Title

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Incidence Rate, Clinical Correlates, and Outcomes of AKI in Patients Admitted to a Comprehensive Cancer Center

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Summary

Background and objectives Incidence of AKI in hospitalized patients with cancer is increasing, but reports are scant. The objective of this study was to determine incidence rate, clinical correlates, and outcomes of AKI in patients admitted to a cancer center.

Design, setting, participants, & measurements Cross-sectional analysis of prospectively collected data on 3558 patients admitted to the University of Texas M.D. Anderson Cancer Center over 3 months in 2006.

Results Using modified RIFLE (Risk, Injury, Failure, Loss, ESRD) criteria, 12% of patients admitted to the hospital had AKI, with severity in the Risk, Injury, and Failure categories of 68%, 21%, and 11%, respectively. AKI occurred in 45% of patients during the first 2 days and in 55% thereafter. Dialysis was required in 4% of patients and nephrology consultation in 10%. In the multivariate model, the odds ratio (OR) for developing AKI was significantly higher for diabetes (OR, 1.89; 95% confidence interval [CI], 1.51–2.36), chemotherapy (OR, 1.61; 95% CI, 1.26–2.05), intravenous contrast (OR, 4.55; 95% CI, 3.51–5.89), hyponatremia (OR, 1.97; 95% CI, 1.57–2.47), and antibiotics (OR, 1.52; 95% CI, 1.15–2.02). In patients with AKI, length of stay (100%), cost (106%), and odds for mortality (4.7-fold) were significantly greater.

Conclusion The rate of AKI in patients admitted to a comprehensive cancer center was higher than the rate in most noncancer settings; was correlated significantly with diabetes, hyponatremia, intravenous contrast, chemotherapy, and antibiotics; and was associated with poorer clinical outcomes. AKI developed in many patients after admission. Studies are warranted to determine whether proactive measures may limit AKI and improve outcomes.

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Introduction

Considerable progress has been made in treating cancer (1). For several cancers, overall mortality is lower with current therapies. Many cases are cured, and others are rendered chronic and manageable. The benefits of such therapies are, however, not fully realized, in part because of the high frequency of therapy-associated organ injury, including of the kidneys (2). AKI seems to be on the rise in hospitalized patients with cancer. To our knowledge, the frequency of AKI in hospitalized patients with cancer or the extent of its effect on clinical outcomes has not been reported. This lack of information is of particular concern because several unique aspects of cancer therapy, such as stem cell transplant (SCT), tumor lysis syndrome, and the use of potential nephrotoxic drugs, predispose hospitalized patients with cancer to AKI (3–6). Furthermore, cancer therapy is becoming available to elderly patients, a subpopulation that is particularly vulnerable to the nephrotoxic adverse effects of many drugs as well as to the use of intravenous radiocontrast. Currently there are no proven treatments for AKI other than to provide supportive dialysis (7,8). An important and potentially effective strategy in the fight against AKI is to take a proactive approach in patients known to have high risk for AKI (9). We believe a window of opportunity exists to prevent AKI in many hospitalized patients with cancer, especially when these patients are admitted for SCTs, surgeries, chemotherapy, radiation, and interventional and noninterventional radiologic procedures. Unlike in patients with cancer, the frequency of AKI is known in hospitalized noncancer settings (about 5%–8%), and AKI in such settings is also known to be associated with poorer clinical outcomes (10,11). The objective of this study was to gather missing information on the incidence rate of AKI and associated clinical factors in hospitalized patients with cancer and to assess the effect of AKI on clinical outcomes and healthcare cost. For this, we undertook a cross-sectional analysis of a set of prospectively collected clinical data on patients admitted to the University of Texas M.D. Anderson Cancer Center (MDACC) during a 3-month period in 2006.

Materials and Methods

The Institutional Review Board of MDACC had approved the prospective collection of the data and subsequent undertaking of this study. The data were collected into an electronic database for all patients admitted to MDACC for 3 months (May–July 2006). An admission was defined as a stay of >23 hours in the hospital that included midnight. The eligibility for inclusion in this analysis was any patient admitted to MDACC during this period with a serum creatinine value at admission and at least one such value during hospital stay. For each patient, information on demographic characteristics, medical conditions, laboratory data, treatments, clinical outcomes, and billing data were collected. Part of this database was analyzed previously to define hyponatremia in this population, and the findings were published (12). For this analysis, only the first admission data were used. The primary outcome variable was AKI, defined using modified RIFLE (Risk, Injury, Failure, Loss, ESRD) criteria (13–15). The urine output was not part of the criteria. The time for an increase in serum creatinine from admission included any time during hospitalization. The baseline serum creatinine was the first serum creatinine that was measured after admission. In addition to the original electronic data, electronic case records of individual patients who developed AKI were accessed (chart check) to obtain additional information.

Any potential bias due to the exclusion of patients with missing serum creatinine values was addressed by imputing missing creatinine values. Groups were compared with a *t* test or chi-squared test, as appropriate. A two-sided *P* value of ≤0.05 was considered to represent a statistically significant difference. Logistic regression analyses were performed to test the association between AKI and relevant demographic, clinical, and outcome factors and between AKI and in-hospital mortality. Factors were chosen on the basis of clinical relevance and initial exploratory analysis. All variables with a *P* value >0.1 in the univariate model except for age, sex, and race were excluded from the multivariate model. For the latter, all variables in the model were introduced in a single step. Overall model fit was assessed by a likelihood ratio test. A cross-validated Hosmer-Lemeshow chi-square statistic was used to assess for calibration. The specification and linearity of predictor variables were tested and found to be intact, with no significant correlation between variables. For AKI severity, the RIFLE criteria of Risk, Injury, and Failure were used. Time-to-discharge was measured from the date of hospital admission to discharge. The data on hospital bill and length of stay were skewed. Box plots were used to report the details, and the statistical differences between AKI and non-AKI groups were analyzed using a Mann-Whitney test. Statistical analyses were carried out by using Stata software, version 10.0 (Stata Corp., College Station, TX), and SPSS software, version 16.0 (SPSS Inc., Chicago, IL).

Results

Identification and Validation of AKI

During the 3 months of this data collection, a total of 3940 patients were admitted 5015 times, 71% 1 time, 24% 2–3 times, and 5% >3 times. Serum creatinine values were not reported in 380 (10%) patients in the first admission data (Figure 1). However, when patients with missing serum creatinine values were included using the imputed values in the analyses (Supplemental Table 1), the key results were not statistically different from analyses presented here, using patients excluded for missing serum creatinine values. Two patients, one with ESRD and another with mismatching admission date, were excluded, yielding a total of 3558 (90%) patients for the final analysis (Figure 1). Chart check on individual patients who had AKI in the electronic database revealed that AKI was misclassified in 15 patients (serum creatinine level decreased in 10 patients and did not change in 5 patients) and was missed in 9 patients (acute dialysis was started immediately after admission to the intensive care unit [ICU]); these patients were reclassified before analysis.

Patient Characteristics and AKI Rates

The mean age ± SD was 56±17 years; 52% of patients were male, and 73% were white (Table 1). Among patients admitted, 66% were under the medical oncology, 32% surgical oncology, and 2% rehabilitation and general internal medicine services. Eight percent of patients admitted had received SCT: 3.5% autologous, 3.0% allogeneic, and 1.5% combined. On the basis of the RIFLE criterion of at least a 50% increase in serum creatinine during hospital stay, 12% of patients were found to have AKI. The severity categories based on RIFLE classification of Risk, Injury, and Failure were 68%, 21%, and 11%, respectively. Forty-five percent of AKI was noted to occur during the first 2 days of admission, 49% between days 2 and 21, and 6% after 21 days (Figure 2).

Logistic Regression Analysis and AKI

In the univariate model, significantly higher odds for developing AKI were seen with diabetes, leukemia, SCT, hyponatremia, antibiotics, chemotherapy, intravenous contrast, and transfer to the ICU (Table 2). Age was significant in the univariate model but not in the multivariate. Sex and race were not significant in either model. In the multivariate model, significantly higher risks for AKI persisted with diabetes (odds ratio [OR], 1.89; 95% confidence interval [CI], 1.51–2.36; *P*<0.001), chemotherapy (OR, 1.61; 95%

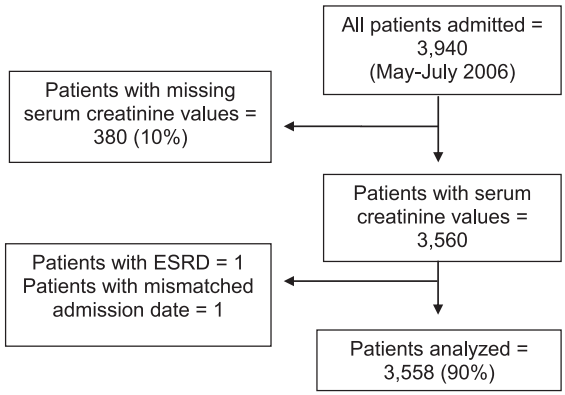


Figure 1. | Flowchart displaying the chart evaluation process for all patients admitted to the cancer center during a 3-month period.

Table 1. Features of all patients and patients with and without AKI admitted over 3 months to cancer center

Variable	All Patients (*n*=3558)	Patients with AKI (*n*=427)	Patients without AKI (*n*=3131)	*P* Value (AKI versus non-AKI)
Age (year)	56±17	55±18	56±16	0.62
Men (%)	52	52	52	0.89
Race (%)				
White	73	70	73	0.68
Black	10	11	10	
Hispanic	13	14	13	
Other	4	5	4	
Type of cancer (%):				
Nonhematologic	64	62	68	<0.001
Hematologic	24	28	19	
Other[a]	12	10	13	
Stem cell transplant (%)[b]	8	15	7	<0.001
Diabetes (%)	40	60	38	<0.001
Antibiotics (%)	68	83	69	<0.001
Chemotherapy (%)	27	38	25	<0.001
Intravenous radiocontrast (%)	9	36	9	<0.001
Hyponatremia (%)	51	69	48	<0.001
Transfer to ICU (%)	6	14	5	<0.001

Values for age are the mean ± SD. ICU, intensive care unit.
[a]Primary cancer unidentified or missing.
[b]Autologous and allogeneic.

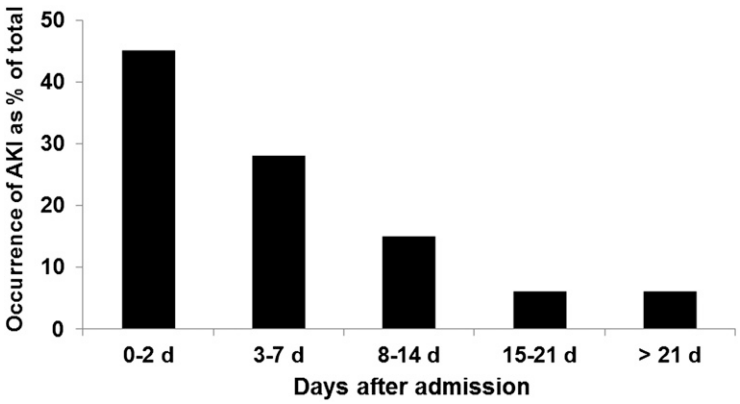


Figure 2. | The timing of AKI, presented as percentages of total AKI against days after admission to the cancer center.

CI, 1.26–2.05; $P<0.001$), hyponatremia (OR, 1.97; 95% CI, 1.57–2.47; $P<0.001$), antibiotic therapy (OR, 1.52; 95% CI, 1.15–2.02; $P=0.004$), intravenous contrast (OR, 4.55; 95% CI, 3.51–5.89; $P<0.001$), and transfer to the ICU (OR, 2.34; 95% CI, 1.66–3.31; $P<0.001$). Leukemia and SCT were no longer significant in the adjusted model (Table 2).

To further explore the types of cancers or cancer services associated with AKI in our hospitalized patients, the frequency of AKI as a function of admitting service was examined. The AKI rate in patients admitted to medical service was much higher than that in patients admitted to surgical service, and no patients admitted to the radiation service had AKI (radiation therapy was an outpatient procedure, and very few patients were admitted) (Table 3). Within the medical admission, admission to gynecology medical oncology, SCT, leukemia, and general internal medicine services had the highest rates of AKI (33%, 22%, 19%, and 23%, respectively). When the rates were reanalyzed using cancer types described in the billing documents (Supplemental Table 2), patients with hematologic cancers (leukemia, lymphoma, and myeloma) had higher rates of AKI. Renal cancer diagnosis was associated with an AKI rate of 20% (most patients were admitted for nephrectomies). When the data were reanalyzed using the admitting diagnosis given in the billing document (data not shown), the AKI rates were 20% for agranulocytosis, 14% for fever, 10% for nausea and vomiting, and 13% for encounter for chemotherapy.

Among patients who required dialysis (4% of all patients with AKI), leukemia was the cancer of diagnosis in 59%, lymphoma in 21%, and solid tumors in 20%. Septic shock was present in 40% of these patients. Among patients

Table 2. Logistic regression analyses yielding odds ratios for factors associated with AKI in patients admitted to cancer center

Factors	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age	0.99 (0.98–0.99)	0.03	0.99 (0.99–1.00)	0.05
Sex (male/female)	1.01 (0.83–1.24)	0.89	0.92 (0.74–1.13)	0.44
Race (white/others)	1.15 (0.94–1.40)	0.10	1.04 (0.83–1.31)	0.68
Leukemia (yes/no)	2.04 (1.56–2.66)	<0.001	1.16 (0.85–1.59)	0.35
Stem cell transplant (yes/no)	2.18 (1.62–2.95)	<0.001	1.16 (0.80–1.68)	0.43
Diabetes (yes/no)	2.48 (2.02–3.05)	<0.001	1.89 (1.51–2.36)	<0.001
Chemotherapy (yes/no)[a]	1.80 (1.46–2.22)	<0.001	1.61 (1.26–2.05)	<0.001
Antibiotics (yes/no)[a]	2.16 (1.66–2.81)	<0.001	1.52 (1.15–2.02)	0.004
Intravenous radiocontrast (yes/no)[a]	5.84 (4.62–7.34)	<0.001	4.55 (3.51–5.89)	<0.001
Hyponatremia (yes/no)[a]	2.38 (1.92–2.96)	<0.001	1.97 (1.57–2.47)	<0.001
Transfer to ICU (yes/no)[a]	3.28 (2.38–4.54)	<0.001	2.34 (1.66–3.31)	<0.001

CI, confidence interval; ICU, intensive care unit.
[a]Only patients who had these factors or events occurred before AKI were coded as "yes."

Table 3. Rate of AKI as percentage of patients admitted to each service in cancer center

Admitting Departments	In-Hospital AKI		Total (*n*)
	No (*n*)	Yes, *n* (%)	
Medical			
Stem cell transplantation	204	58 (22)	266
Leukemia	288	68 (19)	356
General internal medicine	41	12 (23)	51
Gynecology medical oncology	30	15 (33)	45
Clinical center for targeted therapy	82	12 (13)	94
GI medical oncology	175	24 (12)	204
Breast medical oncology	128	15 (10)	143
GU oncology	154	7 (4)	161
Head and neck medical oncology	59	7 (11)	66
Melanoma medicine	80	11 (12)	91
Neuro-oncology	48	5 (10)	50
Sarcoma medicine	83	15 (15)	96
Symptom control and palliative center	51	3 (1)	54
Thoracic medicine	141	17 (11)	158
Pediatrics	92	11 (11)	103
Surgical			
Melanoma surgical	68	2 (3)	70
Neurosurgery	159	3 (2)	162
Gynecology	210	23 (10)	233
Head and neck surgery	132	10 (7)	137
GI surgical	233	29 (11)	270
Orthopedics: sarcoma	40	0 (0)	40
Orthopedics	52	9 (15)	61
Sarcoma surgical	44	8 (15)	52
Plastic surgery	45	0 (0)	45
Breast surgical	27	1 (3)	28
Surgical endocrinology	45	8 (16)	48
Thoracic surgery	201	24 (11)	225
Urology	209	30 (13)	239
Radiation			
Radiation therapy	10	0 (0)	10
Total	3131	427 (12)	3558

GI, gastrointestinal; GU, genitourinary.

receiving dialysis, 10% had developed tumor lysis syndrome and 31% had received chemotherapy. The frequently used chemotherapeutic agents were methotrexate, cyclophosphamide, and rituximab. Although the use of chemotherapy and the rate of AKI were significantly associated (Table 2), identifying the specific chemotherapeutic agent causing AKI was not possible in this analysis. Nearly 76 chemotherapeutic agents, mostly in combinations, were used in 186 patients who developed AKI. The frequencies of AKI were higher in agents already known to be associated with nephrotoxicity, such as cisplatin, carboplatin, methotrexate, IL-2, rituximab, and ifosfamide (data not shown).

Outcome Analyses

The length of hospital stay (median [25th–75th percentile]) was 5 days (3–9 days) for patients without AKI and 10 days (6–19 days) for patients without AKI; this difference represents a 100% increase ($P<0.001$) (Figure 3, upper panel). Similarly, the hospital bill was 106% higher in patients with AKI than in patients without AKI (median, 25th–75th percentile: $82,835 [$42,293–$153,575] versus $40,164 [$22,555–$68,408]; $P<0.001$) (Figure 3, lower panel).

The crude in-hospital mortality rate for the entire study population was 4.6%. The rate in patients with AKI was 15.9%, which was significantly higher than the 2.7% rate in those without AKI ($P<0.001$). The Kaplan-Meyer survival curve plotted against AKI severity also showed a severity-related reduced probability for survival (Figure 4). In the univariate regression analysis (Table 4), significantly higher odds for in-hospital mortality were noted in patients who had AKI (OR, 7.41; 95% CI, 5.36–10.24; $P<0.001$). Also associated with higher odds were leukemia, diabetes, chemotherapy, antibiotics, intravenous contrast, ICU transfer, and hyponatremia (Table 4). After adjustment for these covariates, along with age, sex, and race, AKI in these hospitalized patients was still associated with several-fold higher odds for mortality (OR, 4.47; 95% CI, 3.16–6.32; $P<0.001$). Significantly higher odds for mortality were also noted in the adjusted model for leukemia, diabetes, hyponatremia, and transfer to the ICU (Table 4). Use of antibiotics, chemotherapy, or intravenous contrast were no longer associated with higher odds for in-hospital mortality.

Discussion

On the basis of modified RIFLE criteria, 12% of patients admitted to a comprehensive cancer center had AKI with severity in the Risk, Injury, and Failure categories of 68%, 21%, and 11%, respectively. Forty-five percent of AKI occurred during the first 2 days of admission and 55% thereafter. The AKI was more frequent in medical services than in surgical or radiation services. One in 10 patients with AKI received nephrology consultation, and 1 in 26 required dialysis. Nearly half of the patients requiring dialysis presented with septic shock, and many had hematologic malignancies and had received chemotherapy. In the adjusted model, significant odds for developing AKI was noted only for noncancer factors, such as diabetes, intravenous contrast use, hyponatremia, and antibiotic therapy. According to outcome analyses, AKI in patients with cancer was associated with higher odds for deaths, longer hospital stays, and higher health care bills.

Cancer and its therapy can be associated with several AKI-provoking events (2). Furthermore, more elderly patients, who are susceptible to AKI, are receiving cancer therapy that often includes intense chemotherapy, allogeneic SCT, and nephrotoxic drugs. Moreover, in many patients, control of cancer may entail repeat chemotherapy, which in turn can be associated with higher rates of complications, including AKI. Thus, the overall frequency of AKI in patients with cancer can be expected to be higher than the rate reported for the noncancer setting. Yet few reports are available, and none to our knowledge have addressed hospitalized patients with cancer. In one population-based study, the AKI rate in patients with cancer was 26% during a 5-year observation period (16). Thus, the rate of AKI in patients with cancer, whether in the community or, as we noted, in the hospital (12%), seems to be higher than that reported in most noncancer settings (10,11,17). Consistent with our finding of a higher rate of AKI, we and others have also reported higher rates in select groups of patients with cancer, such as those receiving SCT or patients with cancer confined to critical care units (18–20).

The etiology of AKIs in hospitalized patients with cancer is often multifactorial, and, indeed, our analysis identified several independent factors associated with AKI (20,21). That antibiotic use was associated with AKI in our study suggests a role for sepsis, toxicity of antibiotics, or both in AKI. Indeed, the AKI rate was higher in our patients with neutropenic fever, but this difference did not reach statistical significance. However, the association between use of antibiotics and AKI was strong. A likely explanation would be that patients requiring antibiotics would be sicker than the rest and, therefore, more likely to develop AKI. Alternatively, and speculatively, many of these agents, if used in full doses based on serum creatinine-based GFR (serum creatinine could be lower or spuriously normal due to malnutrition), may prove to be toxic. In an earlier study limited to our leukemia population, a strong and independent association between antibiotic use and AKI was noted (22). The presence of diabetes is a well known factor for AKI—particularly for radiocontrast nephrotoxicity—but not in hospitalized patients with cancer (23). During our analysis, we found a strong and persistent association between having the diagnosis of diabetes and the likelihood of developing AKI in our patients. The use of intravenous contrast is very common in patients with cancer, and in our analysis intravenous contrast use was strongly associated with higher odds for AKI risk. Acute leukemia and lymphoma can have explosive clinical course, including tumor lysis syndrome and septic complications leading to AKI (22). Moreover, SCT is more frequently used in the treatment of hematologic cancers than in solid organ cancers, and SCT (along with its higher rate of septic complications) may partly explain the higher frequency of AKI seen in our patients with hematologic malignancies (4). Consistently, we find in our analysis that when adjusted for several other variables, including SCT and antibiotics, hematologic malignancy was no longer a significant factor for AKI.

The mean age of our patients was 56 years, and age in the multivariate analysis did not differ between the AKI and

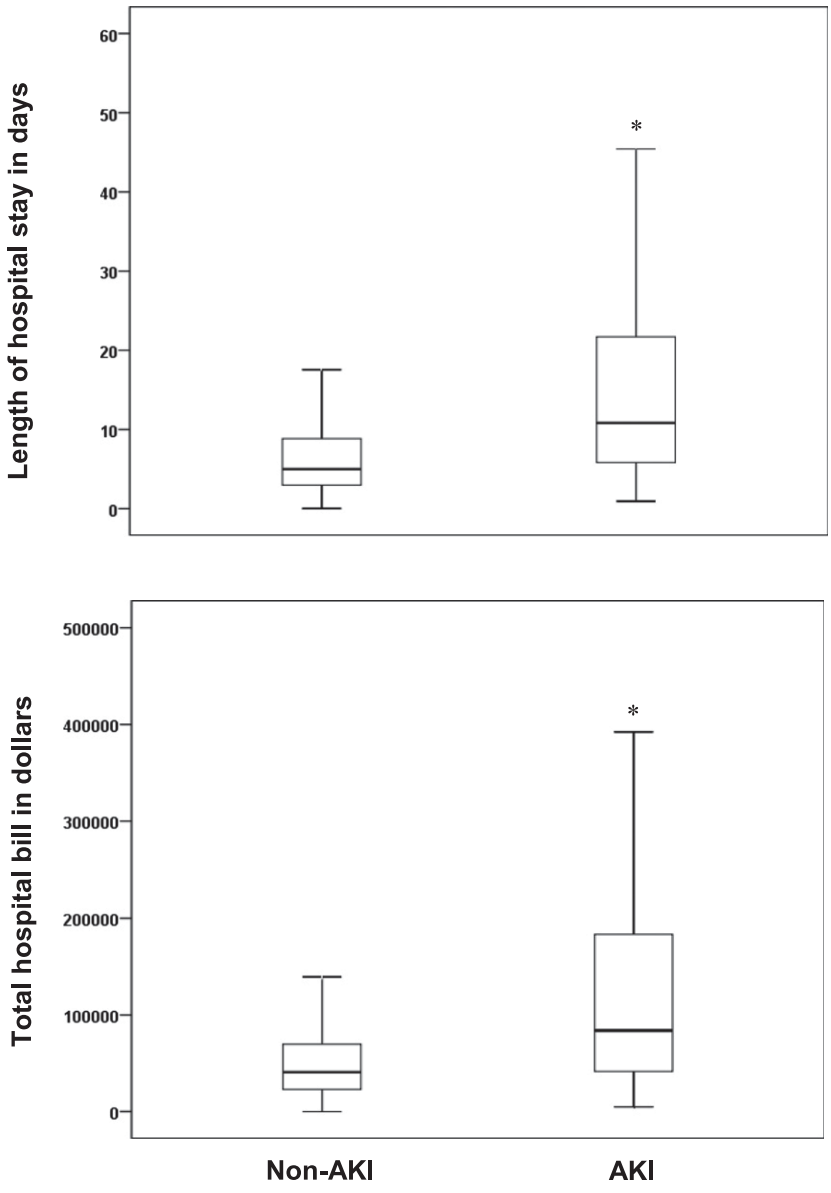
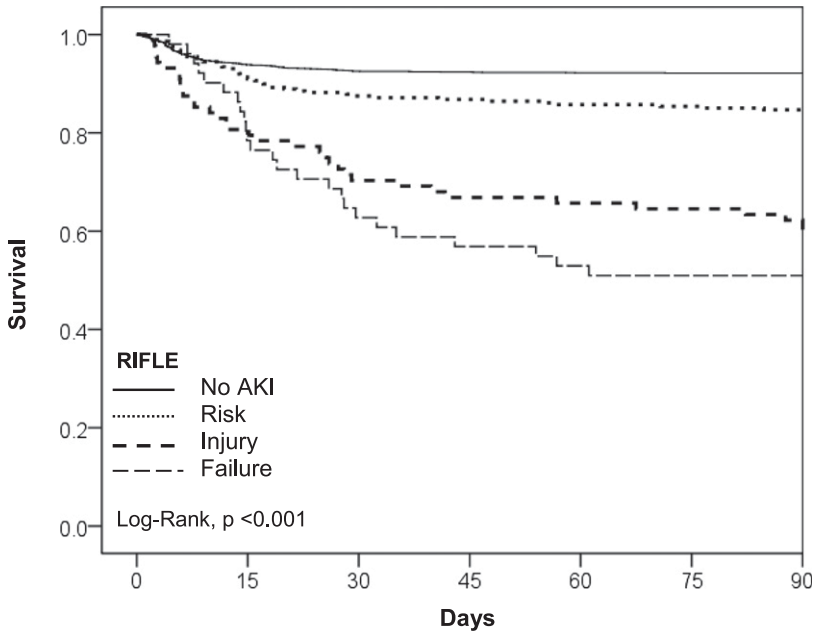


Figure 3. | Box plots of lengths of hospital stay (top panel) and hospital bills (bottom panel) in patients hospitalized in the cancer center with and without AKI. Central lines denote median values, and upper and lower borders represent 25th and 75th percentiles. The whiskers represent the highest and lowest values. Extreme values and outliers are not shown. *$P<0.001$ for AKI versus non-AKI for both plots.

non-AKI groups. This finding suggests that factors other than age were important for AKI in our patients with cancer. Pre-AKI hyponatremia was a strong and independent clinical correlate for AKI in this study. We have previously reported a strong association between hyponatremia and poorer clinical outcomes among patients with cancer, suggesting hyponatremia as a likely marker for sicker patients—as recognized in noncancer settings (12). An important issue, not addressed in this study, is whether development of AKI influenced the choice and dosing of chemotherapy or whether such necessitated change in chemotherapy due to AKI influenced the cancer outcomes. Delay in diagnosing AKI or overestimating the GFR on the basis of serum creatinine can lead to the administration of higher than required doses of chemotherapeutic agents, thus creating a vicious cycle of systemic toxicity and worsening kidney function, leading to neutropenic sepsis and multiorgan failure.

The effect of AKI on the clinical and fiscal outcomes in hospitalized patients in the noncancer setting is known, according to Chertow *et al.* AKI in hospital was associated with a 6.5-fold increase in the odds of death, a 3.5-day increase in length of hospital stay, and a $7500 increase in hospital costs (11); in our patients with cancer, these values were, respectively, 4.7-fold, 3 days, and $42,671 (the latter two were based on median values). Although these are two distinct patient populations, the effect of AKI on clinical outcomes regardless of clinical settings is so severe that limiting AKI should be a priority. A strategy that is likely to be effective, especially in patients hospitalized



Number at risk

No AKI	3131	2939	2898	2893	2888	2886	2886
Risk	288	263	253	251	248	247	245
Injury	88	71	62	59	58	57	55
Failure	51	40	32	29	27	26	26

Figure 4. | Kaplan-Meyer survival curve for 90 days after admission to the cancer center based on AKI severity by RIFLE (Risk, Injury, Failure, Loss, ESRD) criteria.

Table 4. Logistic regression analyses yielding odds ratios for factors associated with in-hospital mortality in patients admitted to the cancer center

Factors	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Age	1.00 (0.99–1.01)	0.35	1.00 (0.99–1.06)	0.17
Sex (male/female)	1.15 (0.84–1.56)	0.38	0.98 (0.69–1.37)	0.89
Race (white/others)	1.22 (0.87–1.70)	0.24	1.10 (0.76–1.62)	0.59
Diabetes (yes/no)	3.00 (2.16–4.16)	<0.001	1.51 (1.04–2.21)	0.03
Leukemia (yes/no)	2.54 (1.76–3.69)	<0.001	1.91 (1.19–3.06)	0.007
Chemotherapy (yes/no)	1.44 (1.01–1.95)	0.04	1.06 (0.71–1.60)	0.77
Stem cell transplant (yes/no)	1.56 (0.96–2.56)	0.07	0.83 (0.44–1.55)	0.55
Antibiotics (yes/no)	2.62 (1.69–4.06)	<0.001	1.28 (0.78–2.09)	0.34
Intravenous radiocontrast (yes/no)	2.29 (1.52–3.47)	<0.001	1.22 (0.71–2.11)	0.47
Hyponatremia (yes/no)	4.01 (2.73–5.89)	<0.001	2.90 (1.91–4.39)	<0.001
Transfer to ICU (yes/no)	7.62 (5.20–11.11)	<0.001	4.23 (2.75–6.56)	<0.001
AKI (yes/no)	7.41 (5.36–10.24)	<0.001	4.72 (3.30–6.75)	<0.001

ICU, intensive care unit.

electively, is to identify higher-risk patients for AKI and institute, whenever possible, anti-AKI measures—a proactive or prophylactic approach—to prevent ATN. It is noteworthy that in our study nearly 55% of AKI cases occurred 48 hours after admission, suggesting the existence of a rare opportunity to potentially intervene against AKI in patients with cancer. Our analysis has also discerned several clinical correlates associated with in-hospital AKI in patients with cancer. These and other risk factors, once confirmed in prospective studies, can be used to create a predictive scoring system to identify high-risk patients and to test certain clinical algorithms that may limit kidney injury.

The strengths of our study were that the data were collected sequentially for 3 months from a large comprehensive cancer center and that the dataset constitutes a large sample size of all types of cancers. Because the data

were collected prospectively, one of us (P.S.) was able to verify the incoming data. The electronic database was cross-validated during manual chart check. One of the limitations of our study is that our data have not provided details on the causes of AKI in this population. Moreover, although the data were prospectively collected, the analysis is still based on a database, and hence the findings and hypotheses generated herein are to be confirmed prospectively.

In summary, the AKI rate in hospitalized patients with cancer was higher than that in most noncancer settings. Irrespective of the underlying cancer, patients who are diabetic; have hyponatremia; are receiving antibiotics, chemotherapy, or intravenous contrast; or have been transferred to the ICU during hospital stay were at a higher risk for developing AKI in the hospital. AKI in our hospitalized patients was associated with poor clinical outcomes. More than half of the AKI cases in our patients occurred several days after admission, and many patients were admitted electively. Therefore, studies are warranted to test whether preventive measure against AKI, especially in high-risk patients, may reduce the occurrence of AKI and improve clinical outcomes in patients hospitalized in cancer centers.

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Table 5 (supplemental): The rate of AKI in patients admitted to the cancer center as % of total cases for each cancer diagnosis used in billing.

Cancer diagnosis based on billing codes	In-Hospital AKI		Total
	No	Yes (%)	
Adrenal	5	0 (0)	5
Bladder	109	10 (8)	119
Bone/cartilage	82	6 (7)	88
Brain	109	7 (6)	116
Breast	190	20 (10)	210
Burkitt's tumor/lymphoma	10	1 (9)	11
Cerebral meninges	4	0 (0)	4
Cervix	54	5 (8)	59
Colon	100	10 (9)	110
Esophagus	50	10 (16)	60
Eye	4	1 (20)	5
Hodgkin's disease	61	5 (6)	66
Hypopharynx	6	1 (14)	7
Kidney	80	20 (20)	100
Larynx	30	0 (0)	30
Letterer-siwe disease	1	0 (0)	1
Leukemia	339	68 (17)	407
Leukemic reticuloendotheliosis	4	0 (0)	4
Lip	3	0 (0)	3
Liver, gallbladder & ducts	51	9 (15)	60
Lung, bronchial tree and trachea	223	18 (8)	241
Lymphoma	82	16 (16)	98
Lymphosarcoma	11	0 (0)	11
Malignant histiocytosis	1	0 (0)	1
Melanoma	61	9 (13)	70
Metastatic cancer	364	56 (13)	420
Mixed lymphosarcoma	9	3 (25)	12
Multiple myeloma	96	24 (20)	120
Mycosis fungoides	16	2 (11)	18
Myelodysplastic syndrome	41	6 (13)	47
Nasal/middle ear/sinus	10	2 (17)	12
Nasopharynx	6	1 (14)	7
Neurofibromatosis	5	0 (0)	5
Oral cavity	52	7 (12)	59
Oropharynx	14	3 (18)	17

Other female genital cancer	15	2 (12)	17
Other/ill-defined	40	2 (5)	42
Ovary/fallopian tube/uterine adnexa	76	7 (8)	83
Pancreas	71	12 (15)	83
Penis	6	0 (0)	6
Peritoneum	22	5 (19)	27
Pineal	1	0 (0)	1
Pituitary/craniopharyngeal duct	7	2 (22)	9
Plasmacytoma	1	0 (0)	1
Polycythemia vera	1	0 (0)	1
Prostate	127	15 (10)	142
Rectum/anus	96	15 (14)	111
Renal pelvis	5	1 (17)	6
Reticulosarcoma	95	16 (14)	111
Salivary glands	4	0 (0)	4
Scrotum	1	0 (0)	1
Sezary's disease	1	0 (0)	1
Skin	23	0 (0)	23
Small intestine	5	0 (0)	5
Soft tissue	90	8 (8)	98
Spinal cord	1	0 (0)	1
Stomach	37	5 (10)	42
Testis	14	3 (18)	17
Thymus/heart/mediastinum	11	2 (15)	13
Thyroid	33	1 (3)	34
Ureter	3	0 (0)	3
Urethra	10	0 (0)	10
Uterus	52	11(17)	63
Total	**3131**	**427 (12)**	**3558**

Table 6 (supplemental): The comparison of results from dataset on patients admitted to the cancer center that excluded 10% of patients with missing serum creatinine with results from dataset that included all patients by using imputed serum creatinines for the missing values.

	Original data	Imputed data					P value*
		1	2	3	4	5	
AKI (%)	12.0	14.2	13.8	14.3	14.2	13.9	
Risk (% of AKI)	68	65	63	64	63	65	>0.5
Injury (% of AKI)	21	22	24	22	24	23	
Failure (% of AKI)	11	13	13	14	13	12	
In-hospital mortality	167 (4.7%)	176 (4.5%)	180 (4.6%)	179 (4.6%)	174 (4.5%)	180 (4.6%)	>0.5
Cost of stay (mean in $)							
No- AKI	60652	59648	59578	59478	59456	59394	
AKI	136112	128014	130742	127599	128246	130761	>0.5
Percent increase	55%	53%	54%	53%	54%	55%	

* p values between results from the original data and the imputed data .