Epidemiology and Outcomes of Acute Renal Failure in Hospitalized Patients: A National Survey

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The aim of this study was to provide a broad characterization of the epidemiology of acute renal failure (ARF) in the United States using national administrative data and describe its impact on hospital length of stay (LOS), patient disposition, and adverse outcomes. Using the 2001 National Hospital Discharge Survey, a nationally representative sample of discharges from nonfederal acute care hospitals in the United States, new cases of ARF were obtained from hospital discharge records coded according to the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM). Multivariate regression analyses were used to explore the relation of ARF to hospital LOS and mortality as well as discharge disposition. Review of discharge data on a projected total of 29,039,599 hospitalizations identified 558,032 cases of ARF, with a frequency of 19.2 per 1000 hospitalizations. ARF was more commonly coded for in older patients; men; black individuals; and the setting of chronic kidney disease, congestive heart failure, chronic lung disease, sepsis, and cardiac surgery. ARF was associated with an adjusted prolongation of hospital LOS by 2 d ($P < 0.001$) and an adjusted odds ratio of 4.1 for hospital mortality and of 2.0 for discharge to short- or long-term care facilities. In a US representative sample of hospitalized patients, the presence of an ICD-9-CM code for ARF in discharge records is associated with prolonged LOS, increased mortality, and, among survivors, a greater requirement for posthospitalization care. These findings suggest that in the United States, ARF is associated with increased in-hospital and post-hospitalization resource utilization.

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Acute renal failure (ARF) is a serious complication in hospitalized patients, with single-center studies reporting a rising incidence over the past two decades (1,2) and case fatality rates exceeding 50% among those who require dialytic support (3–10). Whereas these single-center reports might have excelled in the systematic collection of epidemiologic data, the results are not generalizable to the population at large and might reflect known and unknown biases and confounders inherent to the reporting institution. Consequently, accurate estimates of the incidence of ARF and its impact on short-term and intermediate outcomes in a national representative sample are lacking.

Large administrative databases can identify individuals and hospital admissions for population-based research endeavors and have been used in studies of various medical conditions, including sepsis (11), heart failure (12), and cirrhosis (13). The aim of this study was to provide a broad characterization of the epidemiology of ARF among adults (age ≥ 18 yr) who were hospitalized in the United States, using the National Hospital Discharge Survey (NHDS), a nationally collected database for use in epidemiologic estimates, and to identify specific groups with an altered susceptibility to the development of ARF. This study also examined whether ARF influences hospital length of stay (LOS), mortality, and patient disposition at time of hospital discharge, mainly transfers to short- and long-term care facilities.

Materials and Methods

Data Source

For this analysis, we used the 2001 NHDS database, which was acquired from the National Center for Health Statistics (14). In brief, this annual survey comprises a sample of all nonfederal acute care hospitals (with an average patient LOS of <30 d) in the United States and includes approximately 500 hospitals, with equal representation from all geographic regions (14). This survey excludes federal, military, and Department of Veterans Affairs hospitals; institutional hospital units (*e.g.*, prison hospitals); and hospitals with fewer than six beds (14).

The database is constructed through the survey of discharge records for inpatients from each participating hospital, representing approximately 1% of all hospitalizations, or 330,210 discharges annually in the United States. The data set includes weighted frequencies, which can be generalized to the entire population. The weighted sample of approximately 1% hospital discharges projects to a national estimate of 29,039,599 discharges.

Discharge records are abstracted for demographic information (age, gender, ethnic background, geographic location, and marital status), seven diagnostic codes, four procedural codes, date of hospital admis-

sion and discharge, LOS, sources of payment, and disposition at discharge. The diagnosis and procedure codes are derived from the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) (15).

Case Definitions

Cases were identified from discharge records in the NHDS, which included a code for ARF. ARF was defined by the presence of any of the following ICD-9-CM codes: 584.0 (ARF, unspecified), 584.5 (acute tubular necrosis), 584.6 (cortical ARF), 584.7 (medullary ARF), 584.8 (ARF with other specified pathologic lesion), and 584.9 (ARF not otherwise specified). Discharge records with an ICD-9-CM code for chronic dialysis status (V45.1, V56.0, V56.31, V56.32, or V56.8) were excluded. Requirement for acute dialysis was defined by one of two codes: 39.95 or 54.98.

Coexisting conditions were defined by the following ICD-9-CM codes: Diabetes (250 and 250.01 to 250.03), hypertension (401.0, 401.1, and 401.9), coronary artery disease (414, 414.02, 414.03, and 414.9), congestive heart failure (428), chronic kidney disease (403.11, 403.91, 404.13, 404.92, 404.93, 250.40 to 250.43, 581.0 to 581.3, 581.81, 581.89, 581.9, 582, 582.1, 582.2, 582.81, 582.89, 582.9, 583.0 to 583.6, 583.81, 583.89, 583.9, and V42.0), chronic lung disease (chronic obstructive lung disease [492.8] and emphysema [496]), cancer (colon [153.9], breast [174.9], lung [162.9], prostate [185], melanoma [172.9], myeloma [203], kidney [189], and bladder [188.9]), and HIV infection (042).

Acute hospital-related factors were defined by the following diagnosis and procedure ICD-9-CM codes: Sepsis (038, 020.0, 790.7, 117.9, 112.5, and 112.81) (11), cardiac catheterization (37.22 and 37.23), and cardiac surgery (coronary artery bypass graft surgery [36.10 to 36.16] and valve repair [35.1 to 35.2, 35.11 to 35.14, and 35.21 to 35.28]). Acute organ system dysfunction (AOSD) was defined using a previously published ICD-9-CM–based classification (11) with some minor modifications, and comprised the respiratory, cardiovascular, hepatic, hematologic, and neurologic organ systems (Appendix 1).

Validation of ARF ICD-9-CM Case Definitions

The accuracy of ICD-9-CM for ARF was validated by reviewing the records of all patients who were discharged from a tertiary medical center (Caritas St. Elizabeth's Medical Center, Boston, MA) during 2001 ($n = 13,412$). The Human Investigation Review Committee approved this validation study. Admissions involving patients with ESRD ($n = 175$) were excluded from further analysis. We compared ARF diagnostic coding (defined by the presence or absence of ICD-9-CM codes 584.5 to 584.9) with well-established criteria for ARF that are based on changes in serum creatinine (1). Nadir and peak serum creatinine values over the course of the admission were used to establish the presence of ARF on the basis of a rise in serum creatinine level of 0.5, 1, or 1.5 mg/dl from nadir values of ≤ 1.9, 2.0 to 4.9, and ≥ 5.0 mg/dl, respectively.

Statistical Analyses

Continuous data are presented as medians with interquartile range, and nominal data are presented as percentages. All statistical analyses were performed using SAS (SAS Institute, Cary, NC) version 9.1. Following the NHDS guidelines, data with a sample size of <60 or with a relative SE >30% were not used for the analyses. Unless specified, all descriptive statistics and analyses were weighted to allow inflation to national estimates, based on the weight variable provided by the NHDS. Of note, because of this very large sample size, this study has extremely high power, and P values are expected to be significant, regardless of magnitude or clinical relevance.

Kaplan-Meier survival analysis was used to compare hospital LOS (in weeks) among patients with and without ARF. This analysis was stratified by presence or absence of other nonrenal AOSD. The log-rank statistic was used to test differences between groups. In this analysis, death was censored, and patients with missing discharge status were excluded.

Logistic regression analysis was used to explore the relationship between ARF and hospital death and patient disposition at time of hospital discharge. The analysis was adjusted in a stepwise manner for the following covariates: Demographic factors (age, gender, ethnic background, and source of payment), coexisting conditions, acute hospital-related factors, and number of AOSD. The end points were ascertained at time of hospital discharge, no censoring was required, and there was no loss of follow-up. Twenty-four percent of discharges were excluded from this analysis as a result of missing values for either the predictor or outcome variables. Most of the missing values (96%) were on the ethnicity variable. However, the results were not significantly different when missing ethnicity was included as an indicator variable.

A separate robust regression model explored the relationship of ARF and other AOSD to hospital LOS. This regression method is more appropriate than linear regression for outcome variables with a skewed distribution (16). In brief, this analysis uses the median of the squared residuals instead of the sum of the squared residuals. Admissions of <24 h were assigned a LOS of 1 d. Although records with missing data for either predictor or outcome variables were excluded from the final analysis, the results were very similar when those with missing ethnicity were included as an indicator variable.

Results

Cohort Characteristics

Approximately 1.9% of hospitalizations in the United States included a discharge diagnosis of ARF during the study period of 2001. The characteristics of patients with and without a discharge diagnosis of ARF are summarized in Table 1. ARF was more common in older patients, men, and black patients. A discharge diagnosis of ARF was also more commonly assigned to individuals with a coexisting diagnosis of congestive heart failure, chronic lung disease, chronic kidney disease, cancer, and HIV infection but less commonly to individuals with a coexisting diagnosis of coronary artery disease, diabetes, and hypertension. Patients with a diagnosis code of ARF were also more likely to have a diagnosis of sepsis or have undergone cardiac surgery. Finally, patients with an ARF diagnosis code were more likely to have other nonrenal AOSD. A total of 7.5% of patients with a diagnosis of ARF required dialysis. Whereas overall hospital mortality was 2.6%, patients who were discharged with a diagnosis of ARF had a higher mortality rate compared with those without ARF (21.3 *versus* 2.3%; $P < 0.0001$).

ARF and Hospital LOS

As shown in Table 1, hospital LOS was significantly higher among patients with a discharge diagnosis of ARF. Table 2 displays the LOS data for different diagnostic categories and is stratified according to survivor status. Compared with other single AOSD, a discharge diagnosis of ARF *per se* was associated with the longest median LOS (7 d), whereas acute cardiovascular system dysfunction was associated with the shortest LOS, which might be due to a high early fatality rate (see also

Table 1. Characteristics of patients with and without a discharge diagnosis of ARF[a]

Characteristic	All Patients (n = 29,039,599)	Patients without ARF (n = 28,481,567)	Patients with ARF (n = 558,032)	P
Median age (yr)	58.0 (38.0,75.0)	58.0 (37.0,75.0)	73.0 (60.0,82.0)	<0.0001
Male gender (%)	37.9	37.6	51.8	<0.0001
Ethnic background (%)				<0.0001
white	62.7	62.7	62.3	
black	11.2	11.2	14.4	
other/not specified	26.1	26.1	23.4	
Payment source (%)				<0.0001
Medicare	43.1	42.6	66.1	
Medicaid	12.2	12.3	8.0	
private	36.6	36.9	21.6	
other	8.2	8.3	4.4	
Coexisting conditions (%)				
coronary artery disease	4.7	4.7	4.2	<0.0001
congestive heart failure	10.9	10.5	31.5	<0.0001
chronic kidney disease	4.6	4.1	30.6	<0.0001
chronic lung disease	6.9	6.8	12.1	<0.0001
cancer	2.2	2.2	2.9	<0.0001
diabetes	11.7	11.7	10.6	<0.0001
hypertension	25.4	25.6	13.6	<0.0001
HIV infection	0.5	0.4	1.1	<0.0001
Acute hospital-related factors (%)				
sepsis	0.4	0.4	1.7	<0.0001
cardiac catheterization	4.0	4.0	4.1	<0.0001
cardiac surgery	1.2	1.2	2.5	<0.0001
AOSD (%)				
respiratory	2.3	2.1	13.4	<0.0001
cardiovascular	0.3	0.2	2.9	<0.0001
hepatic	0.2	0.1	2.1	<0.0001
hematologic	1.4	1.3	6.6	<0.0001
neurologic	0.8	0.8	2.4	<0.0001
Hospital outcomes				
median LOS (d)	3.0 (2.0, 6.0)	3.0 (2.0, 5.0)	7.0 (4.0, 13.0)	<0.0001
dialysis requirement (%)	0.1	0.0	7.5	<0.0001
death (%)	2.6	2.3	21.3	<0.0001
Hospital discharge disposition (%)				<0.0001
home	78.7	79.1	53.4	
short-term care facility	4.8	4.8	9.6	
long-term care facility	9.2	8.9	23.3	
other/not stated	7.3	7.2	13.7	

[a]The data are presented as medians with interquartile ranges (25th and 75th percentiles) or percentages. ARF, acute renal failure; AOSD, acute organ system dysfunction; LOS, length of stay.

Figure 1). The presence of ARF coupled to single or multiple, nonrenal AOSD was associated with the longest hospital LOS (median 10 d). Of note, the presence of ARF alone and without other nonrenal AOSD was associated with longer LOS than for patients with single nonrenal AOSD (Table 2). ARF was the second most frequent AOSD (1.9%), after acute respiratory system dysfunction (2.3%).

Kaplan-Meier survival analysis demonstrated that the sole presence of ARF, as well as its addition to other nonrenal AOSD, confers the most prolonged hospital LOS (P < 0.0001 by log rank test; Figure 2). In addition, dialysis-requiring ARF was associated with a more prolonged LOS compared with hospitalization in which ARF did not require dialysis (P < 0.0001 by log rank test; Figure 3).

On multivariate analysis (Table 3), a discharge diagnosis of ARF was associated with an estimated prolongation of hospital LOS by 2 d (P < 0.0001) and was surpassed only by cardiac surgery (3.9 additional days) and sepsis (2.6 additional days). Several other groups of diagnosis codes were also associated with LOS but to a lesser degree, including a discharge diagnosis

Table 2. Hospital LOS stratified by ARF, AOSD, and survival status

Diagnosis	Hospital LOS (days)[a]			
	%[b]	All Patients	Survivors	Nonsurvivors
Absence of ARF				
absence of AOSD	93.8	3 (2, 5)	3 (2, 5)	4 (2, 10)
presence of single AOSD	4.0	6 (3, 11)	6 (3, 11)	5 (2, 12)
presence of multiple AOSD	0.3	8 (3, 16)	11 (5, 18)	5 (1, 12)
Presence of ARF				
absence of AOSD	1.5	7 (4, 13)	7 (4, 12)	7 (3, 14)
presence of single AOSD	0.4	10 (5, 17)	11 (6, 19)	7 (3, 15)
presence of multiple AOSD	0.1	10 (3, 17)	13 (8, 22)	7 (2, 14)

[a]The data are presented as medians with interquartile ranges (25th and 75th percentiles).
[b]The percentage distribution refers to the weighted patient sample.

of chronic kidney disease (0.2 additional day). Factors associated with a shorter LOS included a discharge diagnosis of coronary artery disease, hypertension, and cardiac catheterization.

ARF and Hospital Discharge Disposition

The characteristics of patients who had ARF and were discharged from the hospital alive are shown in Table 4 and are stratified according to disposition. Compared with patients who had ARF and were discharged home, those who were discharged to a short-term care facility were older and had a higher frequency of congestive heart failure, chronic lung disease, sepsis, and acute respiratory system dysfunction. However, compared with patients who had ARF and were discharged to a short-term care facility, those who were discharged to a long-term care facility were older by a median of 6 yr, more likely to be female, and more likely to have a coexisting diagnosis of HIV infection and acute cardiovascular or neurologic system dysfunction.

On multivariate analysis (Table 5), ARF was associated with a 2.0-fold higher odds for transfer to a short- or long-term care facility after adjustment for age, gender, ethnic background, payment source, coexisting conditions (including chronic kidney disease), acute hospital-related factors, and other AOSD.

ARF and Hospital Death

On multivariate analysis (Table 5), ARF was associated with an eight-fold higher odds for death after adjustment for age, gender, ethnic background, and payment source. This association was weakened but persisted with 4.1-fold higher odds for death after adjustment for age, gender ethnic background, payment source, coexisting conditions (including chronic kidney disease), acute hospital-related factors, and other AOSD.

ARF Coding Validation

We performed an audit of ARF coding practices by reviewing the electronic discharge records of all patients who were discharged from our tertiary medical center during the 2001 cal-
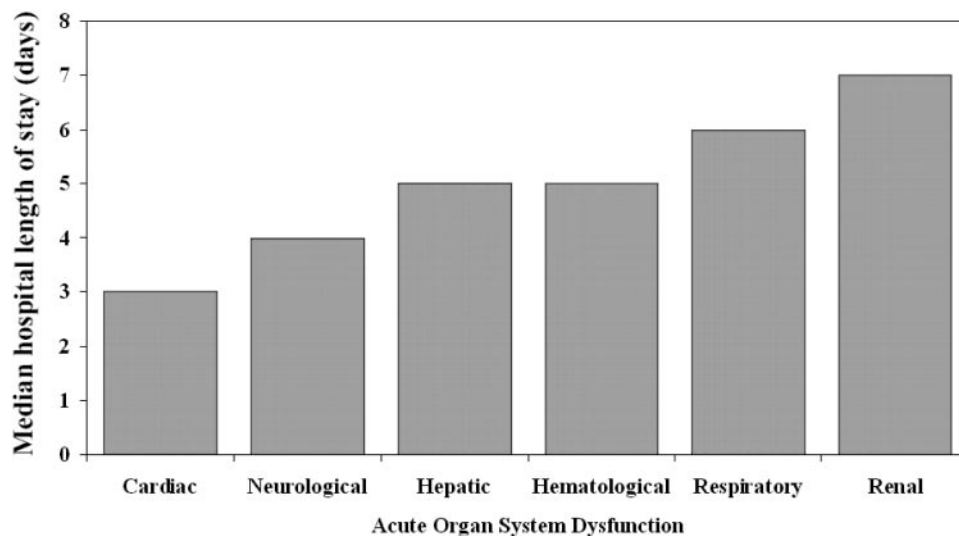

Figure 1. Median hospital length of stay (LOS) stratified by single acute organ system dysfunction (AOSD), including acute renal failure (ARF).
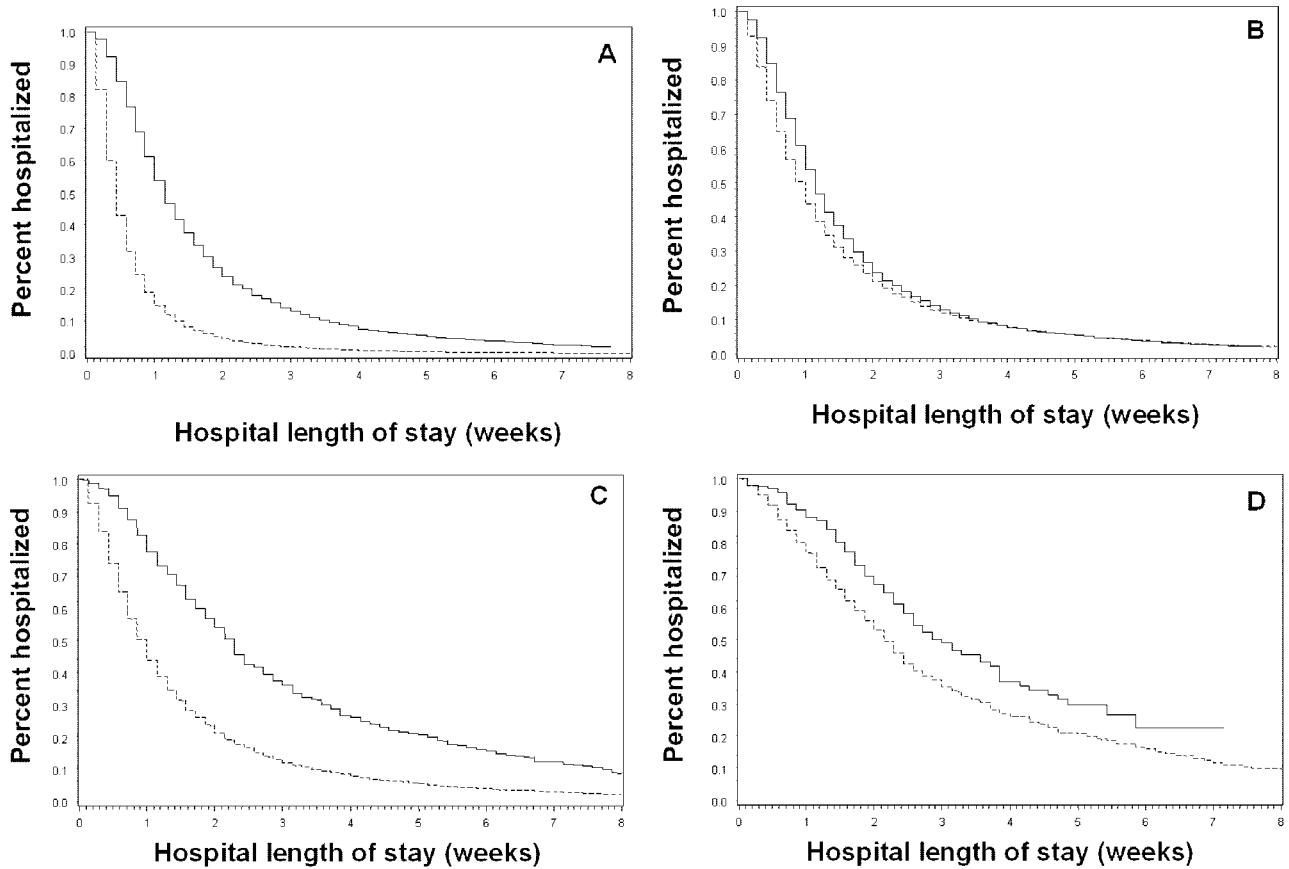
Figure 2. Kaplan-Meier analysis for the cumulative percentage of patients who remained hospitalized according to presence or absence of ARF with or without other single or multiple AOSD. (A) No ARF and no other single AOSD (hatched line), and ARF and no other single AOSD (solid line), *P* < 0.0001 by log rank test. (B) No ARF but presence of other single AOSD (hatched line), and ARF and no other single AOSD (solid line), *P* < 0.0001 by log rank test. (C) No ARF but presence of other single AOSD (hatched line), and ARF and presence of other single AOSD (solid line), *P* < 0.0001 by log rank test. (D) No ARF but presence of other multiple AOSD (hatched line), and ARF and presence of other multiple AOSD (solid line), *P* < 0.0001 by log rank test.
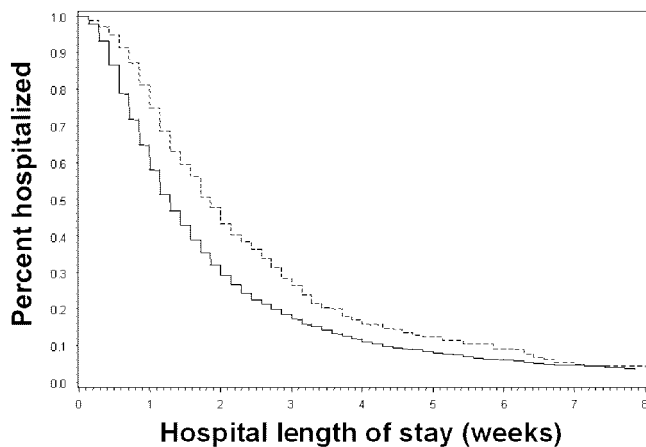

Figure 3. Kaplan-Meier analysis for the cumulative percentage of patients who had ARF and remained hospitalized according to dialysis requirement. ARF requiring dialysis (hatched line) and ARF not requiring dialysis (solid line), *P* < 0.0001 by log rank test.

endar year. After exclusion of the discharges of 175 patients with ESRD, 13,237 records were available for analysis. Using serum creatinine–based laboratory criteria, ARF supervened on 1584 hospital admissions (12.0%). An ICD-9-CM code for ARF was present in 347 (2.6%) discharge records during this period. Acute renal failure was confirmed by biochemical criteria in 304 of these cases, yielding a positive predictive value of 87.6%. However, the sensitivity of ARF ICD-9-CM coding was 19.2% (304 of 1584). Among the 12,890 discharge records without an ARF ICD-9-CM code, serum creatinine criteria for ARF were not met in 11,610, yielding a negative predictive value of 90.1%. The specificity of ARF coding was 99.6%.

Discussion

Administrative data sets such as the NHDS, although potentially less precise with regard to diagnostic accuracy and the relationship of cause and effect than patient-oriented clinical studies, can provide valuable, nationally relevant data that could improve our understanding of the impact of ARF on the entire US hospital system. Registries that are based on laboratory results would represent a much more precise method of

Table 3. Multivariate (robust regression) analyses examining the association of ARF and other covariates with hospital LOS[a]

Parameter	Estimate	95% CI	P
Age (per year)	0.02	0.02 to 0.02	<0.0001
Male (*versus* female)	0.01	−0.01 to 0.03	0.39
Black (*versus* white)	0.33	0.30 to 0.36	<0.0001
Other race (*versus* white)	−0.01	−0.06 to 0.03	0.58
Payment source			
Medicare (*versus* private)	0.41	0.37 to 0.43	<0.0001
Medicaid (*versus* private)	0.27	0.24 to 0.31	<0.0001
other insurance (*versus* private)	0.04	−0.01 to 0.08	0.10
Coexisting conditions			
coronary artery disease	−0.48	−0.54 to −0.42	<0.0001
congestive heart failure	0.73	0.69 to 0.77	<0.0001
chronic kidney disease	0.18	0.12 to 0.23	<0.0001
chronic lung disease	0.38	0.33 to 0.42	<0.0001
cancer	0.14	0.06 to 0.22	0.0004
diabetes	−0.01	−0.04 to 0.03	0.75
hypertension	−0.29	−0.32 to −0.26	<0.0001
HIV infection	1.25	1.11 to 1.39	<0.0001
Acute hospital-related factors			
sepsis	2.61	2.45 to 2.77	<0.0001
cardiac catheterization	−0.32	−0.40 to −0.26	<0.0001
cardiac surgery	3.88	3.78 to 3.99	<0.0001
ARF (*versus* no ARF)	2.02	1.94 to 2.10	<0.0001
AOSD			
1 AOSD (*versus* none)	1.09	1.03 to 1.14	<0.0001
≥2 AOSD (*versus* 0 to 1 AOSD)	0.82	0.65 to 0.99	<0.0001

[a]The results for the robust regression analysis are not weighted.

capturing this information, but the development of such registries would require significant resources and a concerted effort of all regional health care provider systems. The analysis of existing administrative databases could provide an overview of the importance of ARF within a health care system such as that of the United States and could support the premise that ARF is an important factor for health care resource utilization.

In the 2001 NHDS cohort, the overall incidence of ARF was 1.9%, which is lower than that observed in studies of single academic centers (1,2). It is conceivable that academic tertiary hospitals likely provide care to patients with greater severity of illness and in whom ARF might be more likely to develop. However, these discrepancies are more likely due to differences in case definitions, contrasting clinical with administrative diagnosis of ARF. In contrast to results from single-center studies, the NHDS data are collected from a representative sample of hospitals that reflect a broad spectrum of care throughout the United States. The observed incidence of ARF in our study is considerably higher than the 0.4% reported by Liano *et al.* (17) in a population-based study from Madrid, Spain. This is likely due to the adoption of a more specific but less sensitive definition of ARF by these authors, which required a sudden elevation in serum creatinine concentration by 2 mg/dl from a baseline of <3 mg/dl with subsequent recovery of at least 50%

of kidney function at time of hospital discharge. The NHDS analysis was based on ICD-9-CM codes, which likely enabled a more liberal definition of ARF and therefore cannot exclude disease misclassification.

The hospital mortality rate of patients with ARF was 21%, which is similar to the 19% rate reported by a large prospective cohort study that was conducted at a US urban academic center (2). Notably, this mortality rate was lower than that observed in several other studies, primarily focused on critically ill patients with a higher degree of disease severity and a less favorable outcome (3,7,18,19). Our results suggest that the high mortality associated with ARF is observed not only in tertiary care hospitals but also throughout the entire spectrum of acute care hospitals in the United States, and our data support an independent impact of ARF on mortality, after adjustment for several factors, including coexisting conditions and concomitant single or multiple nonrenal AOSD, and thus support the generalizability of the results of smaller, single-center, patient-oriented studies (3,6,20,21).

In this study, presence of a discharge diagnosis of ARF was associated with prolonged hospital LOS, surpassing acute respiratory system dysfunction (Figure 1). Furthermore, the combination of ARF and multiple AOSD was associated with the highest hospital LOS burden, particularly among survivors.

Table 4. Characteristics of patients who had ARF and were discharged from the hospital alive and stratified by disposition[a]

Characteristic	Hospital Discharge Disposition		
	Home	Short-Term Care Facility	Long-Term Care Facility
Median age (yr)	66.0 (54.0, 77.0)	73.0 (60.0, 82.0)	79.0 (70.0, 85.0)
Male gender (%)	53.8	56.4	43.5
Ethnic background (%)			
white	59.6	68.5	68.9
black	19.4	10.1	11.2
other/not specified	21.0	21.4	19.9
Payment source (%)			
Medicare	57.1	63.5	75.2
Medicaid	9.8	8.1	6.7
private	26.9	22.7	17.6
other	6.2	5.7	0.6
Coexisting conditions (%)			
coronary artery disease	3.9	5.9	3.5
congestive heart failure	27.7	32.7	32.6
chronic kidney disease	34.6	28.9	27.7
chronic lung disease	10.9	13.4	12.1
cancer	3.0	2.4	2.9
diabetes	11.6	13.3	9.9
hypertension	17.7	15.0	10.6
HIV infection	1.1	0.1	1.5
Acute hospital-related factors (%)			
sepsis	1.1	5.0	2.1
cardiac catheterization	4.7	2.8	2.5
cardiac surgery	2.1	1.8	2.6
AOSD (%)			
respiratory	7.0	10.2	8.0
cardiovascular	0.6	1.0	2.1
hepatic	1.1	1.3	1.2
hematologic	6.4	4.5	5.1
neurologic	1.1	0.6	1.6
Hospital-related outcomes			
median LOS (d)	6.0 (4.0, 11.0)	7.0 (3.0, 3.0)	11.0 (6.0, 17.0)
dialysis requirement (%)	7.7	4.4	5.7

[a]The data are presented as medians with interquartile ranges (25th and 75th percentiles) or percentages.

Our study also demonstrates an association between assignment of an ARF diagnosis and discharge to short- and long-term care facilities. This suggests that ARF independently and adversely affects recovery of physical function after an acute illness, irrespective of kidney function recovery. Consequently, ARF may be associated with a substantial cost burden on the health care system that persists after hospital discharge. To our knowledge, this association has not been described previously.

The lower prevalence of hypertension among patients with a discharge diagnosis of ARF may be caused by less frequent coding for less threatening chronic conditions such as hypertension in the setting of a severe acute illness with numerous complications as described previously (22). The association of hypertension, coronary artery disease, and cardiac catheterization with a shorter LOS likely reflects the typical short hospitalizations associated with cardiac catheterizations for diagnostic or therapeutic purposes.

The primary limitation of this study was our dependence on ICD-9-CM codes to ascertain the diagnosis of ARF. As administrative coding is dependent on accurate documentation by health care professionals and hospital "coders," there is an unquestionable potential for misclassification. As others have done for congestive heart failure (23) and sepsis (11), we attempted to validate ICD-9-CM coding for ARF at our institution. We demonstrated that ARF codes were effective at identifying patients with and without ARF (positive predictive value 87.6% and negative predictive value 90.1%, respectively). However, approximately 80% of patients with biochemical criteria for ARF were not identified by ICD-9-CM codes. If this is truly representative of coding practices across the United States, then the marked impact of ARF that we described may have been relatively conservative. When we projected the test characteristics from our single-center validation study to the entire NHDS population, the positive predictive value of ARF coding was only 50.1% with a negative predictive value of 98.5%. However, it is unclear whether extrapolating the test

Table 5. Multivariate (logistic regression) analyses examining the association of ARF with hospital death and discharge disposition[a]

Model	Hospital Death	Hospital Discharge Disposition		
		Short-Term Care Facility	Long-Term Care Facility	Short- or Long-Term Care Facility
Unadjusted	11.5 (11.4, 11.6)	2.8 (2.8, 2.8)	3.8 (3.8, 3.9)	3.5 (3.4, 3.5)
Adjusted for				
age, gender, ethnic background, and payment source	8.0 (7.9, 8.1)	2.1 (2.1, 2.1)	2.7 (2.7, 2.7)	2.4 (2.4, 2.5)
age, gender, ethnic background, payment source, and co-existing conditions	6.1 (6.0, 6.1)	2.0 (2.0, 2.0)	2.4 (2.3, 2.4)	2.2 (2.2, 2.2)
age, gender, ethnic background, payment source, co-existing conditions, and acute hospital-related factors	6.0 (6.0, 6.1)	2.0 (2.0, 2.0)	2.3 (2.3, 2.4)	2.2 (2.2, 2.2)
age, gender, ethnic background, payment source, co-existing conditions, acute hospital-related factors, and AOSD	4.1 (4.0, 4.1)	1.8 (1.8, 1.8)	2.2 (2.1, 2.2)	2.0 (2.0, 2.0)

[a]The data are presented as odds ratios (95% confidence interval). Discharge records with missing ethnicity and discharge status were excluded from all analyses. The reference group for all analyses involving discharge to short-term is discharge to home (only discharge to home and short-term discharges were included in these analyses). For the hospital discharge disposition analysis, the reference group for the discharge to either short-term or long-term is discharge to home.

characteristics from a single institution to the entire NHDS cohort is appropriate.

There are other shortcomings that require mention. The NHDS collects data on hospital discharges and not individual patients. Thus, a patient may be captured on multiple occasions as a result of frequent admissions. The NHDS contains only seven diagnosis codes, which may or may not contain the relevant coexisting conditions for which we attempted to adjust. In addition, because of the large sample size, small differences in the characteristics of patients with and without ARF might be statistically significant but not of clinical significance. Therefore, care must be taken in the interpretation of these differences as to their clinical importance and relevance.

In summary, this study demonstrates that using the NHDS, a nationwide administrative database, the existence of ARF in a hospital discharge record is independently associated with adverse outcomes, including higher hospital-associated mortality. Furthermore and more importantly, hospitalizations in which ARF is reported are associated with a prolonged LOS and with a greater likelihood of discharge to short-term and long-term care facilities. These factors suggest higher costs associated with the care for patients with ARF and a significant burden that ARF places on the health care system. Future research should focus on the ascertainment of more accurate national estimates of ARF and better describe the relative contribution of ARF to the utilization of health care resources in the United States today. Such research endeavor would underscore the urgent need to improve health care delivery by allocating research budgets to the development of more effective preventive strategies and to the early diagnosis and timely management of ARF, particularly in high-risk populations.

Appendix: ICD-9-CM– and CPT-based classification of AOSD (11)

Types of AOSD	ICD-9-CM or CPT Codes
Respiratory	
acute respiratory failure	518.81
acute respiratory distress syndrome	518.82
acute respiratory distress syndrome after shock or trauma	518.85
respiratory insufficiency	786.09
respiratory arrest	799.1
ventilator management	96.7
Cardiovascular	
shock	785.5
shock, cardiogenic	785.51
shock, circulatory or septic	785.59
Hepatic	
acute hepatic failure or necrosis	570
hepatic encephalopathy	573.3
Hematologic	
disseminated intravascular coagulation	286.2
purpura fulminans	286.6
coagulopathy	286.9
thrombocytopenia, primary, secondary, or unspecified	287.3–5
Neurologic	
transient organic psychosis	293
anoxic brain injury	348.1
encephalopathy, acute	348.3
coma	780.01
altered unconsciousness, unspecified	780.09

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