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Incidence, risk factors and mortality of acute kidney injury in solid malignancies: a retrospective cohort study

Mücahid Kulaksız

mucahid.kulaksiz@saglik.gov.tr

University of Health Sciences

Arzu Velioglu

Marmara University School of Medicine

Bülent Demirelli

Marmara University School of Medicine

Dilek Barutçu Ataş

University of Health Sciences

Ebru Aşıcıoğlu

Marmara University School of Medicine

İzzet Hakkı Arıkan

Marmara University School of Medicine

Mehmet Koç

Marmara University School of Medicine

Murat Tuğcu

Marmara University School of Medicine

Sultan Temiz

University of Health Sciences

Z. Serhan Tuğlular

Marmara University School of Medicine

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Abstract

Background:

Patients with solid malignancies are susceptible to acute kidney injury due to cancer, patient, and treatment-related factors, leading to interrupted oncologic care and worsened survival. We evaluated the incidence, risk factors, and mortality association of acute kidney injury in patients with newly diagnosed solid tumors.

Methods:

This single-center retrospective cohort study included 669 adults with newly diagnosed solid malignancies in 2017 and at least 6 months of follow-up. Demographic, clinical, oncologic, and renal variables were recorded. Acute kidney injury incidence was estimated using cumulative incidence functions with death as a competing event. Factors associated with acute kidney injury were assessed using Cox and Fine–Gray regression models. The association between acute kidney injury and all-cause mortality was evaluated using a time-dependent Cox model.

Results:

Among 669 patients, 131 (19.6%) developed AKI during follow-up. At 20, 40, and 60 months, cumulative AKI incidence reached 11.6%, 16.1%, and 18.9%, while mortality reached 22.0%, 30.4%, and 33.5%, respectively. Risk factors identified via multivariable analysis included male sex, diabetes mellitus, advanced-stage disease, poor performance status (ECOG score ≥ 2), cisplatin, anti-vascular endothelial growth factor therapy, and lower baseline estimated glomerular filtration rate and albumin. Male sex, poor performance status, cisplatin, and anti-vascular endothelial growth factor therapy remained significant in competing risk analysis. Acute kidney injury was significantly associated with mortality when modeled as a time-dependent covariate (HR 8.35, 95% CI 6.57–10.63; $p < 0.001$).

Conclusions:

Acute kidney injury is a common and clinically significant complication in patients with newly diagnosed solid tumors and is strongly associated with mortality. Early identification of high-risk patients and closer renal monitoring may improve renal and overall outcomes.

BACKGROUND

Acute kidney injury (AKI) is a common and clinically significant complication in patients with malignancy and is associated with substantial increases in morbidity, mortality, and healthcare burden.(1, 2) The etiology of AKI in cancer patients is multifactorial and includes prerenal, intrinsic, and postrenal

mechanisms related to sepsis, hypovolemia, urinary obstruction, tumor lysis, and nephrotoxic diagnostic or therapeutic exposures.(1, 3)

Patient-related factors such as older age, chronic kidney disease, diabetes, dehydration, and renal hypoperfusion may further increase susceptibility to kidney injury.(4) Moreover, newer targeted therapies have introduced additional renal risks. The convergence of these risks renders oncology patients particularly vulnerable to AKI, which may interrupt or delay anticancer treatment and ultimately worsen survival.(2, 5)

Early recognition of AKI and identification of modifiable risk factors therefore remain essential to improving prognosis.(6) However, contemporary data on the incidence, determinants, and prognostic implications of AKI among patients with newly diagnosed malignancies are limited. Accordingly, this study was designed to determine the incidence of AKI, identify associated risk factors, and evaluate its relationship with mortality in this patient population.

METHODS

Study design and participants

This retrospective, single-center cohort study was conducted at the Medical Oncology Clinic of Marmara University Faculty of Medicine. The calendar year 2017 was selected as the index year to ensure a minimum 5-year follow-up for long-term renal and survival analyses. “Time zero” for all time-to-event analyses was defined as the date of the initial oncology visit, which coincided with the date of cancer diagnosis.

The primary objectives were to determine the incidence of AKI and identify factors associated with its development in patients with newly diagnosed solid malignancies; secondary objectives were to evaluate its relationship with mortality and post-AKI renal outcomes.

Eligible participants were adults (≥ 18 years) with histologically confirmed solid tumors who had at least 6 months of follow-up, allowing assessment of renal outcomes over time. Patients with hematologic malignancies or those receiving renal replacement therapy at baseline were excluded. Individuals who developed a second primary malignancy during follow-up were retained.

Cancer type and stage at diagnosis were recorded based on standard clinical and radiologic staging systems. Gynecologic and urologic malignancies were analyzed separately due to their potential association with obstructive uropathy and AKI risk.

Baseline demographic and clinical characteristics, body size measures, comorbidities, renal parameters, oncologic characteristics, performance status, treatment exposures, and follow-up renal and oncologic outcomes were collected retrospectively from institutional electronic medical records and clinic archives.

Clinical and laboratory variables

Baseline serum creatinine was defined as a stable value measured around the time of diagnosis. Laboratory parameters reviewed included serum creatinine, blood urea nitrogen (BUN), electrolytes, urinalysis, and proteinuria. Proteinuria assessment methods varied (dipstick, spot protein testing or 24-hour urine collection); therefore, proteinuria was analyzed as a binary variable (present/absent). The most recent pre-treatment value was used.

Estimated glomerular filtration rate (eGFR) was expressed as absolute (non-indexed) values in mL/min by de-indexing CKD-EPI results to each patient's body surface area using the Du Bois formula.

Definitions and outcomes

AKI was defined and staged according to Kidney Disease: Improving Global Outcomes (KDIGO) serum creatinine criteria. Urine output criteria could not be applied due to insufficient documentation.(7) When multiple AKI episodes occurred, only the first event was included in the analysis. De novo CKD was defined as persistent eGFR < 60 mL/min for at least 3 months follow-up in patients without baseline CKD.

Exposure to chemotherapeutic and targeted agents was extracted from oncology records and chemotherapy unit logs. Because cumulative dose data were inconsistent, exposure to platinum compounds, VEGF inhibitors, EGFR inhibitors, tyrosine kinase inhibitors and immune checkpoint inhibitors was analyzed as binary (ever/never), considering only treatments administered before the first AKI event.

Statistical Analyses

All analyses were performed using IBM SPSS Statistics for Windows, Version 27.0 and R 3.6.3. Normality was assessed with the Shapiro–Wilk test. Since most variables were non-normally distributed, continuous variables are reported as median (interquartile range), and categorical variables as frequency (percentage).

Between-group comparisons (AKI vs. no AKI) were performed using the Mann–Whitney U test for continuous variables and the chi-square (χ^2) test for categorical variables.

To assess the association between AKI and all-cause mortality, a time-dependent Cox proportional hazards model was applied, with AKI entered as a time-dependent covariate. Overall survival was calculated from cancer diagnosis to death or last follow-up. Univariable hazard ratios (HRs) and 95% confidence intervals (CIs) were reported.

Cumulative incidence functions (CIF) were calculated to estimate the incidence of AKI over time with death treated as a competing event.

Factors associated with time to AKI were assessed using Cox proportional hazards regression as the primary analysis and Fine–Gray subdistribution hazard regression as a complementary competing-risk analysis. Multivariable models included variables that were either clinically relevant or statistically significant in univariable analyses. Variables with excessive missingness were excluded, missing data were not imputed and $p < 0.05$ was considered statistically significant.

Use of artificial intelligence tools

ChatGPT 5.2 (OpenAI) was used only for language support and translation assistance during manuscript preparation. All scientific content, interpretation, and final editing were performed by the authors.

RESULTS

Demographic characteristics and comorbidities according to AKI status are presented in Table 1, baseline and follow-up renal parameters in Table 2, and baseline and follow-up oncologic characteristics in Table 3. Univariable analyses showed significant associations between AKI development and male sex, older age at diagnosis, ECOG score ≥ 2, diabetes mellitus, chronic kidney disease, genitourinary or gynecologic malignancy, advanced-stage disease, cisplatin exposure, EGFR or VEGF pathway inhibitor use, lower baseline eGFR, and lower baseline serum albumin. Age and malignancy stage were also evaluated according to sex, demonstrating that male patients were older and more likely to have advanced-stage disease (Supplementary Table 1). Patients who developed AKI also had lower follow-up renal function and more frequent eGFR decline, new-onset proteinuria, electrolyte imbalance, and hematuria during follow-up (Table 2). In addition, AKI was associated with poorer performance status, more advanced disease, and greater exposure to cisplatin and VEGF pathway inhibitors (Table 3).

Table 1
Demographic characteristics and comorbidities by AKI status

Female, n (%)	**All patients (n:669)**	**AKI (n:131)**	**No AKI (n:538)**	**P Value**
	342 (51.1)	**45 (34.4)**	**297 (55.2)**	**< 0.001**
Male, n (%)	327 (48.9)	86 (65.6)	241 (44.8)	**< 0.001**
Age, year, median [Q1-Q3]	57 [47.5–66]	61 [53–68]	56 [46–65]	**< 0.001**
BSA, m^2, median [Q1-Q3]	1.76 [1.6–1.9]	1.83 [1.65–1.96]	1.76 [1.63–1.90]	**0.016**
BMI kg/m^2, median [Q1-Q3]	25.2 [22.4–28.7]	25.4 [22.5–29.3]	25 [22.4–28.7]	0.625
DM, n (%)	116 (17.3)	32 (24.4)	84 (15.6)	**0.017**
HT, n (%)	207 (30.9)	43 (32.8)	164 (30.5)	0.603
CHF, n (%)	36 (5.4)	8 (6.1)	28 (5.2)	0.681
Cirrhosis, n (%)	8 (1.2)	2 (1.5)	6 (1.1)	0.658
CKD, n (%)	35 (5.2)	10 (7.6)	25 (4.6)	0.169

AKI: acute kidney injury, BSA: body surface area, CHF: congestive heart failure, CKD: chronic kidney disease, DM: diabetes mellitus, HT: hypertension

Percentages were calculated using the number of patients in the corresponding column as the denominator, unless otherwise indicated; variables marked with an asterisk were calculated using non-missing data only.

Comparison of demographic characteristics and comorbidities between patients with and without AKI.

Table 2
Baseline and follow-up renal parameters by AKI status

Albumin, g/dL, median [Q1-Q3]	**All patients (n:669)**	**AKI (n:131)**	**No AKI (n:538)**	**P Value**
	4.1 [3.7–4.4]	**3.9 [3.5–4.3]**	**4.1 [3.8–4.4]**	**< 0.001**
Initial eGFR, mL/min, median [Q1-Q3]	103.6 [91.9-115.9]	100.3 [84-114.1]	104.5 [93.2-116.5]	**0.039**
Last eGFR, mL/min, median [Q1-Q3]	99.1 [79.2-111.8]	60.6 [41.6–87.6]	102.7 [89-115.4]	**< 0.001**
eGFR decline, n (%)	149 (22.3)	86 (65.6)	63 (11.7)	**< 0.001**
Initial Proteinuria, n (%)*	39 (7.9)	17 (13.9)	22 (5.9)	**0.004**
New-onset Proteinuria, n (%)*	141 (29.6)	64 (52.5)	77 (21.7)	**< 0.001**
New-onset Electr. imb., n (%)	427 (63.8)	125 (95.4)	302 (56.3)	**< 0.001**
New-onset Hematuria, n (%)*	151 (31.7)	57 (46.7)	94 (26.5)	**< 0.001**

AKI: acute kidney injury, eGFR: estimated glomerular filtration rate, Electr. imb.: electrolyte imbalance

Percentages were calculated using the number of patients in the corresponding column as the denominator, unless otherwise indicated; variables marked with an asterisk were calculated using non-missing data only.

Comparison of baseline and follow-up renal parameters between patients with and without AKI.

Table 3
Baseline and follow-up oncologic characteristics by AKI status

GU/GYN malignancy, n (%)	All patients (n:669)	AKI (n:131)	No AKI (n:538)	P Value
	87 (13)	**28 (21.4)**	**59 (11)**	**0.001**
Stage 1–2, n (%)	257 (39.7)	35 (27.3)	222 (42.7)	**0.001**
Stage 3–4, n (%)	391 (60.3)	93 (72.7)	298 (57.3)	**0.001**
ECOG Scale ≥ 2, n (%)	41 (6.1)	16 (12.2)	25 (4.6)	**0.001**
Conventional Chemo, n (%)	548 (81.9)	116 (88.5)	432 (80.3)	**0.028**
Cisplatin, n (%)	124 (18.5)	38 (29)	86 (16)	**< 0.001**
Tyrosine Kinase inh, n (%)	46 (6.9)	15 (11.5)	31 (5.8)	**0.021**
VEGF inhibitor, n (%)	74 (11.1)	26 (19.8)	48 (8.9)	**< 0.001**
EGFR inhibitor, n (%)	28 (4.2)	10 (7.6)	18 (3.3)	**0.028**
Immunotherapy, n (%)	9 (1.3)	1 (0.8)	8 (1.5)	**1**
Second Malignancy, n (%)	20 (3)	8 (6.1)	12 (2.2)	**0.039**
Follow-up, month, median [Q1-Q3]	35.5 [11–60]	21 [11.2–47.7]	41.6 [14.2–64.9]	**< 0.001**

AKI: acute kidney injury, ECOG: Eastern Cooperative Oncology Group, EGFR: epidermal growth factor receptor, GU: genitourinary, GYN: gynecologic, VEGF: vascular endothelial growth factor

Percentages were calculated using the number of patients in the corresponding column as the denominator, unless otherwise indicated; variables marked with an asterisk were calculated using non-missing data only.

Comparison of baseline and follow-up oncologic characteristics between patients with and without AKI.

During follow-up, AKI developed in 131 patients (19.6%). Competing risk analysis showed that death was a substantial competing event for AKI. The cumulative incidence of AKI was 11.6%, 16.1%, and 18.9% at 20, 40, and 60 months, respectively, compared with 22.0%, 30.4%, and 33.5% for death (Fig. 1).

Among the 131 patients who developed AKI, 10 had pre-existing CKD and 121 did not. Among the 10 patients with baseline CKD, 3 died during the AKI episode, 6 experienced CKD progression, and 1 returned to baseline renal function. Among the 121 patients without baseline CKD, 45 died after the AKI episode, 32 developed de novo CKD, and 44 recovered renal function after AKI.

The parameters included in the multivariable models and the corresponding results are presented in Table 4. In Cox regression, male sex, diabetes mellitus, advanced-stage disease, ECOG score ≥ 2, cisplatin exposure, anti-VEGF therapy, lower baseline eGFR, and lower baseline serum albumin were

independently associated with AKI development. In Fine–Gray analysis, male sex, ECOG score ≥ 2, cisplatin exposure, and anti-VEGF therapy remained significant.

Table 4
Multivariable predictors of AKI in Cox and Fine–Gray models

	Cox Regression Analysis			Competing Risk Regression Analysis		
	P Value	**HR**	**95% CI**	**P Value**	**SHR**	**95% CI**
Male sex	**< 0.001**	**2.562**	**1.716–3.824**	**< 0.001**	**1.986**	**1.312–3.006**
Age at Diagnosis	0.400	1.009	0.989–1.029	0.95	0.999	0.979–1.020
Presence of DM	**0.040**	**1.550**	**1.021–2.354**	0.12	1.405	0.918–2.150
Stage 3 or 4 Malignancy	**0.024**	**1.600**	**1.064–2.407**	0.520	1.150	0.752–1.759
GU or GYN Malignancy	**0.041**	**1.780**	**1.023–3.098**	0.86	1.684	0.929–3.052
ECOG score 2 or higher	**< 0.001**	**2.578**	**1.527–4.353**	**0.019**	**1.958**	**1.118–3.427**
Use of Cisplatin	**0.004**	**1.800**	**1.208–2.682**	**0.005**	**1.823**	**1.201–2.769**
Use of Anti-VEGF	**0.001**	**2.162**	**1.360–3.438**	**0.009**	**1.927**	**1.178–3.153**
Use of Anti-EGFR	0.603	1.208	0.594–2.456	0.20	1.560	0.796–3.059
Higher Serum Albumin	**0.008**	**0.671**	**0.500–0.900**	0.14	0.795	0.585–1.081
Higher eGFR	**0.003**	**0.986**	**0.977–0.995**	0.13	0.989	0.975–1.003
Presence of CKD	0.807	1.107	0.489–2.508	0.104	1.048	0.431–2.551

CKD: chronic kidney disease, CI confidence interval, DM: diabetes mellitus, ECOG: Eastern Cooperative Oncology Group, eGFR: estimated glomerular filtration rate, EGFR: epidermal growth factor receptor, GU: genitourinary, GYN: gynecologic, HR: hazard ratio, SHR: subdistribution hazard ratio, VEGF: vascular endothelial growth factor

Multivariable models identifying independent predictors of AKI.

Table 5 summarizes the association between AKI and all-cause mortality, including mortality distributions by AKI stage and etiologic classification and the corresponding univariable time-dependent

Cox analysis. Mortality occurred in 77.1% of patients with AKI compared with 40.0% of those without AKI. AKI was strongly associated with subsequent all-cause mortality.

Table 5
Mortality according to AKI status, stage, etiology, and time-dependent Cox analysis

Categorical Comparison		MORTALITY					
		YES		**NO**			
		Number of Patients	**Rate (%)**	**Number of Patients**	**Rate (%)**	**P Value**	**Total Number**
AKI Development	**Yes**	101	77.1	30	22.9	**< 0.001**	131
	No	215	40	323	60		538
AKI Phase According to KDIGO	**Stage 1**	21	67.7	10	32.3	0.326	31
	Stage 2	43	78.2	12	21.8		55
	Stage 3	37	82.2	8	17.8		45
AKI Classification*	**Prerenal**	71	79.8	18	20.2	0.795	89
	Renal	15	75	5	25		20
	Postrenal	11	73.3	4	26.7		15
Univariable time-dependent Cox model			**HR**	**95% CI**		**P Value**	
			8.35	6.57–10.63		**< 0.001**	

AKI: acute kidney injury, KDIGO: Kidney Disease: Improving Global Outcomes, HR: hazard ratio, CI: confidence interval

The upper section shows categorical mortality comparisons by AKI status, and the lower section presents the univariable time-dependent Cox analysis for all-cause mortality.

Percentages were calculated using the corresponding AKI-related subgroup as the denominator.

*Seven AKI episodes with insufficient etiologic data were excluded from etiologic subgroup analysis.

Line graph showing cumulative incidence over time for acute kidney injury and death in patients with newly diagnosed solid malignancies. Both curves rise over follow-up, with death occurring more frequently than acute kidney injury.

DISCUSSION

In this retrospective cohort of patients with newly diagnosed solid malignancies, AKI was found to be a common complication associated with distinct clinical risk factors and markedly increased mortality. AKI occurred early in the disease course, underscoring the vulnerability of patients during the initial

phase of cancer care. These results highlight the need for early identification of high-risk individuals and targeted strategies to mitigate AKI-related adverse outcomes.

Large epidemiological studies have consistently shown that AKI is a common complication in cancer populations. Christiansen et al. reported a 27% AKI incidence in a nationwide cohort of 37,267 patients, (8) while a meta-analysis by Can et al. identified a cumulative incidence of 24%.(9) In our cohort, AKI occurred in 19.6% of patients. This lower incidence may reflect the exclusion of hematologic malignancies, the use of serum creatinine–based KDIGO criteria without urine output assessment, and the exclusion of patients with less than six months of follow-up. Competing risk analysis demonstrated that death was a substantial competing event for AKI, indicating that many patients died before renal injury could develop (Fig. 1).

The predominance of prerenal AKI in our cohort suggests that many cases were driven by potentially reversible factors, such as dehydration, poor oral intake, or treatment-related hypovolemia. Similar patterns have been reported in patients with solid tumors, in whom volume depletion, sepsis, and renal hypoperfusion are common precipitants of AKI, whereas intrinsic renal injury appears less frequent but clinically important.(10, 11) These findings support a distinct etiologic profile of AKI in solid malignancies, in which prerenal and treatment-related mechanisms predominate, whereas intrinsic renal injury remains a smaller but clinically important subset.

Age and sex appear to influence susceptibility to AKI in cancer populations. A large prospective cohort reported a higher AKI incidence in males than in females,(12) while older age is a well-established determinant of renal vulnerability.(13) In our cohort, AKI was more frequent in males, who were also older and more likely to have advanced-stage disease at diagnosis (Supplementary Table 1). Although age was associated with AKI in univariable analysis, it did not remain significant after multivariable adjustment, suggesting that its effect may be mediated by cancer-related and clinical factors.

Diabetes mellitus emerged as an independent risk factor for AKI in our cohort, consistent with previous studies supporting its role in renal vulnerability.(14) Other comorbidities such as hypertension (HT), congestive heart failure (CHF), and cirrhosis were not significantly associated with AKI, possibly because of their low prevalence in our cohort. Prior studies have reported heterogeneous findings regarding these conditions in cancer populations.(15, 16) It is also possible that, in patients with cancer, the effects of these comorbidities are overshadowed by cancer-related factors such as tumor burden, performance status, and nephrotoxic treatment exposure.

In our study, pre-existing CKD was not independently associated with AKI, whereas reduced baseline eGFR was. This suggests that subclinical renal impairment—rather than a documented CKD diagnosis—may better capture true susceptibility to AKI. Baseline proteinuria was also associated with AKI in univariable analysis, further supporting the importance of early markers of renal vulnerability. Prior studies have likewise shown that both proteinuria and low eGFR are independently associated with AKI risk and poorer renal outcomes.(17, 18) Taken together, these observations suggest that subtle or unrecognized kidney injury—reflected by proteinuria and modest reductions in eGFR—may predispose

patients to AKI even in the absence of a formal CKD diagnosis. Furthermore, because cancer patients often exhibit substantial variation in body surface area (BSA) due to sarcopenia or cachexia, we used non–BSA-indexed eGFR to more accurately reflect individual renal function. While BSA-indexed eGFR remains common in clinical practice, further studies are needed to determine the most appropriate method for assessing renal reserve in oncology populations with altered body composition. Prior evidence supports this approach; Akbari et al. showed that non-indexed eGFR provided more accurate drug dosing in obese transplant recipients compared with BSA-indexed values.(19) In our cohort, a substantial proportion of patients who survived an AKI episode developed de novo CKD during follow-up, highlighting the potential long-term renal consequences of AKI in oncology patients.

Tumor burden, tumor location, and the systemic functional decline associated with cancer all appear to contribute to AKI development. Tumors may contribute to renal injury through direct mechanisms—such as parenchymal infiltration, ureteral or vascular obstruction, and nephron loss in renal malignancies—as well as indirect pathways including inflammation, malnutrition, cachexia, and hemodynamic instability. Consistent with earlier reports, Christiansen et al. observed the highest one-year AKI incidence among patients with renal cancers,(8) and Tuğcu et al. noted increased nephrology referrals in gastrointestinal and genitourinary malignancies.(20) Similarly, our study found that genitourinary and gynecologic tumors were associated with higher AKI risk in univariate analysis, likely reflecting both obstructive uropathy from pelvic masses and the structural impact of renal tumors, although these associations did not remain significant after adjustment for disease stage. Advanced cancer stage itself was a strong independent predictor of AKI, in line with findings by Kitchlu et al.,(21) highlighting overall tumor burden as a key determinant of renal outcomes. Performance status further integrates these effects: patients with ECOG ≥ 2 had a significantly increased risk of AKI, suggesting that poor functional capacity—often driven by systemic illness burden, sarcopenia, malnutrition, and reduced tolerance to chemotherapy—amplifies susceptibility to renal injury. In this context, hypoalbuminemia serves as an important clinical marker of these same processes. Prior studies have shown that low albumin reflects both malnutrition and systemic inflammation and independently predicts AKI risk and mortality.(13, 22) Consistent with these observations, low baseline albumin was also associated with AKI in our cohort, supporting the view that tumor burden and cancer-related physiological decline jointly contribute to renal vulnerability.

Several anticancer therapies have well-documented nephrotoxic potential and contribute substantially to AKI in oncology practice. Cisplatin remains one of the most prominent nephrotoxic agents, primarily through proximal tubular toxicity and oxidative injury.(23) Likewise, the association between VEGF pathway inhibition and AKI is biologically plausible and consistent with prior reports linking anti-VEGF agents to proteinuria and renal impairment.(24) Other agents, including immune checkpoint inhibitors, tyrosine kinase inhibitors, antimetabolites, and newer targeted therapies, have also been associated with renal toxicity.(25–27) In our cohort, exposure to cisplatin and anti-VEGF agents independently increased AKI risk, likely reflecting a combination of direct tubular injury, endothelial dysfunction, and patient-related susceptibility. Moreover, most patients receiving cisplatin or anti-VEGF therapy had gastrointestinal or genitourinary malignancies, which themselves carry a higher risk of AKI due to tumor burden, obstructive complications, or intensive treatment protocols; this overlap may have further

amplified the observed associations. These findings support careful baseline assessment and close renal monitoring in patients receiving potentially nephrotoxic anticancer therapies.

Both malignancy and its treatments predispose patients to renal injury, and the development of AKI further amplifies mortality risk. Kang et al. demonstrated that both the occurrence of AKI and higher KDIGO stages independently predicted cancer-related mortality,(28) underscoring the prognostic significance of even modest declines in renal function in oncology populations. In a recent large cohort study, Munch et al. likewise showed that AKI after cancer treatment was associated with increased mortality across most treatment categories.(29) Consistent with these observations, mortality was higher in patients who developed AKI, and AKI remained strongly associated with subsequent all-cause mortality when modeled as a time-dependent exposure. These findings support AKI as an important marker of poor prognosis in patients with solid malignancies. However, neither AKI stage nor etiology associated with mortality in our univariate analysis. This may be partly attributable to referral and documentation bias: patients with more severe AKI episodes were often transferred to external intensive care units, resulting in incomplete follow-up and potential underestimation of mortality associated with higher-stage or intrinsic AKI. In addition, the predominance of prerenal AKI and the limited number of patients in stage- and etiology-based subgroups may have attenuated detectable differences in mortality. These findings suggest that while AKI itself is a strong marker of poor prognosis in solid malignancies, precise evaluation of AKI severity and cause requires comprehensive and uninterrupted follow-up, particularly in settings where critically ill patients are managed across multiple institutions.

In the competing risk analysis, male sex, poor performance status, cisplatin exposure, and anti-VEGF therapy remained significantly associated with AKI, whereas some associations observed in the Cox model were attenuated. This pattern suggests that some variables may have been linked not only to AKI risk but also to early mortality, which acted as a competing event and reduced the probability of observing AKI.

This study has several limitations. Cancer type and stage were categorized by organ system rather than histological subtype, which may introduce heterogeneity in renal risk profiles. Important nephrotoxic exposures—such as contrast agents, diuretics, and NSAIDs—were incompletely documented, and cumulative chemotherapeutic dose data were not consistently available. The temporal relationship between AKI, proteinuria, and electrolyte disturbances could not be fully established, and the duration or severity of comorbidities such as diabetes and hypertension was unavailable. Incomplete urine output data and missing proteinuria measurements restricted assessment of subclinical kidney injury. Furthermore, the minimum follow-up requirement of 6 months may have introduced selection bias by excluding patients with very early death or short observation time.

Despite these limitations, the study benefits from a large cohort of 669 patients with newly diagnosed solid malignancies and long-term follow-up of up to 78 months, providing robust real-world data from a major oncology center in Türkiye. The use of cause-specific Cox and complementary Fine–Gray models allowed a more rigorous assessment of incident AKI in the presence of the competing risk of death. In

addition, modeling AKI as a time-dependent exposure in the mortality analysis provided a more appropriate evaluation of its association with all-cause mortality. The use of non–BSA-indexed eGFR also enabled a more accurate assessment of renal function in sarcopenic or cachectic individuals. Collectively, these methodological strengths add to the limited literature linking hypoalbuminemia, functional impairment, and advanced tumor stage with AKI risk in solid malignancies.

CONCLUSIONS

AKI is a common and clinically significant complication in patients with solid tumors and is strongly associated with increased mortality. In our cohort, male sex, DM, stage III–IV malignancy, genitourinary or gynecologic malignancy, ECOG score ≥ 2, cisplatin exposure, anti-VEGF therapy, lower serum albumin, and baseline eGFR were independent predictors of AKI. These findings remained broadly consistent in competing risk analysis, although some associations were attenuated after accounting for death as a competing event. In addition, AKI occurrence during follow-up was associated with higher all-cause mortality and unfavorable renal outcomes. These findings highlight the multifactorial nature of cancer-related kidney injury and underscore the importance of early recognition and careful renal monitoring in patients with solid malignancies.

Abbreviations

AKI
Acute kidney injury
BSA
Body surface area
BUN
Blood urea nitrogen
CHF
Congestive heart failure
CI
Confidence interval
CIF
Cumulative incidence function
CKD
Chronic kidney disease
CKD-EPI
Chronic Kidney Disease Epidemiology Collaboration
DM
Diabetes mellitus
eGFR
Estimated glomerular filtration rate
EGFR

Epidermal growth factor receptor

ECOG

Eastern Cooperative Oncology Group

GU

Genitourinary

GYN

Gynecologic

HR

Hazard ratio

HT

Hypertension

KDIGO

Kidney Disease:Improving Global Outcomes

NSAIDs

Non-steroidal anti-inflammatory drugs

SHR

Subdistribution hazard ratio

VEGF

Vascular endothelial growth factor

Declarations

Ethics approval and consent to participate

The study was approved by the Marmara University School of Medicine Research Ethics Committee (protocol no. 09.2023.521; meeting date: May 11, 2023). The requirement for informed consent was waived because of the retrospective design of the study.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

Mücahid Kulaksız: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – original draft.

Murat Tuğcu: Conceptualization, Methodology, Supervision, Writing – review & editing.

İzzet Hakkı Arıkan: Data Curation, Formal Analysis, Investigation.

Ebru Aşıcıoğlu: Data Curation, Investigation.

Arzu Velioğlu: Data Curation, Validation.

Dilek Barutçu Ataş: Data Curation, Investigation.

Bülent Demirelli: Data Curation, Investigation.

Z. Serhan Tuğlular: Validation, Supervision, Writing – review & editing.

Sultan Temiz: Writing – review & editing.

Mehmet Koç: Data Curation, Validation, Writing – review & editing.

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Author Contribution

M.Ku. contributed to conceptualization, methodology, data curation, formal analysis, and writing of the original draft. M.T. contributed to conceptualization, methodology, supervision, and review and editing of the manuscript. I.H.A. contributed to data curation, formal analysis, and investigation. E.A. contributed to data curation and investigation. A.V. contributed to data curation and validation. D.B.A. contributed to data curation and investigation. B.D. contributed to data curation and investigation. Z.S.T. contributed to validation, supervision, and review and editing of the manuscript. S.T. contributed to review and editing of the manuscript. M.Ko. contributed to data curation, validation, and review and editing of the manuscript. All authors read and approved the final manuscript.

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Not applicable

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. The data are not publicly available due to institutional and patient privacy restrictions.

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Figures

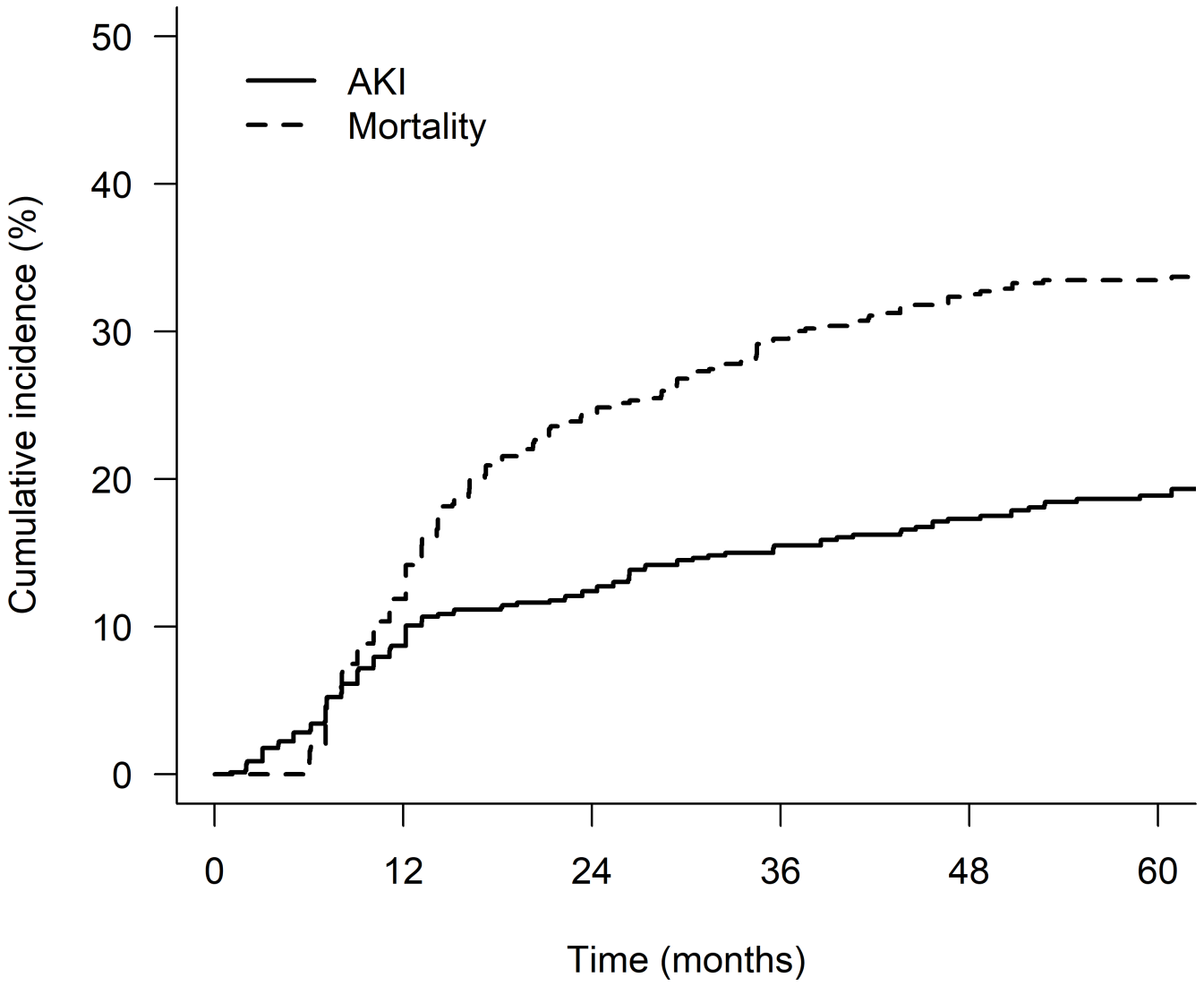


Figure 1

Cumulative incidence of AKI and death over time

Line graph showing cumulative incidence over time for acute kidney injury and death in patients with newly diagnosed solid malignancies. Both curves rise over follow-up, with death occurring more frequently than acute kidney injury.

Supplementary Files

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