heart disease	119 (20%)
Chronic heart failure	61 (10.3%)
History of malignancy	53 (8.9%)
History of stroke	46 (7.7%)
Risk factors for worsening renal function	
Exposure to iodinated contrast media	101 (17%)
Recent surgery (within the previous 30 days)	72 (12.1%)
Nonsteroidal anti-inflammatory drug (NSAID) use	56 (9.4%)

The reasons for intensive care unit (ICU)admission were frequently multifactorial (Figure 1) and included the following:

- Altered level of consciousness in 475 patients (80.0%), with a Glasgow Coma Scale score <15 and a median score of 13 [3–15].
- Respiratory distress in 376 patients (63.3%), with a median oxygen saturation of 90% [60–95]. Acute pulmonary edema (APE) was the leading cause, occurring in 198 patients (52.6%). In addition, pulmonary sepsis was identified in 178 patients (47.3%), often associated with severe metabolic acidosis, highlighting the multifactorial origin of respiratory failure.
- Septic shock in 435 patients (73.2%). The infectious source was predominantly bacterial pneumonia in 165 patients (37.9%), followed by urinary tract infection in 158 patients (36.3%) and infective endocarditis in 40 patients (9.2%). Five patients (1.1%) presented with herpetic encephalitis. Other infectious etiologies were observed in 67 cases (15.4%) (Figure 2).
- Hemorrhagic shock in 130 patients (21.8%).
- Caustic substance ingestion in 30 patients (5%).

From a renal standpoint, oliguria was present in 198 patients (33.3%), while anuria was observed in 178 patients (30.0%). Preserved urine output was noted in

218 patients (36.7%), with a median urine output of 1200 mL/24 h [600–4000].

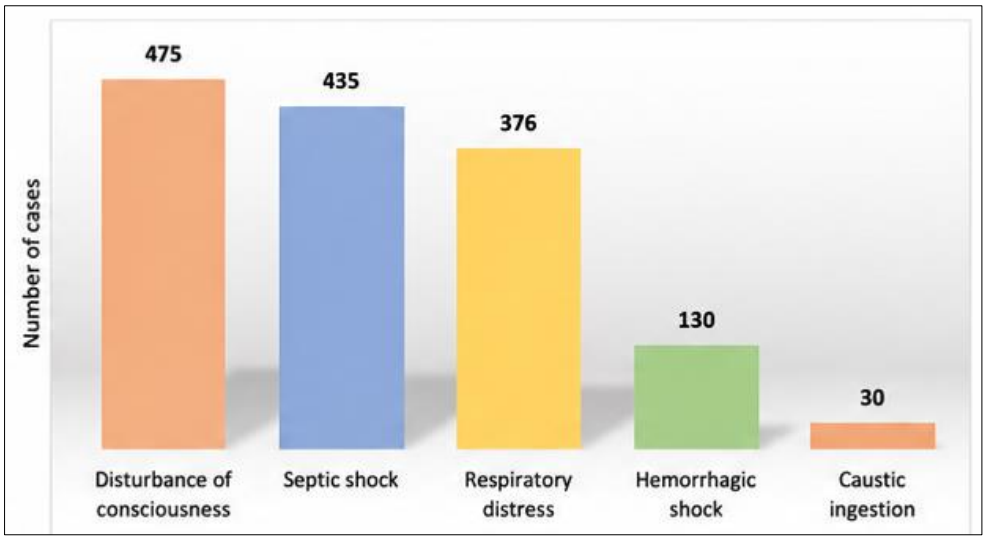

Figure 1: Primary Reasons for Intensive Care Unit Admission among the Study Population.

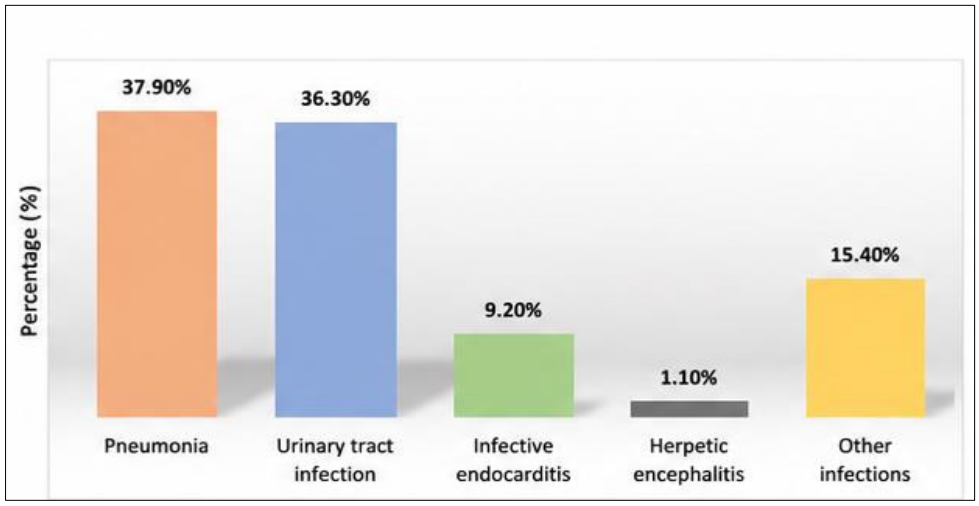

Figure 2: Distribution of Infection Sources Associated With Septic Shock Among the Study Population.

2- Baseline Laboratory Characteristics of the Study Population

Upon admission to ICU, the mean blood urea level was 2.71 ± 0.95 g/L (range: 0.7–4.28 g/L). A blood urea concentration exceeding 3 g/L was observed in 40.1**%** of patients. The mean serum creatinine level was 102 ± 59.9 mg/L, with nearly 47% of patients presenting values above 100 mg/L**.**

The median serum sodium concentration at admission was 135 mmol/L (range: 111–148 mmol/L). Normonatremia was observed in 50% of patients, whereas moderate hyponatremia (120–129 mmol/L) and severe hyponatremia (<120 mmol/L) were identified in 9.9% and 6.6% of cases, respectively.

Before initiation of renal replacement therapy, the mean serum potassium level was **5.75** ± 1.48 mmol/L**.** Severe hyperkalemia (**>7** mmol/L**)** was present in 36.3% of patients. Severe metabolic acidosis, defined by a bicarbonate level below 10 mmol/L, was observed in 56.7**%** of cases. The median bicarbonate concentration was 9 mmol/L (range: 5–21 mmol/L).

From a hematological perspective, the mean hemoglobin level was 8.5 ± 1.5 g/dL, and severe anemia (hemoglobin <8 g/dL) was documented in 316 patients (53.2%)**.** Leukocytosis was present in 66.7**%** of patients, with white blood cell counts ranging from 11,456 to 22,321 cells/mm³**.** Thrombocytopenia, defined as a platelet count below 150,000/mm³**,** was observed in 43.3% of cases. The mean prothrombin time was 61% ± 22**%** (range: 49–100%) (Table 2).

Table 2: Baseline Laboratory Characteristics at ICU Admission

Parameter	Value	Number of Patients (%)
Blood urea (g/L)[ac]	2,71 ± 0,95 g/L	Urea > 3 g/L : 238 (40,1 %)
Serum creatinine (mg/L)[ac]	102 ± 59,9 mg/L	Creatinine S > 100 mg/L : 277 (46,6 %)
Serum sodium (mmol/L)[bc]	135 [111–148]	Normal sodium: 297 (50,0 %) Moderate hyponatremia (120–129) : 59 (9,9%) Severe hyponatremia (<120) : 39 (6,6 %)
Serum potassium (mmol/L)[ac]	5,75 ± 1,48	Potassium > 7 mmol/L : 216 (36,3 %)
Serum bicarbonate (mmol/L)[bc]	9 [5–21]	Bicarbonate < 10 mmol/L : 337 (56,7 %)
Hemoglobin (g/dL)[ac]	8,5 ± 1,5	Hemoglobin< 8 g/dL : 316 (53,2 %)
Platelet count (/mm³)[ac]	125 632 ± 76 000	Platelet count< 150 000/mm³ : 257 (43,3 %)
White blood cell count (/mm³)[ac]	16 823 ± 8000	Leukocytosis> 12 000/mm³ : 396 (66,7 %)

a. Expressed as mean ± standard deviation (SD).
b. Expressed as median and interquartile range (IQR).
c. Expressed as number of patients (%).

Regarding the infectious workup, the median C-reactive protein (CRP) level was 114 mg/L (IQR: 28.1–227 mg/L), with values exceeding 100 mg/L in 316 patients (53.2%). The median procalcitonin level was 0.6 ng/mL (IQR: 0.325–2.94 ng/mL), ranging from 0.05 to 200 ng/mL.

Urine culture was performed in all patients and yielded positive results in 158 patients (26.6%). The most frequently isolated pathogens were *Escherichia coli* (47.5%), *Klebsiella pneumoniae* (19.0%), Pseudomonas aeruginosa (11.4%), *Enterococcus faecalis* (9.5%), *Proteus mirabilis* (6.3%), and *Staphylococcus aureus* (5.1%) (Figure 3)

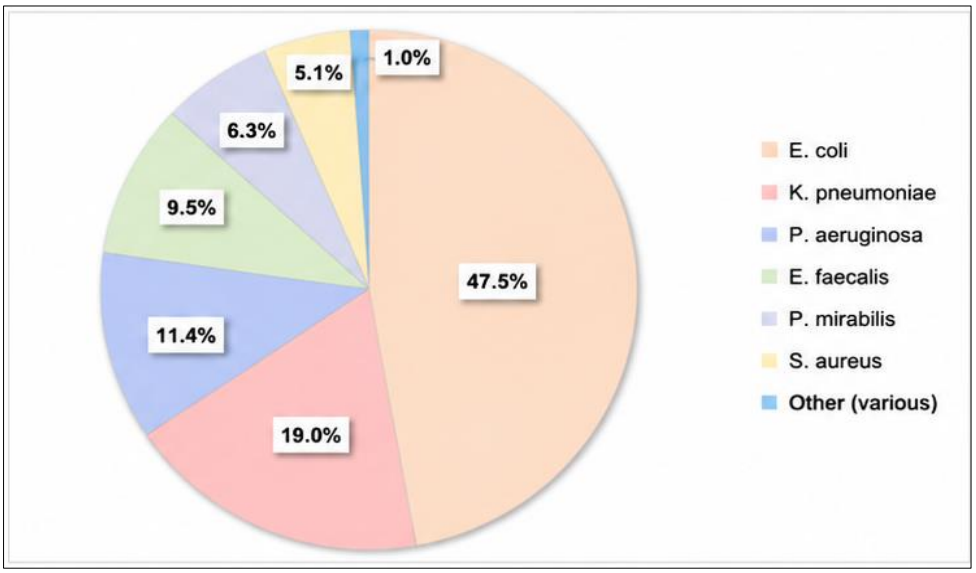

Figure 3: Pathogens Identified in Urine Cultures among Patients with Urinary Tract Infection

3. Therapeutic Management

The therapeutic interventions implemented, targeting both the underlying cause and the associated clinical manifestations, included the following:

- Intravenous fluid resuscitation was administered to 516 patients (87.0%), with 0.9% normal saline being the most frequently used crystalloid solution.
- Blood transfusion was required in 378 patients (63.6%).
- Vasoactive agents were administered to 357 patients (60.1%). Norepinephrine was used in all cases and was combined with epinephrine in 80 patients (22.4%). Dobutamine was administered in 20 patients (5.6%).
- Broad-spectrum antibiotic therapy was initiated in patients presenting with septic shock. The most commonly prescribed regimens were ceftriaxone plus ciprofloxacin in 297 cases (68.2%) and colistin plus piperacillin–tazobactam in 50 cases (11.5%). Aminoglycosides were used when methicillin-resistant *Staphylococcus aureus* (MRSA) infection was suspected. Antibiotic dosages were adjusted according to renal function.
- Furosemide was prescribed in 267 patients (45.0%), either as intermittent intravenous

boluses or continuous infusion, primarily in cases of oligo-anuric acute kidney injury associated with fluid overload.

- Oxygen therapy via nasal cannula was administered to 356 patients (60.0%), of whom 142 (40.0%) subsequently required a high-concentration oxygen mask.
- Non-invasive ventilation (NIV) was used in 267 patients (45.0%), whereas invasive mechanical ventilation following endotracheal intubation was required in 207 patients (34.8%)

4. Indications for Initiation of Hemodialysis

The main indications for extrarenal renal replacement therapy (RRT) were as follows:

- Oligo-anuria and/or acute pulmonary edema (APE), frequently associated with fluid overload and/or electrolyte disturbances. The ultrafiltration volume was individualized according to the patient's hemodynamic status and degree of volume overload, ranging from 1 to 3 liters per session, with the aim of gradually correcting fluid excess while minimizing the risk of intradialytic hypotension.
- Severe uremia in 238 patients (40.1%).
- Severe electrolyte disturbances, particularly life-threatening hyperkalemia, in 216 patients (36.3%).
- Severe metabolic acidosis in 337 patients (56.7%).

A total of 1545 renal replacement therapy (RRT) sessions were performed in our cohort, with a median of 2 sessions per patient (range: 1–11 sessions). One hundred and thirty patients (21.8%) underwent daily dialysis, with a mean treatment duration of 6 ± 2 days.

The timing of dialysis initiation following ICU admission varied among patients. RRT was initiated within 24 hours of admission in 337 patients (56.7%), between 48 and 72 hours in 158 patients (26.6%), between the 4th and 6th day in 59 patients (10.0%), and more than one week after admission in 40 patients (6.7%).

The mean duration of a hemodialysis session was 150 ± 45 minutes, with session lengths ranging from 90 to 240 minutes.

Systemic anticoagulation during dialysis was administered to 464 patients (78.1%). Among them, 310 patients (52.1%) received low-molecular-weight heparin (LMWH), whereas 154 patients (25.9%) received unfractionated heparin. Conversely, 130 patients (21.8%) did not receive anticoagulation because of a high bleeding risk.

Intradialytic complications were observed in 180 patients (30.0%). The most common complication was intradialytic hypotension, occurring in 54 patients (30.0%). Neurological complications, including seizures and altered consciousness, were reported in 18 patients (10.0%). Muscle cramps occurred in 27 patients (15.0%).

Catheter dysfunction, including catheter obstruction or inadequate blood flow, was observed in 22 patients (12.2%), while dialysis circuit clotting occurred in 18 patients (10.0%). Cardiac arrest was reported in 12 patients (6.7%).

Other complications, accounting for 16.1% of all intradialytic adverse events, included hypertensive episodes, nausea, vomiting, dialysis disequilibrium syndrome, headache, hypersensitivity reactions to the dialysis membrane, cardiac arrhythmias, angina, and myocardial infarction (Figure 4).

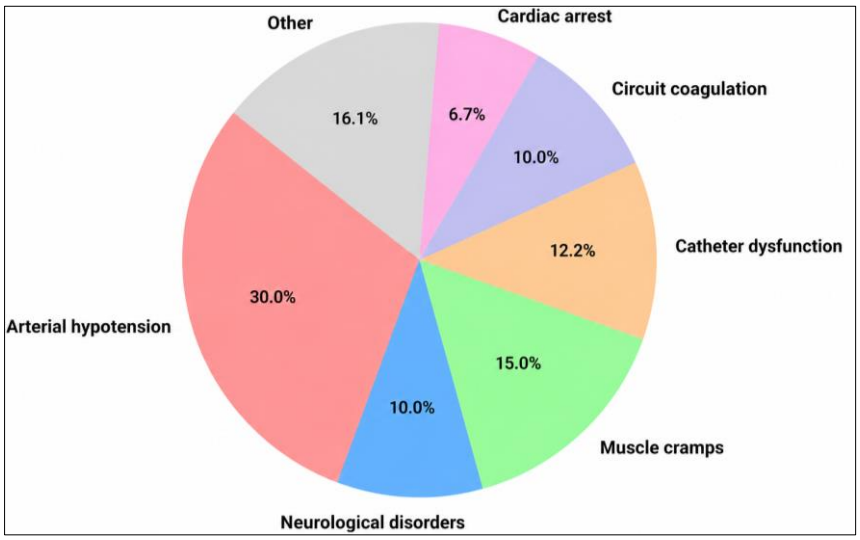

Figure 4: Intradialytic Complications Observed During Hemodialysis Sessions

5. Clinical Outcomes and Predictors of Renal Recovery and Mortality.

To identify predictors of renal function deterioration and non-recovery, patients were divided into two groups:

- Group A: 356 patients (59.9%) who achieved complete recovery of renal function.
- Group B: 238 patients (40.1%) who did not recover normal renal function at the end of their ICU stay.

Descriptive analysis of demographic characteristics showed a non-significant predominance of male patients in both groups (p = 0.12), with an overall male-to-female ratio of 1.6. The mean age was significantly higher in Group B than in Group A (58.7 ± 16.8 vs. 54.1 ± 17.6 years, p = 0.04), suggesting an association between older age and impaired renal recovery.

Regarding comorbidities, hypertension was significantly more prevalent in Group B than in Group A (61.2% vs. 48.5%, p = 0.02). Similarly, diabetes mellitus was observed in 39.1% of patients in Group B**,** compared with 28.4**%** in Group A (p = 0.03)**.** Ischemic heart disease was also significantly more frequent among patients who failed to recover normal renal function (27.3% vs. 18.5%, p = 0.05).

Furthermore, oligo-anuria was present in 78% of patients in Group B, compared with 53% in Group A (p = 0.01). Likewise, septic shock was significantly more common in Group B than in Group A (72% vs. 45%, p < 0.001), suggesting a strong association between severe hemodynamic compromise, sepsis, and poor renal recovery.

Regarding laboratory findings, patients in Group B had significantly higher blood urea levels than those in Group A(3.12 ± 1.05 g/L vs. 2.45 ± 0.75 g/L, p < 0.001). Similarly, serum creatinine levels were significantly higher in Group B(110 ± 65 mg/L vs. 92 ± 50 mg/L, p = 0.03**),** as were serum potassium levels **(**6.1 ± 1.6 mmol/L vs. 5.4 ± 1.2 mmol/L, p = 0.02).

Metabolic acidosis was also significantly more severe in Group B, with a bicarbonate level below 10 mmol/L observed in 62.7**%** of patients compared with **52.3%** in Group A **(**p = 0.04**) (**Table 3**).**

In multivariate analysis adjusted for age**,** major comorbidities (hypertension, diabetes mellitus, and ischemic heart disease), hyperkalemia, septic shock, oligo-anuria, and severe metabolic acidosis were identified as independent predictors of failure to recover normal renal function**.**

In our cohort, sex, as well as the number and duration of hemodialysis sessions, did not significantly influence renal function recovery.

Parameters	Group A (Recovery, n = 356; 59.9%)	Group B (Non-recovery, n = 238; 40.1%)	p value
Age (years, mean ± SD)	54.1 ± 17.6	58.7 ± 16.8	**0.04**
Male sex, n (%)	214 (60.1%)	151 (63.4%)	0.12
Hypertension, n (%)	48.5%	61.2%	**0.02**
Diabetes mellitus, n (%)	28.4%	39.1%	**0.03**
Ischemic heart disease, n (%)	18.5%	27.3%	0.05
Oligo-anuria, n (%)	53%	78%	**0.01**
Septic shock, n (%)	45%	72%	**<0.001**
Urea (g/L, mean ± SD)	2.45 ± 0.75	3.12 ± 1.05	**<0.001**
Potassium (mmol/L, mean ± SD)	5.4 ± 1.2	6.1 ± 1.6	**0.02**
Severe metabolic acidosis (bicarbonate < 10 mmol/L), n (%)	52.3%	62.7%	**0.04**
Number of hemodialysis sessions, median [IQR]	2 [1–3]	2 [1–4]	0.28
Average session duration (min), mean ± SD	148 ± 42	152 ± 47	0.31

Table 3: Predictors of Failure to Recover Normal Renal Function

Among the 594 patients included in our study, 265 (44.6%) died during hospitalization. A comparative analysis between survivors and non-survivors identified several factors significantly associated with mortality.

The mean age was significantly higher among non-survivors compared with survivors (61.5 ± 15.9 years vs. 52.8 ± 17.5 years, respectively; $p < 0.001$).

Major comorbidities, including hypertension, diabetes mellitus, and ischemic heart disease, were significantly more prevalent in patients who died than in

those who survived. Hypertension was present in 65.3% of non-survivors versus 50.5% of survivors, diabetes mellitus in 42.3% versus 28.9%, and ischemic heart disease in 31.7% versus 18.4%, respectively ($p < 0.01$ for all comparisons).

These findings suggest that advanced age and the presence of major cardiovascular and metabolic comorbidities are important predictors of mortality in critically ill patients requiring acute hemodialysis.

From a clinical perspective, hemodynamic instability, particularly persistent hypotension requiring vasoactive support, was significantly more frequent among non-survivors than survivors (61.5% vs. 25.3%, $p < 0.001$). Likewise, the presence of septic shock was strongly associated with mortality, occurring in 73.6% of patients who died compared with 35.4% of survivors ($p < 0.001$).

Biologically, serum urea, creatinine, and potassium levels were significantly higher in the non-survivor group. Severe anemia (hemoglobin < 8 g/dL) and severe metabolic acidosis (serum bicarbonate < 10 mmol/L) were also significantly more common among patients who died (Table IV).

Multivariate analysis identified several factors independently associated with in-hospital mortality, including age > 60 years ($p = 0.001$), septic shock ($p < 0.001$), the need for invasive mechanical ventilation ($p < 0.001$), and severe anemia ($p= 0.02$).

In contrast, neither the number of hemodialysis sessions nor the duration of dialysis treatment was significantly associated with mortality in our cohort.

Parameters	Deceased (n = 265)	Survivors (n = 329)	p value
Demographics			
Age (years, mean ± SD)	61.5 ± 15.9	52.8 ± 17.5	**<0.001**
Comorbidities			
Hypertension, n (%)	65.3%	50.5%	**<0.01**
Diabetes mellitus, n (%)	42.3%	28.9%	**<0.01**
Ischemic heart disease, n (%)	31.7%	18.4%	**<0.01**
Clinical parameters			
Hemodynamic instability (need for vasopressors), n (%)	61.5%	25.3%	**<0.001**
Biological parameters			
Potassium (mmol/L, mean ± SD)	6.3 ± 1.7	5.3 ± 1.1	0.01
Severe anemia (Hb < 8 g/dL), n (%)	62.7%	45.2%	**0.03**
Severe metabolic acidosis, n (%)	68.9%	49.8%	**0.02**
Number of hemodialysis sessions, median [IQR]	2 [1–3]	2 [1–4]	0.41
Average session duration (min), mean ± SD	151 ± 46	149 ± 43	0.56

Table 4: Factors Associated with In-Hospital Mortality

V. DISCUSSION

Acute kidney injury (AKI) is a frequent and severe complication in critically ill patients, representing an additional source of morbidity and mortality and a major determinant of long-term outcomes [1-3]. In our cohort of 594 patients, the mean age was 43 years, reflecting a younger population than those reported in most European and North American studies, where the median age typically ranges from 60 to 70 years. This difference may be explained by regional variations in the epidemiology of AKI, demographic characteristics, and the prevalence of underlying comorbidities. The male predominance observed in our study (61%) is consistent with previous reports in the literature [5].

Cardiovascular comorbidities were highly prevalent in our cohort, including hypertension (40.1%), diabetes mellitus (29.6%), and ischemic heart disease (20%), and ischemic heart disease (24%). These findings are consistent with previous reports and highlight the important role of these conditions as major risk factors for the development of AKI. Several studies have demonstrated that pre-existing cardiovascular disease predisposes patients to renal hypoperfusion and impaired renal autoregulation during critical illness, particularly in the setting of sepsis, shock, or mechanical ventilation [6].

Hemodynamic instability was a prominent feature in our cohort and was frequently associated with

septic shock, which was present in 73.2% of patients. This finding is consistent with previous studies identifying sepsis as the leading cause of AKI in critically ill patients and one of the principal indications for renal replacement therapy (RRT) in the intensive care setting [5-16]. The pathophysiology of sepsis-associated AKI is multifactorial, involving systemic inflammation, microcirculatory dysfunction, endothelial injury, and renal hypoperfusion.

According to KDIGO recommendations and published evidence, fluid overload and acute pulmonary edema remain among the most common indications for initiating RRT. In our series, the main indications for RRT were oligo-anuria with or without acute pulmonary edema (63%), severe metabolic acidosis (56%), life-threatening hyperkalemia (36%), and symptomatic uremia (40%). These findings are broadly consistent with those reported in previous studies and current clinical practice guidelines [7-21], supporting the appropriateness of RRT initiation in our cohort.

During hemodialysis sessions, intradialytic hypotension was the most common complication, occurring in nearly 30% of patients, a rate comparable to those reported in previous studies [10-21]. Intradialytic hypotension remains a major challenge in critically ill patients undergoing intermittent hemodialysis, as recurrent episodes of hemodynamic instability may further impair residual renal perfusion, exacerbate ischemic kidney injury, and delay renal recovery. In our cohort, the frequent need for vasoactive support (61%) further reflects the severity of hemodynamic compromise and underscores the critical condition of patients requiring renal replacement therapy in the intensive care setting.

The in-hospital mortality rate reached 44.6% in our cohort, which is consistent with rates reported in large contemporary studies of critically ill patients with AKI requiring renal replacement therapy, where mortality typically ranges from 35% to 55% [1]. Advanced age, septic shock, invasive mechanical ventilation, and severe anemia emerged as the main factors independently associated with mortality. These findings are in agreement with previous reports identifying older age and the severity of critical illness, particularly hemodynamic and respiratory failure, as major determinants of adverse outcomes in patients with severe AKI. Severe anemia may further contribute to tissue hypoxia and multiorgan dysfunction, thereby worsening prognosis in this high-risk population.

Recovery of normal renal function at one month was achieved in only 60% of our patients, a rate comparable to those reported in previous studies of critically ill patients with AKI requiring renal replacement therapy [4,8,18]. Nevertheless, a substantial proportion of patients remain dialysis-dependent in the long term, with some studies reporting rates approaching one-third of survivors [4].

Whether hemodialysis itself constitutes an independent risk factor for incomplete renal recovery remains a matter of debate. Current evidence suggests that renal outcomes are primarily driven by the severity of the underlying illness, the extent of kidney injury, and associated comorbidities rather than by renal replacement therapy itself. In our cohort, factors such as advanced age, major comorbidities, septic shock, oligo-anuria, hyperkalemia, and severe metabolic acidosis were independently associated with the absence of complete renal recovery, highlighting the predominant role of disease severity in determining long-term renal outcomes.

Some authors argue that the need for renal replacement therapy primarily reflects the severity of AKI and the associated organ dysfunction rather than constituting a direct cause of adverse renal outcomes. However, several recent studies have suggested that dialysis-related factors, including treatment duration, ultrafiltration rate, and the occurrence of intradialytic hypotension, may significantly influence renal recovery. Excessive ultrafiltration, recurrent hemodynamic instability, or overly aggressive dialysis strategies have been hypothesized to impair renal perfusion, delay tubular regeneration, and potentially promote the transition from AKI to chronic kidney disease [16-20].

In our cohort, neither the number of hemodialysis sessions nor dialysis duration was identified as an independent predictor of non-recovery of renal function. These findings support the hypothesis that patient-related factors and the severity of the underlying critical illness may play a more important role in determining renal outcomes than dialysis exposure itself.

The ELAIN trial suggested that early initiation of renal replacement therapy (RRT) may confer clinical benefits in patients with severe AKI, including faster renal recovery and earlier liberation from mechanical ventilation [18]. However, more than 80% of the study population consisted of postoperative cardiac surgery patients, a subgroup characterized by a high prevalence of fluid overload and a distinct clinical profile. In this setting, delayed RRT initiation was associated with slower recovery of kidney function, prolonged ventilatory support, and, in some cases, the need for subsequent intubation.

In contrast, large multicenter randomized controlled trials, including AKIKI, IDEAL-ICU, and STARRT-AKI, failed to demonstrate a survival benefit associated with an early RRT initiation strategy compared with a more conservative approach, in which RRT was initiated only when urgent clinical indications developed [19, 20]. Moreover, delayed strategies avoided unnecessary RRT in approximately 40–50% of

patients, thereby reducing exposure to procedure-related complications. Collectively, these findings support an individualized approach to RRT initiation based on clinical assessment and the patient's overall condition rather than a systematic early-start strategy.

In our cohort, all patients ultimately required RRT because they fulfilled conventional indications for dialysis initiation. Consequently, a direct comparison between early and delayed initiation strategies could not be performed.

Renal replacement therapy (RRT), whether delivered as intermittent hemodialysis or continuous kidney replacement therapy, has not demonstrated clear superiority of one modality over the other with regard to mortality, hemodynamic stability, or renal recovery. Consequently, the choice of RRT modality should be individualized according to the patient's clinical condition, therapeutic objectives, local expertise, and resource availability within the intensive care unit [11-21]. In our cohort, all patients were treated exclusively with intermittent hemodialysis, reflecting the standard practice and logistical resources of our institution.

Persistent dialysis dependence following an episode of AKI is recognized as a major adverse prognostic outcome. Failure to recover kidney function has been associated with increased long-term mortality, a higher incidence of cardiovascular events, and progression to chronic kidney disease. Recent evidence further underscores the prognostic importance of renal recovery. In a 2025 study by Wu *et al*., patients who failed to recover renal function after AKI exhibited approximately a twofold higher risk of death within one year compared with those who achieved renal recovery [4]. These findings highlight the importance of identifying patients at risk of non-recovery and implementing strategies aimed at preserving residual kidney function and optimizing long-term follow-up.

VI. CONCLUSION

Acute kidney injury (AKI) in the intensive care setting remains a complex and multifactorial condition associated with substantial morbidity and mortality. Early recognition and timely initiation of appropriate supportive therapies, including renal replacement therapy when indicated, can lead to satisfactory renal recovery in a significant proportion of patients.

Our findings are consistent with those of major international cohorts, confirming the central role of sepsis and cardiovascular comorbidities as key determinants of both mortality and renal outcomes. However, our study also provides valuable insight into the epidemiological characteristics of AKI in our setting, where patients tend to be younger and exhibit a different comorbidity profile compared with those reported in Western populations.

These observations highlight the importance of developing individualized management strategies tailored to local patient characteristics and healthcare resources. Further prospective multicenter studies are needed to refine prognostic assessment and optimize therapeutic approaches for critically ill patients with AKI requiring renal replacement therapy.

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