

Incidence and Mortality of Acute Renal Failure in Medicare Beneficiaries, 1992 to 2001

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This study's objective was to determine the incidence and mortality of acute renal failure (ARF) in Medicare beneficiaries. Data were from hospitalized Medicare beneficiaries (5,403,015 discharges) between 1992 and 2001 from the 5% sample of Medicare claims. For 1992 to 2001, the overall incidence rate of ARF was 23.8 cases per 1000 discharges, with rates increasing by approximately 11% per year. Older age, male gender, and black race were strongly associated ($P < 0.0001$) with ARF. The overall in-hospital death rate was 4.6% in discharges without ARF, 15.2% in discharges with ARF coded as the principal diagnosis, and 32.6% in discharges with ARF as a secondary diagnosis. In-hospital death rates were 32.9% in discharges with ARF that required renal dialysis and 27.5% in those with ARF that did not require dialysis. Death within 90 d after hospital admission was 13.1% in discharges without ARF, 34.5% in discharges with ARF coded as the principal diagnosis, and 48.6% in discharges with ARF as a secondary diagnosis. Discharges with ARF were more ($P < 0.0001$) likely to have intensive care and other acute organ dysfunction than those without ARF. For discharges both with and without ARF, rates for death within 90 d after hospital admission showed a declining trend. In conclusion, the incidence rate of ARF in Medicare beneficiaries has been increasing. Those of older age, male gender, and black race are more likely to have ARF. These data show ARF to be a major contributor to morbidity and mortality in hospitalized patients.

J Am Soc Nephrol 17: 1135–1142, 2006. doi: 10.1681/ASN.2005060668

Acute renal failure (ARF) is a syndrome characterized by a sudden decrease in the GFR accompanied by azotemia (1). Because the onset of ARF often is clinically silent, it is difficult to study the disease, and there has been no national study of ARF. To date, the published incidence and mortality of ARF are mostly from single-center data.

Very few data have been published regarding the incidence of ARF. An often-cited incidence rate (4.9%) was obtained using single-hospital data collected in 1979 (2). Investigators from the same group reported a higher incidence rate (7.0%) using single-center data 17 yr later (3). With a similar definition of ARF, another study reported that 0.9% of patients presented with ARF at hospital admission (4). No study has been conducted to assess the possibility of change in incidence rates of ARF using multiple-year data.

Despite advances in medical techniques during the past several decades, mortality in patients with ARF remains high. Depending on patient characteristics as well as criteria used for the definition of ARF, of those who develop ARF while in the hospital, 25 to 80% die before discharge (3,5–7). No study using

national data has been conducted to determine whether mortality outcomes of patients with ARF have changed over time.

Given the absence of an epidemiologic study of ARF using national data, we decided to study ARF using a 5% sample of US hospitalized Medicare beneficiaries for the years 1992 to 2001. The objectives of the study were to determine the incidence and mortality of ARF in hospital settings.

Materials and Methods

Data Sources

Data on patients in the Medicare 5% sample and a related Medicare Enrollment Denominator File were obtained from the Centers for Medicare and Medicaid Services. The Medicare 5% Sample Beneficiary Standard Analytical File contains data on Medicare beneficiaries who have particular digits in the last two positions of their social security numbers. Because the last two digits of the social security number are randomly assigned by the Social Security Administration, the Medicare 5% sample is in effect a random sample of all Medicare beneficiaries. Medicare inpatient claims include dates of hospital admission and discharge, discharge status (alive or dead), and diseases diagnosed. In Medicare claims, diseases are recorded using *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes. The ESRD database that is maintained by the US Renal Data System Coordinating Center also was used.

Definitions

ARF was determined on the basis of ICD-9-CM diagnosis codes, coded as either the principal or a secondary diagnosis. Those with renal

Received June 28, 2005. Accepted January 15, 2006.

Published online ahead of print. Publication date available at www.jasn.org.

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failure, as defined by registration with the US Renal Data System for ESRD treatment, were excluded. In the ICD-9-CM, ARF is defined as “the sudden, severe onset of inadequate kidney function.” Five sub-codes (584.5, 584.6, 584.7, 584.8, and 584.9) under a main code (584) are used to designate ARF. The validity of ARF in claims data has been evaluated (8). Positive predictive value was 88% in ARF defined by 50% increase of serum creatinine from the baseline and 87% in ARF recorded by ICD-9-CM codes (8).

In Medicare inpatient claims, each admission was assigned one code for the principal diagnosis and as many as nine codes for secondary diagnoses. We scrutinized all principal and secondary diagnosis codes for codes that denoted ARF. For many admissions, fewer than nine secondary diagnosis codes were indicated. In this study, any of nine secondary code positions could have been used to indicate a secondary diagnosis of ARF.

We also determined intensive care unit (ICU) stay, sepsis, other acute organ dysfunction, and renal dialysis during the hospital stay. In Medicare claims, renal dialysis was indicated by revenue center codes (0800 to 0809) and ICD-9-CM procedure codes (3995 and 5498). ICU stay is indicated by revenue center codes (0200 to 0209). Revenue codes are documented for reimbursement purposes, with coding accuracy having been verified before payment was made. Sepsis and acute organ dysfunction were indicated by ICD-9-CM diagnosis codes, which have been used in previous studies (9,10). In this study, acute organ dysfunction pertained to cardiovascular, respiratory, hepatic, hematologic, and neurologic dysfunction (see Appendix 1 for codes for organ dysfunction associated with sepsis).

Patient demographics were recorded in the Medicare Enrollment Denominator File as well as in Medicare claims. Race and ethnicity included white, black, Hispanic, Native American, and Asian American. Because of a small number of records for minorities, we combined Hispanic, Native American, and Asian American into an “other” group. Therefore, in this study, white and black patients were non-Hispanic white and non-Hispanic black, respectively.

The Medicare Enrollment Denominator File includes information on Medicare beneficiary entitlement status, as taken from administrative

enrollment records. This file is an abbreviated version of the Medicare Enrollment Database. The Denominator File includes the date of death. All deaths are required to be reported to the Social Security Administration by statute and are reported to the Centers for Medicare and Medicaid Services.

Statistical Analyses

All data that were used in this study were collected from hospitalized patients (Medicare inpatient claims). We conducted discharge-level analyses of incidence and mortality. All admissions, regardless of whether the patient died during hospitalization or survived to discharge, were included in the study. Design of the study and analysis of the data at the discharge level were conducted using the National Hospital Discharge Survey (10,11).

Data were analyzed using SAS (SAS Institute, Inc., Cary, NC). Proportion data were analyzed using the χ^2 test. By-year rates for ARF and deaths were standardized to the 2000 data, with adjustment for age, gender, and race (12). Odds ratios (OR) for likelihood of ARF, sepsis, ICU stay, other acute organ failure, and death within 90 d after the date of hospital admission were analyzed using logistic regression.

Results

Incidence

For the years 1992 to 2001, there were 5,403,015 hospital discharges in the study population. The number of discharges in individual years was relatively stable, ranging from 511,017 to 578,619. Table 1 presents demographic information on discharged patients. By ICD-9-CM code, 87.3% of ARF discharges were coded as 584.9 (ARF, unspecified), 11.0% as 584.5 (ARF with lesion of tubular necrosis), and the rest as the other three codes (584.6, 584.7, and 584.8). By diagnosis, in 24.2% of ARF discharges, ARF was coded as the principal diagnosis; in the remaining 75.8%, ARF was coded as a secondary diagnosis. Of discharges with ARF, 14.9% were treated with dialysis.

Table 1. Patient characteristics at time of admission^a

Characteristic	ARF-P	ARF-S	ARF-PS	Non-ARF
No. of discharges	30,910	96,704	127,614	5,275,401
Age (y; mean)	76.1	75.8	75.9	73.8
Age group (y; %) ^b				
≤64	11.1	10.6	10.7	13.8
65 to 74	27.7	29.6	29.1	33.2
75 to 84	38.2	38.4	38.4	35.1
≥85	23.0	21.4	21.8	17.9
Male (%) ^b	50.2	52.4	51.9	43.1
Race (%) ^b				
white	78.5	80.9	80.3	85.2
black	16.7	14.1	14.8	10.0
other	4.8	5.0	4.9	4.9
Hospital stay (d; mean)	9.0	13.5	12.4	6.7
Renal dialysis (%) ^c	20.2	13.3	14.9	1.9

^aARF, acute renal failure; ARF-P, ARF coded as the principal diagnosis; ARF-S, ARF coded as a secondary diagnosis; ARF-PS, ARF-P and ARF-S groups combined.

^bDifferences ($P < 0.0001$) among ARF-P, ARF-S, and Non-ARF in age group, gender, race, and renal dialysis were detected using χ^2 statistics, and in mean hospital stay and age using a general linear model.

^cRenal dialysis in non-ARF was for those who were in the ESRD program.

The mean age of people who were hospitalized with ARF was 2.1 yr greater than that of people who were hospitalized without ARF (Table 1). The mean age varied slightly during the 10-yr study period. By individual years, the mean age for people who were hospitalized with ARF ranged from 75.6 to 76.1 yr and for people who were hospitalized without ARF ranged from 73.6 to 73.9 yr. Men were the minority among non-ARF discharges, whereas they were the majority among the ARF discharges. Black patients composed 10.0% of discharges without ARF and 14.8% of discharges with ARF. ARF hospital stays were 5.7 d longer than non-ARF hospital stays.

The overall rate of ARF during the study period was 23.8 cases per 1000 discharges. Older patients were more likely to have ARF than those who were younger. Average ARF rates during the study period were 18.5, 20.8, 25.8, and 28.6 cases per 1000 discharges for age groups ≤ 64 , 65 to 74, 75 to 84, and ≥ 85 yr, respectively. In men and women, the average ARF rates during the 10 yr were 28.3 and 20.0 cases per 1000 discharges, respectively. In white and black patients and patients of other races, the average ARF rates between 1992 and 2001 were 22.3, 34.4, and 24.3 cases per 1000 discharges, respectively.

Standardized ARF rates increased annually by approximately 11% ($P < 0.0001$), from 14.6 cases per 1000 discharges in 1992 to 36.4 cases per 1000 discharges in 2001 (Figure 1). Such an increase was present in subgroups that were defined on the basis of age, gender, and race. The increase of ARF incidence from 1992 to 2001 was also confirmed ($P < 0.0001$) by logistic

regression after adjustment for age, gender, and race. The increase was observed when ARF was coded either as the principal diagnosis or as a secondary diagnosis and when dialysis was and was not required (Figure 2).

Sepsis, Intensive Care, and Other Acute Organ Dysfunction

Percentages of people who were hospitalized with sepsis, ICU care, and other acute organ failure during the study period are presented in Table 2. Acute respiratory dysfunction was the most common organ failure, followed by cardiovascular failure. As with the year trend found for ARF, OR from logistic regression after adjustment for age, gender, and race also showed increases in sepsis, ICU stay, and acute organ failure from 1992 to 2001 (Figure 3). After sepsis, ICU stay, or other organ failure was added in the model of logistic regression for ARF, people with sepsis were 2.3 times more likely (OR 2.307; 95% confidence interval [CI] 2.281 to 2.331) to have ARF than those without sepsis, people with ICU stay were 3.0 times more likely (OR 3.015; 95% CI 2.981 to 3.050) to have ARF than those without ICU stay, and people with other organ failure were 4.6 times more likely (OR 4.562; 95% CI 4.506 to 4.619) to have ARF than those without other organ failure. The findings were seen in both ARF coded as the principal diagnosis and ARF coded as a secondary diagnosis and in ARF that did and did not require dialysis. After adjustment for sepsis, ICU stay, or other organ failure, as well as age, gender, and race, OR for ARF incidence still increased from 1992 to 2001. Furthermore, we separately

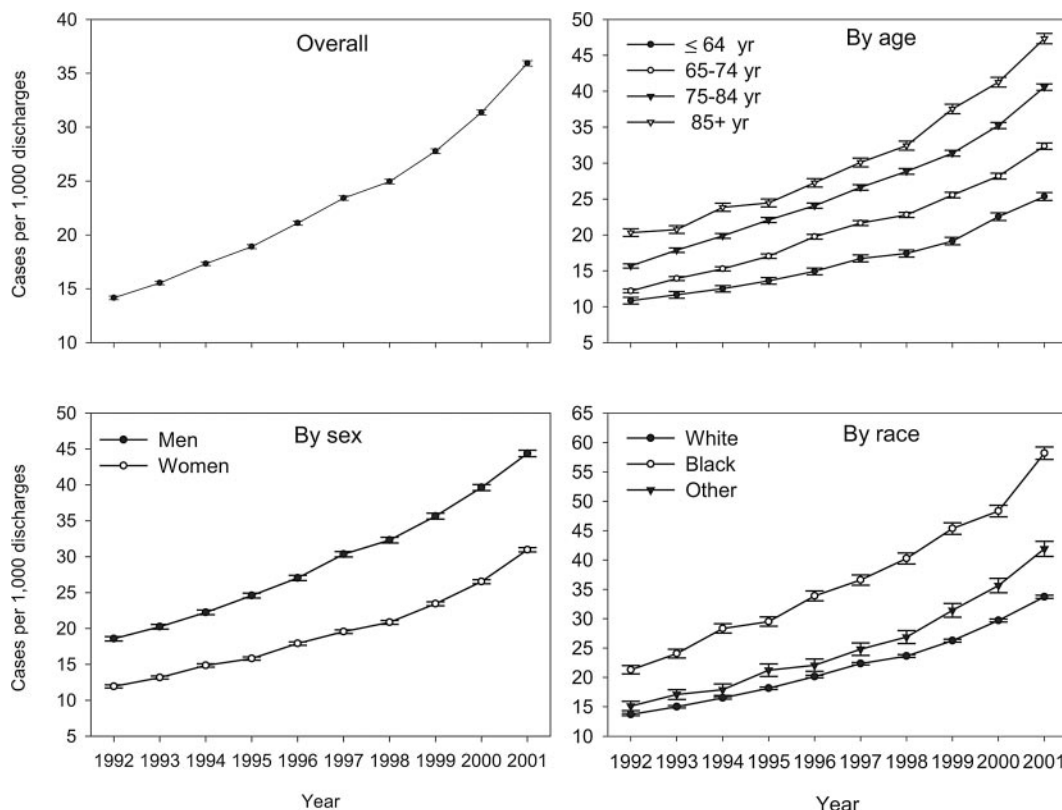


Figure 1. Number of cases of acute renal failure (ARF) per 1000 hospital discharges of US Medicare beneficiaries, 1992 to 2001. I-bars represent SE.

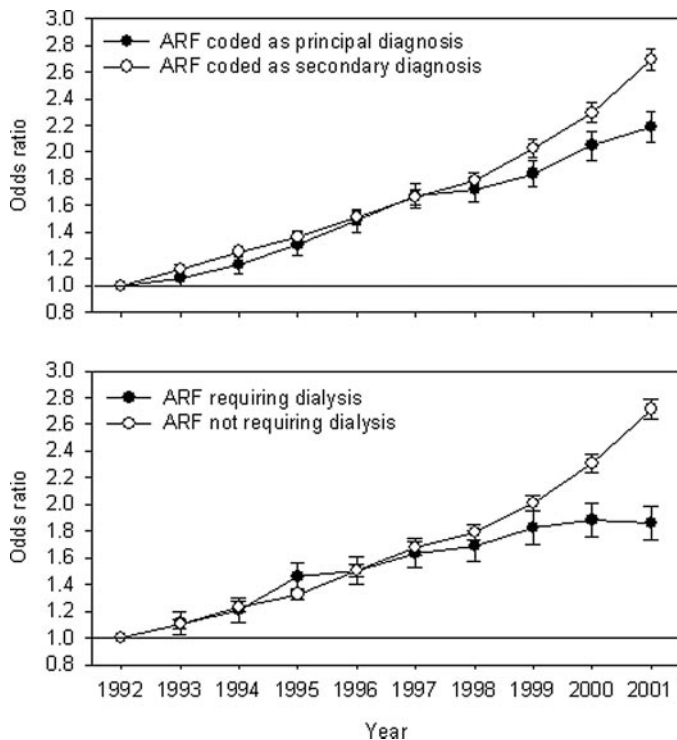


Figure 2. Odds ratio (OR) for ARF defined by diagnosis coding (top) and by renal dialysis (bottom). Year 1992 is the baseline (OR 1.0). I-bars represent 95% confidence interval (CI).

Table 2. Discharges (%) with sepsis, intensive care, and other acute organ dysfunction^a

	Sepsis	ICU	Other Acute Organ Dysfunction
Non-ARF	30.4	19.3	8.4
ARF-P	40.4	27.2	14.7
ARF-S	54.0	46.9	35.2

^aICU, intensive care unit. Differences ($P < 0.0001$) among groups within each column were detected using χ^2 statistics.

analyzed the data using the logistic regression model for patient discharges with and without sepsis, ICU stay, and other organ failure. OR for ARF showed consistent increases from 1992 to 2001 in all groups, with or without these conditions.

Mortality

The overall in-hospital death rate for the period 1992 to 2001 was 15.2% in discharges with ARF coded as the principal diagnosis, 32.6% in discharges with ARF as a secondary diagnosis, and 4.6% in discharges without ARF. In-hospital death rate was 32.9% in discharges with ARF that required dialysis and 27.5% in those with ARF that did not require dialysis. In-hospital death rate declined from 1992 to 2001. Medicare discharges with ICU stay and other acute organ dysfunction

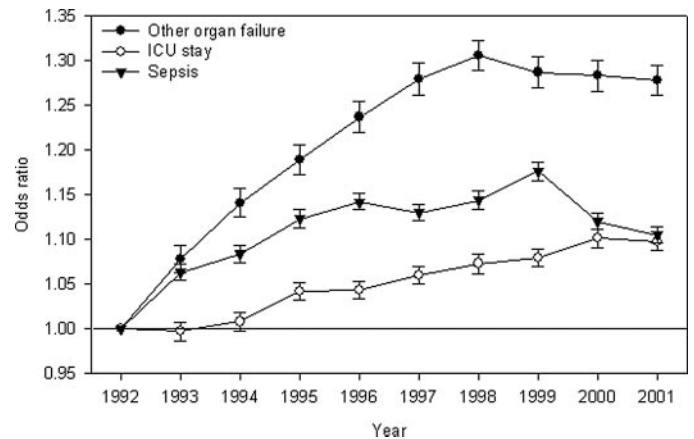


Figure 3. OR for sepsis, intensive care unit (ICU) stay, and other organ failure. Year 1992 is the baseline (OR 1.0). I-bars represent 95% CI.

had higher in-hospital death rates than those without ICU stay and other organ dysfunction (Table 3).

The standardized rate of death within 90 d after hospital admission showed a declining trend from 1992 to 2001. The 90-d death rates in 1992 and 2001 were, respectively, 13.5 and 12.1% in non-ARF, 38.8 and 32.2% in ARF coded as the principal diagnosis, 52.7 and 43.2% in ARF coded as a secondary diagnosis, 45.7 and 44.8% in ARF that required dialysis, and 49.7 and 40.3% in ARF that did not require dialysis. Overall, death within 90 d after hospital admission was 13.1% in discharges without ARF, 34.5% in discharges with ARF coded as the principal diagnosis, and 48.6% in discharges with ARF as a secondary diagnosis. After adjustment for other acute organ failure, as well as age, gender, and race, using logistic regression, OR also showed declining trends for death within 90 d after hospital admission in all groups of ARF and non-ARF patients (Figure 4).

Discussion

We found an increase in the occurrence of ARF among hospital discharges from 1992 to 2001. The increase was found in ARF that was defined as either the principal diagnosis or a secondary diagnosis or as requiring dialysis or not requiring dialysis. Although the increase in ARF that required dialysis was not as steep as the increase in ARF that did not require dialysis, the same pattern of increase was observed from 1997 through 2000. We found no change between 2000 and 2001; this may be accurate, but it also may be because 2001 was the last year in our data set and reflects delayed reimbursement processes in 2002. Our findings are consistent with the findings from two studies that were conducted by other investigators (2,3). Using the same criteria for defining ARF, they found 4.9% of hospitalized patients with ARF in 1979 (2) and 7.2% in 1996 (3). Our preliminary review of data from the National Hospital Discharge Survey also indicated a rise in the occurrence of ARF during the study period (13). In addition, we found a rising pattern of sepsis and ICU stays, which are highly associated

Table 3. Death rates (%) in hospital^a

	Renal Dialysis		Intensive Care		Other Acute Organ Dysfunction	
	Yes	No	Yes	No	Yes	No
Non-ARF	—	—	9.1	3.5	21.2	3.0
ARF-P	17.4	14.6	21.4	12.8	35.4	11.7
ARF-S	40.5	31.3	39.9	26.0	54.0	20.9

^aDifferences ($P < 0.0001$) between Yes and No in all categories were detected using χ^2 statistics.

with ARF (14,15). A recent national study demonstrated an increase in sepsis among hospital discharges between 1979 and 2000 (10). The rate of increase in sepsis was of a similar magnitude to that found in our study. The sepsis study also found that 15% of sepsis cases were associated with renal failure. Thus, increases in sepsis could be a causal factor in increasing rates of ARF.

Earlier studies have observed multiple episodes of ARF in the same individuals (2,3), a phenomenon also found in our study. The majority (85%) of discharges in our study had only one hospital admission with ARF. Considering our 10-yr period, 15% of discharges with more than one episode of ARF is not surprising. When we examined ARF incidence by separating single from multiple episodes, the increases in ARF occurrence were similar in both categories over the 10 yr.

ARF was strongly associated with older age, male gender,

and black race. Several studies have reported older individuals to be at a higher risk for ARF (3,16–18), which is not surprising because kidney function declines in the elderly. Our finding of increased risk for ARF in men is consistent with the finding of a multicenter study by Liano *et al.* (19) and the findings in patients with sepsis (10). However, in patients with heart disease, the findings are less clear. A recent study of patients who had had open-heart surgery found women to be at increased risk for ARF (20). Fortescue *et al.* (21) reported no difference in risk for ARF between men and women who had coronary bypass surgery. Further research seems needed to determine the incidence of ARF in patients with heart disease.

Very few studies have assessed racial differences regarding the incidence of and outcomes related to ARF, probably because of the difficulty of enrolling adequate numbers of minorities in a single-center or even a multicenter study. In a study of patients who had had open-heart surgery, white patients were found to have a lower risk for ARF defined broadly, but no racial differences were found in risk for ARF when ARF was defined more strictly, as requiring dialysis (20). In this study, we found black patients to be at a higher risk for ARF than those of other races. We also found that black patients were more likely to have sepsis and other acute organ failure than white patients. These differences between black and white patients were supported by a recent study (22). Further study is needed to determine the mechanisms of the racial differences.

Our finding that discharges with ARF had a higher in-hospital death rate than those without ARF is consistent with previous findings (18,23,24). The higher in-hospital death rate in ARF discharges was probably due to severe sickness, which requires intensive care (5,7,25). Longer hospital stays in ARF discharges also suggest severe illness. In addition, the severe sickness of ARF discharges was consistent with their other organ system failures. Other studies have indicated that comorbid conditions or surgical complications only partly account for the mortality difference between patients with and without ARF (23,24). Multiple organ failures primarily contributed to high mortality in patients with ARF and were strong predictors of death (6,26). In our study, when the logistic regression model included other organ failure, ARF was still significant for death, suggesting that ARF is an independent predictor of death.

Severity of illness also may account for the difference in

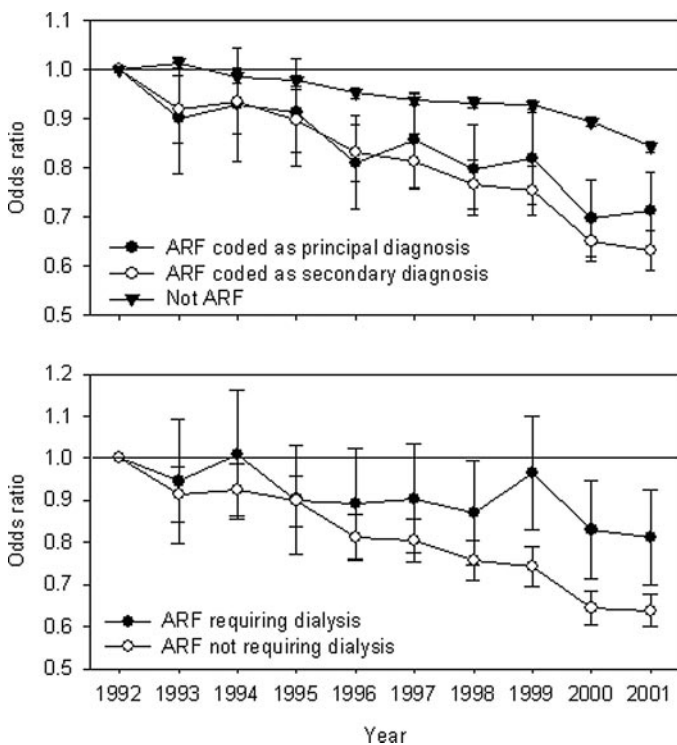


Figure 4. OR for 90-d death for ARF defined by diagnosis coding (top) and by renal dialysis (bottom). Year 1992 is the baseline (OR 1.0). I-bars represent 95% CI.

in-hospital death rate that we found between discharges with ARF coded as the principal diagnosis and those with ARF coded as a secondary diagnosis. Most of the discharges with ARF coded as the principal diagnosis had ARF as the cause for hospital admission, whereas discharges with ARF as a secondary diagnosis had another cause for admission; this suggests that the latter discharges had disease in other organ systems, with the kidney as a secondary complication. The difference in severity of illness between ARF coded as the principal and as a secondary diagnosis is supported by the increase in intensive care and other acute organ failure. This finding is consistent with reports that patients with “community-acquired ARF” (*i.e.*, patients in whom ARF was given as the cause for hospital admission) had a lower death rate than those with hospital-acquired ARF (4,27). Community-acquired ARF typically is related to volume disorders (especially volume depletion), with or without concomitant use of nonsteroidal anti-inflammatory drugs or angiotensin-converting enzyme inhibitors, and usually is reversible (4).

Another finding of our study is the decline in deaths within 90 d after hospital admission from 1992 to 2001, seen in both ARF and non-ARF discharges. Using the same criteria for defining ARF, Hou and colleagues (2,3) found a 25% death rate in a 1979 study and a 19% death rate in a 1996 study. McCarthy studied Mayo Clinic data on ARF patients who required intensive care and hemodialysis in two periods: 1977 to 1979 and 1991 to 1992 (28). Survival rates in hospital were 32% in the 1977 to 1979 period and 52% in the 1991 to 1992 period; 1-yr survival rates were 30 and 21% for the two periods, respectively. In our study, 1-yr death risk estimated by Cox regression also showed a declining trend during the study period (data not shown). The decline in death within 90 d after hospital admission from 1992 to 2001 that was found in this study not only reflects an improvement in hospital care but also suggests that patient mortality was not affected by the declining length of hospital stay during the study period. Since the 1982 implementation of the Prospective Payment System for Medicare, length of hospital stay continues to decline (29,30). A previous study reported that use of a fixed interval for death rather than inpatient death is reasonable (31).

Limitations of this study should be noted. This is a retrospective study using administrative data. Although use of ICD-9-CM codes for identification of ARF has been shown to be valid by a previous study (8), sensitivity was low (15%), suggesting that ARF that is recorded in Medicare claims is likely underreported. A recent study indicated that approximately 80% of patients with biochemical criteria for ARF were not identified by ICD-9-CM code (22). If these findings are applicable to the Medicare population, then the magnitude of underestimations in this study could be up to five- or six-fold. Given the definition of ARF in the ICD-9-CM (“the sudden, severe onset of inadequate kidney function”) and the previous validation of disease codes in claims data (32,33), it is likely that the documentation of ARF and other conditions that were examined in this study was accurate; however, less severe ARF and other conditions may not have

been coded. The possibility that ARF is underreported in Medicare claims has two main implications. First, the true incidence rate of ARF may be higher than that reported in this study. Second, outcomes from claims data may be overestimated; for example, the true mortality rate of ARF may be lower than that reported in this study because those with less severe ARF, unreported in Medicare claims, likely would have lower death risks. Another limitation of our study is that, because our data were analyzed at the discharge level, a potential for survivor bias could contribute to the decreasing 90-d mortality rate over time.

The increase in ARF from 1992 to 2001 may be attributable partially to changes in coding practices. Unfortunately, there is no reliable variable in claims data to test whether these practices have changed. Although there is evidence that associated conditions such as sepsis also are on the rise, without external validation, it is not possible to differentiate clearly real increases from changes in reporting practices. The change in coding practices could be driven by the change in Medicare reimbursement incentives. The smooth curve of rising ARF, however, does not support this notion because the change in reimbursement policy likely would result in a sudden increase or decrease in ARF. Furthermore, the rising trend of ARF that requires dialysis (Figure 2) cannot be linked plausibly with coding practices. In any case, the most recent data do suggest that the current level of ARF should be a cause for concern.

Preexisting kidney impairment likely has an impact on ARF occurrence as well. Patients with impaired kidney function may be more susceptible to risk factors for ARF; therefore, chronic kidney disease may be an important contributor to the increase in ARF that was found in this study. Impaired kidney function can be diagnosed in outpatient or inpatient settings. For investigation of the effect of impaired kidney function on the development of ARF, the impairment should be present first. Further research, with a study design that is different from the design of this study is needed for that purpose.

The main strength of this study is its use of a large sample that covered broad geographic areas, including all 50 US states and the District of Columbia. Medicare patients are older, and our results may not be generalizable to younger patients. However, the data used in this study were from a random sample of the Medicare population, and the results are highly representative of the older US population.

Conclusion

The incidence of ARF is increasing steadily among hospitalized Medicare beneficiaries, accompanied by declining mortality. Black patients are especially at risk for ARF. Patients with ARF have longer hospital stays and higher mortality than those without ARF. Although death of hospitalized patients showed a declining trend, patients with ARF were more likely to die compared with those without ARF. The cause of the increased incidence of ARF warrants further study. Additional study is also required to identify the conditions that give rise to hospital-acquired ARF.

Appendix 1. ICD-9-CM codes for acute organ dysfunction associated with sepsis^a

Organ System	ICD-9-CM Code Description	ICD-9-CM Code
Cardiovascular	Shock without trauma	785.5
	Hypotension	458
Respiratory	Mechanical ventilation	96.7
	Acute respiratory failure	518.81
	Acute respiratory distress syndrome	518.82
	Respiratory insufficiency	786.09
	Respiratory arrest	189.1
Hepatic	Acute or subacute necrosis of liver	570
	Hepatic encephalopathy	572.2
	Hepatic infarction	573.4
Hematologic	Defibrination syndrome	286.6
	Other/unspecified coagulation defects	286.9
	Thrombocytopenia	287.3–5
Neurologic	Transient organic psychosis	293
	Anoxic brain damage	348.1
	Encephalopathy	348.3
	Coma	780.01

^aICD-9-CM, *International Classification of Diseases, Ninth Revision, Clinical Modification*.

Acknowledgments

The data reported here were supplied by the US Renal Data System. This study was performed as a deliverable under contract N01-DK-9-2343 (National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, MD).

We thank Beth Forrest, James M. Kaufmann, PhD, and Nan Booth, MSW, MPH, for assistance with manuscript preparation and editing.

References

- Star RA: Treatment of acute renal failure. *Kidney Int* 54: 1817–1831, 1998
- Hou SH, Bushinsky DA, Wish JB, Cohen JJ, Harrington JT: Hospital-acquired renal insufficiency: A prospective study. *Am J Med* 74: 243–248, 1983
- Nash K, Hafeez A, Hou S: Hospital-acquired renal insufficiency. *Am J Kidney Dis* 39: 930–936, 2002
- Kaufman J, Dhakal M, Patel B, Hamburger R: Community-acquired acute renal failure. *Am J Kidney Dis* 17: 191–198, 1991
- Liano F, Junco E, Pascual J, Madero R, Verde E; the Madrid Acute Renal Failure Study Group: The spectrum of acute renal failure in the intensive care unit compared with that seen in other settings. *Kidney Int Suppl* 66: 16–24, 1998
- Mehta RL, Pascual MT, Gruta CG, Zhuang S, Chertow GM; for the PICARD Study Group: Refining predictive models in critically ill patients with acute renal failure. *J Am Soc Nephrol* 13: 1350–1357, 2002
- Schiff H, Lang SM, Fischer R: Daily hemodialysis and the outcome of acute renal failure. *N Engl J Med* 346: 305–310, 2002
- Winterstein AG, Weiner ID, Johns TE, Hatton RC: Validation of automated database algorithms to identify hospital-acquired acute renal failure [Abstract]. *Value Health* 7 (3): PUK13, 2004
- Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR: Epidemiology of severe sepsis in the United States: Analysis of incidence, outcome, and associated costs of care. *Crit Care Med* 29: 1303–1310, 2001
- Martin G, Mannino DM, Eaton S, Moss M: The epidemiology of sepsis in the United States from 1979 through 2000. *N Engl J Med* 348: 1546–1554, 2003
- Dennison C, Pokras R: Design and operation of the National Hospital Discharge Survey: 1988 redesign. *Vital Health Stat* 1: 1–42, 2000
- Woodward M: *Epidemiology: Study Design and Data Analysis*, Boca Raton, Chapman & Hall/CRC, 1999
- Eggers P, Star R, Xue J, Kimmel P, Molitoris B, Himmelfarb J, Collins A: ARF: An under-recognized contributor to ESRD. Presented at the American Society of Nephrology Annual Scientific Meeting; October 27 to November 1, 2004; St. Louis, Missouri
- Hoste EAJ, Lameire NH, Vanholder RC, Benoit DD, Decruyenaere JM, Colardyn FA: Acute renal failure in patients with sepsis in a surgical ICU: Predictive factors, incidence, comorbidity, and outcome. *J Am Soc Nephrol* 14: 1022–1030, 2003
- Schrier RW, Wang W: Acute renal failure and sepsis. *N Engl J Med* 351: 159–169, 2004
- Pascual J, Orofino L, Liano F, Marcen R, Orte L, Ortuno J: Incidence and prognosis of acute renal failure in older patients. *J Am Geriatr Soc* 38: 25–30, 1990
- Rich MW, Crecelius CA: Incidence, risk factors, and clinical course of acute renal insufficiency after cardiac catheterization in patients 70 years of age or older: A prospective study. *Arch Intern Med* 150: 1237–1242, 1990
- Rihal CS, Textor SC, Grill DE, Berger PB, Ting HH, Best PJ, Singh M, Bell MR, Barsness GW, Mathew V, Garratt KN, Holmes DR Jr: Incidence and prognostic importance of acute renal failure after percutaneous coronary intervention. *Circulation* 105: 2259–2264, 2002
- Liano F, Pascual J; the Madrid Acute Renal Failure Study

- Group: Epidemiology of acute renal failure: A prospective, multicenter, community-based study. *Kidney Int* 50: 811–818, 1996
20. Thakar CV, Liangos O, Yared JP, Nelson D, Piedmonte MR, Hariachar S, Paganini: ARF after open-heart surgery: Influence of gender and race. *Am J Kidney Dis* 41: 742–751, 2003
 21. Fortescue EB, Bates DW, Chertow GM: Predicting acute renal failure after coronary bypass surgery: Cross-validation of two risk-stratification algorithms. *Kidney Int* 57: 2594–2602, 2000
 22. Liangos O, Wald R, O'Bell JW, Price L, Pereira BJ, Jaber BL: Epidemiology and outcomes of acute renal failure in hospitalized patients: A national survey. *Clin J Am Soc Nephrol* 1: 43–51, 2006
 23. Levy EM, Viscoli CM, Horwitz RI: The effect of acute renal failure on mortality: A cohort analysis. *JAMA* 275: 1489–1494, 1996
 24. Chertow GM, Levy EM, Hammermeister KE, Grover F, Daley J: Independent association between acute renal failure and mortality following cardiac surgery. *Am J Med* 104: 343–348, 1998
 25. Mehta RL, McDonald B, Gabbai FB, Pahl M, Pascual MT, Farkas A, Kaplan RM; Collaborative Group for Treatment of ARF in the ICU: A randomized clinical trial of continuous versus intermittent dialysis for acute renal failure. *Kidney Int* 60: 1154–1163, 2001
 26. Schwilk B, Wiedeck H, Stein B, Reinelt H, Treiber H, Bothner U: Epidemiology of acute renal failure and outcome of haemodiafiltration in intensive care. *Intensive Care Med* 23: 1204–1211, 1997
 27. Feest TG, Round A, Hamad S: Incidence of severe acute renal failure in adults: Results of a community based study. *BMJ* 306: 481–483, 1993
 28. McCarthy JT: Prognosis of patients with acute renal failure in the intensive-care unit: A tale of two eras. *Mayo Clin Proc* 71: 117–126, 1996
 29. Kominski GF, Witsberger C: Trends in length of stay for Medicare patients: 1979–87. *Health Care Financ Rev* 15: 121–135, 1993
 30. Baker DW, Einstadter D, Husak SS, Cebul RD: Trends in postdischarge mortality and readmissions: Has length of stay declined too far? *Arch Intern Med* 164: 538–544, 2004
 31. Jencks SF, Williams DK, Kay TL: Assessing hospital-associated deaths from discharge data. The role of length of stay and comorbidities. *JAMA* 260: 2240–2246, 1988
 32. Jollis JG, Ancukiewicz M, DeLong ER, Pryor DB, Muhlbaier LH, Mark DB: Discordance of databases designed for claims payment versus clinical information systems. Implications for outcomes research. *Ann Intern Med* 119: 844–850, 1993
 33. Quan H, Parsons GA, Ghali WA: Validity of information on comorbidity derived from ICD-9-CM administrative data. *Med Care* 40: 675–685, 2002

See related editorial, "The Rise of Prevalence and the Fall of Mortality of Patients with Acute Renal Failure: What the Analysis of Two Databases Does and Does Not Tell Us," on pages 923–925.