

Potentially Avoidable Readmissions in United States Hemodialysis Patients



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Introduction: Patients with end-stage kidney disease have a high risk of 30-day readmission to hospital. These readmissions are financially costly to health care systems and are associated with poor health-related quality of life. The objective of this study was to describe and analyze the frequency, causes, and predictors of 30-day potentially avoidable readmission to hospital in patients on hemodialysis.

Methods: We conducted a retrospective cohort study using the US Renal Data System data from January 1, 2008, to December 31, 2008. A total of 107,940 prevalent United States hemodialysis patients with 248,680 index hospital discharges were assessed for the main outcome of 30-day potentially avoidable readmission, as identified by a computerized algorithm.

Results: Of 83,209 30-day readmissions, 59,045 (70.1%) resulted in a 30-day potentially avoidable readmission. The geographic distribution of 30-day potentially avoidable readmission in the United States varied by state. Characteristics associated with 30-day potentially avoidable readmission included the following: younger age, shorter time on hemodialysis, at least 3 or more hospitalizations in preceding 12 months, black race, unemployed status, treatment at a for-profit facility, longer length of index hospital stay, and index hospitalizations that involved a surgical procedure. The 5-, 15-, and 30-day potentially avoidable readmission cumulative incidences were 6.0%, 15.1%, and 25.8%, respectively.

Conclusion: Patients with end-stage kidney disease on maintenance hemodialysis are at high risk for 30-day readmission to hospital, with nearly three-quarters (70.1%) of all 30-day readmissions being potentially avoidable. Research is warranted to develop cost-effective and transferrable interventions that improve care transitions from hospital to outpatient hemodialysis facility and reduce readmission risk for this vulnerable population.

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KEYWORDS: avoidable; epidemiology; ESKD; hemodialysis; hospitalization; readmission

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Hospital readmission is associated with poor quality of life and health outcomes,^{1,2} as well as high costs. In the United States, an estimated \$17 billion spent on return trips to the hospital can be saved annually with appropriate management.³ Given the high societal, emotional, and financial costs, research has focused on identifying patient populations at high risk for readmission, as well as developing and testing interventions to reduce this risk. For example, more than 40 randomized controlled trials have tested

interventions to reduce readmission risk in patients with congestive heart failure.⁴

Patients with end-stage kidney disease (ESKD) on maintenance hemodialysis (HD) face particularly high rates of readmission to hospital. In 2013, 34.9% of HD patients were readmitted within 30 days of an index hospitalization.⁵ In comparison, 19% of the general Medicare population⁶ and approximately 25% of patients with congestive heart failure⁷ are readmitted to hospital within 30 days of an index hospital discharge. Hospitalizations in ESKD are exceptionally costly, and 38% of the nearly \$30 billion in annual Medicare expenditures for ESKD is spent on acute inpatient care.⁵

After an index hospital discharge, a patient with ESKD will experience 1 of 3 outcomes: remain out of hospital, be readmitted to hospital, or die. Perhaps

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related to definitions levied by pay-for-performance programs,⁸ readmissions are often defined as within 30 days of an index hospitalization, and are categorized as planned or unplanned. Planned readmissions are scheduled during or shortly after the index hospitalization, and are often for a procedure, chemotherapy, transplant, or rehabilitation. Approximately 10% of all readmissions are planned in the United States.^{6,9} An example scenario would be a patient admitted for a urologic procedure, with a planned readmission within 10 days for stent removal.

Of the remaining unplanned readmissions, some are unavoidable, whereas others might be avoidable with appropriate transitional and/or ambulatory care after index hospital discharge. For example, if a patient is discharged from hospital after an episode of atrial fibrillation, then readmitted within 30 days with acute cholecystitis, this readmission would be considered unplanned and also unavoidable. Conversely, if the same patient discharged from hospital after an episode of atrial fibrillation is then readmitted within 30 days with an episode of congestive heart failure, this would be considered an unplanned, but potentially avoidable readmission to hospital. The literature shows much variation regarding the proportion of potentially avoidable readmissions to hospital. In a recent systematic review, 27.1% of readmissions were deemed potentially avoidable in general medicine patients, ranging from 5% to 79%.¹⁰ Similarly, conditions in HD patients who are ambulatory-sensitive (e.g., volume overload, electrolyte imbalance) can result in readmission but may have been avoided with the appropriate transitional care on discharge.

Vest *et al.*¹¹ recently published a systematic review of readmissions, and defined a potentially avoidable readmission as: “an unintended and undesired subsequent post-discharge hospitalization, where the probability is subject to the influence of multiple factors.” However, the methodology to identify an avoidable readmission varies widely in the literature, often based on subjective criteria,^{12–15} or predefined lists of discharge categories or diagnoses.^{16,17} These methodologies lack generalizability and are inadequate for use with large datasets or more sophisticated analyses. 3M Health Information Systems has developed a proprietary potentially preventable readmissions classification system,¹⁸ but its use for research purposes is limited. Halfon *et al.*¹⁹ derived an algorithm using administrative data (International Classification of Diseases, Ninth Revision codes and diagnosis-related group [DRG] codes) in a general medical inpatient population in Switzerland. The algorithm had 96% sensitivity and 95.7% specificity against the gold standard of chart review and has been used for research

purposes to aid in the identification of predictive factors for potentially avoidable readmission in the United States.²⁰

Despite the high risks, negative impact on patient outcomes, and financial consequences, there is a paucity of literature on the frequency and predictors of potentially avoidable readmission in ESKD,²¹ and lack of a standardized metric to define potentially avoidable readmission. Although some studies and reports have described all-cause,^{22–25} or cause-specific^{5,26–29} readmissions in ESKD, potentially avoidable readmissions have not been previously studied. Given these gaps in the literature, we conducted an observational study using the US Renal Data System (USRDS) database to describe and analyze the frequency, causes, and predictors associated with potentially avoidable readmission.

METHODS

This study was conducted and reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology guidelines.³⁰

Data Source, Setting, and Participants

We conducted an observational cohort study of the USRDS database using data from the core and hospitalized datasets. Patients with Medicare as their primary insurance type, 18 to 95 years of age at day ≥ 91 after first ESKD service, with acute hospital discharges from January 1, 2008, to November 30, 2008, were included in the study population. All 30-day readmissions were assessed until December 31, 2008. Data were obtained on patient characteristics and comorbidities at baseline from the 2728 medical evidence form. Data on comorbid conditions were also collected from claims over a 3- to 6-month entry period (dependent on date of first ESKD service). Hospitalization claims with discharge status of “left against medical advice,” or DRG of 998, 999, or 000 (invalid or ungroupable) were excluded. Hospital discharges with primary reason for admission being rehabilitation (DRG 945, 946), psychiatric diagnosis (DRG 876–887), cancer (International Classification of Diseases, Ninth Revision principal discharge code of 140.xx-172.xx, 174.xx-208.xx, 230.xx-231.xx, 233.xx-234.xx), or renal transplant (DRG 652) were similarly excluded. An index hospital discharge was eligible only if it occurred during an HD treatment period, thus excluding patients on peritoneal dialysis. Patients listed as “recovered function,” with an unknown ESKD start date, who died during the index hospitalization, or with conflicting information on 1995 and 2005 medical evidence forms were also excluded. The study protocol was approved for Exempt Status by the Institutional

Review Board of Northwell Health and issued a waiver of authorization as per 45 CFR 164.512 for the use and disclosure of information for research purposes.

Outcome Definitions

Thirty-Day Potentially Avoidable Readmission

The main study outcome was the proportion of index hospitalizations resulting in a potentially avoidable 30-day readmission (30-day PAR). Thirty-day PAR was identified by a computerized algorithm that uses routinely available International Classification of Diseases, Ninth Revision and DRG codes from administrative data. The algorithm was initially developed using a random sample of 3474 hospitalized patients from across Switzerland. Prediction was based on a Poisson regression model, with intra-sample sensitivity and specificity of the computerized screening algorithm reaching 96%, compared with a gold standard of systematic medical record review to identify potentially avoidable readmissions.¹⁹ A subsequent validation study of the predictive value of the computerized algorithm was then conducted, including 131,809 hospitalizations, and a random sample of 570 discharge/readmission pairs for chart review by 2 trained independent physicians.³¹ In this study, the predictive value was very good at 78%, for the computerized algorithm identifying potentially avoidable readmission. For a readmission to be categorized as potentially avoidable, the algorithm requires the readmission (i) is related to at least 1 diagnosis already known during the previous hospital stay; (ii) was unforeseen at the time of the previous hospital discharge; and (iii) occurs within the 30 days after the previous hospital discharge.

Thirty-Day Planned Readmission

As per the Planned Readmissions Algorithm version 2.1 published by the Centers for Medicare and Medicaid Services,³² 3 principles guide the identification of a planned readmission: (i) a few specific, limited types of care are always considered planned (obstetrical delivery, transplant surgery, maintenance chemotherapy/radiotherapy/immunotherapy, rehabilitation); (ii) a planned readmission is defined as a nonacute readmission for a scheduled procedure; and (iii) admissions for acute illness or for complications of care are never planned. For this study, we defined a planned readmission using criteria for “planned readmission” from the National Quality Forum technical report on all-cause readmissions,⁹ or for solely vascular access reasons, as defined by USRDS analytic methods.³³

Thirty-Day Unplanned and Unavoidable Readmissions

These were defined as all other hospitalizations occurring within 30 days of an index hospitalization that did

not meet the definition of potentially avoidable or planned readmission.

Statistical Analysis

Patient demographic and comorbid characteristics were obtained from patient profile, hospitalization inpatient data, facility standard analysis file, and the 2728 Centers for Medicare and Medicaid Services Medical Evidence form and expressed as categorical variables. Descriptive statistics were used to describe the sample of index hospitalizations. Demographic characteristics included were gender, race, ethnicity, employment status, HD facility, HD vintage in years, and cause of ESKD. A comorbidity index, encompassing 11 comorbidities and validated for use in the ESKD population to model outcomes of mortality and hospitalization, was used to report the comorbidity burden and adjust for potential confounding of the primary outcome of 30-day PAR.³⁴ Comorbid characteristics included in the index are atherosclerotic heart disease, congestive heart failure, cerebrovascular disease, peripheral vascular disease, other cardiac disease, chronic obstructive pulmonary disease, gastrointestinal bleed, liver disease, dysrhythmia, cancer, and diabetes. This index was used to increase stability of effect estimates and simplify comparisons. The comorbidity index outperforms the Charlson Comorbidity Index in both predictive ability and inference. Geographic-level median income was described by linking USRDS data to 2010 US census data by zip code, and unadjusted risk of 30-day potentially avoidable readmission for each state was mapped using Pitney Bowes MapInfo (Troy, NY). There were no missing zip codes in our final sample and only 8700 patients (8%) did not have income-level data and were excluded from the analysis. Because missing data were uncommon, multiple imputation was not performed.

Reason for index hospital discharge was reported using Clinical Classification Software (CCS) category. The CCS is a diagnosis and procedure categorization scheme based on International Classification of Diseases, Ninth Revision codes developed with sponsorship from the Agency for HealthCare Research and Quality for research purposes. The 5 most common single-level CCS categories of index hospital discharge that resulted in the largest proportions of 30-day PAR were identified. We then tabulated the rate, proportion, and 5 most frequent causes of 30-day PAR that resulted from each of these index hospitalization categories (defined by single-level CCS category³⁵).

Logistic regression using generalized estimating equation methods was used to model 30-day PAR as a function of each potential risk factor of interest, with hospitalization as the unit of analysis. Generalized

estimating equation estimation with robust SEs was used to account for the clustering of multiple index hospitalizations within a patient. Predictors that were individually significantly associated with 30-day PAR ($P < 0.05$) were included in the final multivariable model. Predictors of interest included all demographic and clinical characteristics, as well as dialysis facility type and median income. All predictors, excluding geographic-level median income and index admission primary diagnosis, were significant and included in the final model. To identify risk factors unique to PAR, we repeated these multivariable models using all readmission, all readmission + death, and PAR+ death as outcome of interest.

Time to potentially avoidable readmission was analyzed using competing risks methodology,³⁶ because deaths, and unplanned and planned readmissions represent competing risks to the primary outcome of 30-day PAR (because the occurrence of any of these events prevents PAR from being observed). The cumulative incidence function for 30-day PAR was

used to estimate the probability of a potentially avoidable readmission at 5, 10, 15, 20, 25, and 30 days after an index hospital discharge. Index hospitalizations that experienced neither death nor any type of readmission by 30 days postdischarge was considered to be censored at 30 days. In sensitivity analyses, the Kaplan-Meier method was also used, treating all events other than a potentially avoidable readmission as censored. All analyses assumed a 2-sided significance level of 0.05. All analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Participant and Index Hospitalization Characteristics

A total of 107,940 patients with 247,680 index hospitalizations met our predefined inclusion criteria, and were included in the study cohort (Figure 1). Of 346,671 possible adults, Medicare index admissions with discharges that occurred between January 1,

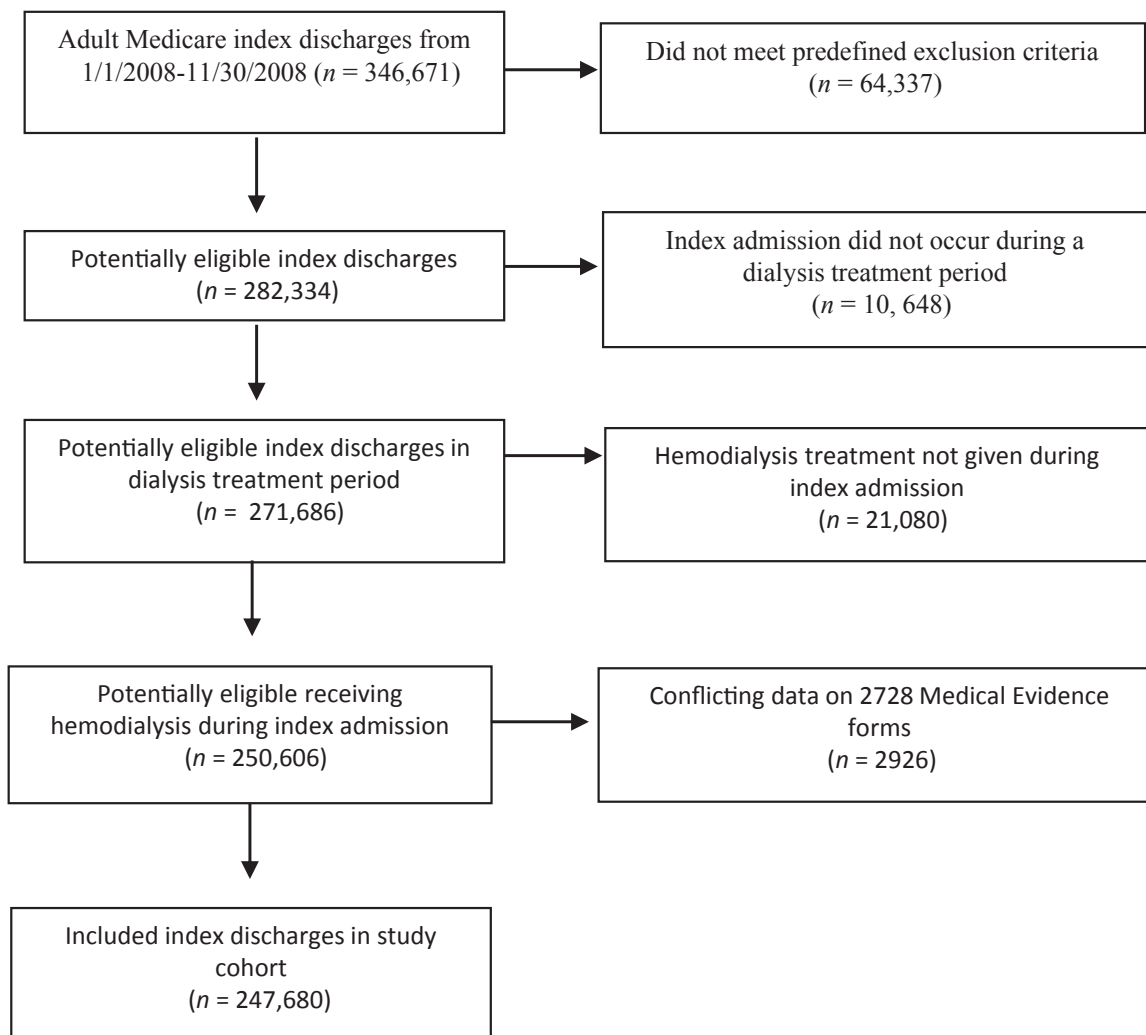


Figure 1. Study flow diagram.

2008, and November 30, 2008, 64,337 admissions were excluded due to either death during the index admission, discharged after November 30, 2008, transferred in another hospital or rehabilitation center, or some other predefined exclusion criteria (see Data Source, Setting, and Participant section). Of those remaining, 10,648 admissions were removed because the index admission did not occur during a treatment period. Of those remaining, 21,080 were removed because the treatment given during the index admission was not HD. Finally of those remaining, 2,926 were removed because of conflicting data on the medical evidence forms. Patient and index hospitalization characteristics

stratified by the outcome of potentially avoidable readmission are shown in Tables 1 and 2. At baseline (i.e., time of index hospitalization discharge), the median patient age was 66 years with an interquartile range of 53 to 76, 50% of patients were female, 38.9% were of black race, 13.5% were of Hispanic ethnicity, 49% had diabetes as the primary cause for ESKD, and 74.6% dialyzed at for-profit HD facilities. The median time on HD (vintage) was 2.61 years (interquartile range 1.20 to 4.87). When admitted to hospital, most patients (43%) had between 1 and 3 prior hospitalizations in the preceding 12 months, with 30% having had more than 3 prior hospitalizations in the preceding

Table 1. Baseline patient characteristics at index hospitalization in 107,940 patients and 247,680 hospitalizations

Characteristics, <i>n</i> (col %) or median (interquartile range)	Total <i>n</i> = 247,680	Potentially avoidable readmission ^a (<i>n</i> = 59,045)	No potentially avoidable readmission ^a (<i>n</i> = 188,635)	Standardized difference
Age, yr	66 (53–76)	65 (42–88)	66 (44–88)	–0.08
Gender				–0.02
Male	123,709 (49.9)	29,039 (49.2)	94,670 (50.2)	
Female	123,971 (50.1)	30,006 (50.8)	93,965 (49.8)	
Race				0.07
White	138,904 (56.1)	31,925 (54.1)	106,979 (56.7)	
Black	96,361 (38.9)	24,415 (41.4)	71,946 (38.1)	
Asian	6955 (2.8)	1544 (2.6)	5411 (2.9)	
Native American	4015 (1.6)	811 (1.4)	3204 (1.7)	
Other	1372 (0.6)	330 (0.6)	1042 (0.6)	
Unknown	73 (0.0)	20 (0.0)	53 (0.0)	
Ethnicity				0.02
Hispanic	33,336 (13.5)	7,616 (12.9)	25,720 (13.6)	
Non-Hispanic	208,835 (84.3)	50,178 (85.0)	158,657 (84.1)	
Unknown	5509 (2.2)	1251 (2.1)	4258 (2.3)	
Employment status				0.07
Employed/Student	11,593 (4.7)	2,566 (4.4)	9,027 (4.8)	
Homemaker	10,714 (4.3)	2,484 (4.2)	8,230 (4.4)	
Retired – Disability/Medical LOA	64,332 (26.0)	15,443 (26.2)	48,889 (25.9)	
Retired – Age	87,021 (35.1)	19,609 (33.2)	67,412 (35.7)	
Unemployed	64,014 (25.9)	16,570 (28.1)	47,444 (25.2)	
Missing/other	10,006 (4.0)	2,373 (4.0)	7633 (4.1)	
Geographic-level income, \$	44,037 (35,089–57,047)	43,661 (34,729–56,818)	44,146 (35,239–57,154)	–0.03
Dialysis vintage years	2.61 (1.20–4.87)	2.56 (1.16–4.78)	2.63 (1.21–4.89)	–0.03
<1 year	51,340 (20.7)	12,734 (21.6)	38,606 (20.5)	0.03
1–3 years	85,669 (34.6)	20,328 (34.4)	65,341 (34.6)	
>3 years	110,671 (44.7)	25,983 (44.0)	84,688 (44.9)	
ESKD primary cause				0.03
Glomerulonephritis/cystic kidney	21,662 (8.8)	4,859 (8.2)	16,803 (8.9)	
Diabetes	121,811 (49.2)	28,886 (48.9)	92,925 (49.3)	
Hypertension	70,995 (28.7)	17,147 (29.0)	53,848 (28.6)	
Other	33,212 (13.4)	8,153 (13.8)	25,059 (13.3)	
Dialysis facility				0.02
Nonprofit	49,851 (20.1)	11,475 (19.4)	38,376 (20.3)	
Profit	184,840 (74.6)	44,547 (75.5)	140,293 (74.4)	
Unknown	12,989 (5.2)	3023 (5.1)	9966 (5.3)	
Comorbidity Index	11.00 (8.00–13.00)	11.00 (9.00–13.00)	10.00 (7.00–13.00)	0.31
Number of prior admissions	2.00 (0.00–4.00)	2.00 (1.00–5.00)	2.00 (0.00–4.00)	0.27
None	67,400 (27.2)	13,273 (22.5)	54,127 (28.7)	0.26
1–3	106,559 (43.0)	22,759 (38.6)	83,800 (44.4)	
>3	73,721 (29.8)	23,013 (39.0)	50,708 (26.9)	

ESKD, end-stage kidney disease; LOA, leave of absence; Q, quartile.

^aPercentages represent row percentage.

Table 2. Baseline characteristics of index hospitalizations

Characteristics <i>n</i> (col %) or median (interquartile range)	Total <i>n</i> = 247,680	Potentially avoidable readmission ^a (<i>n</i> = 59,045)	No potentially avoidable readmission ^a (<i>n</i> = 188,635)	Standardized difference
LOS Index, d	4.00 (2.00–7.00)	4.00 (2.00–8.00)	4.00 (2.00–7.00)	0.13
0–4	134,360 (54.3)	29,649 (50.2)	104,711 (55.5)	0.12
>4–8	64,517 (26.1)	15,837 (26.8)	48,680 (25.8)	
>8	48,803 (19.7)	13,559 (23.0)	35,244 (18.7)	
Type of index hospitalization				0.05
Primary surgical	61,477 (24.8)	14,261 (24.2)	47,216 (25.0)	
Primary medical	186,203 (75.2)	44,784 (75.8)	141,419 (75.0)	
Without surgical procedure	17,469 (9.4)	3,680 (8.2)	13,789 (9.8)	
With surgical procedure	168,734 (90.6)	41,104 (91.8)	127,630 (90.3)	

LOS, length of stay; Q, quartile.
^aPercentages represent row percentage

12 months. Seventy-five percent of index hospitalizations were for a primary medical reason, as identified by DRG. The median length of stay for index hospitalizations was 4 days (interquartile range 2 to 7); however, 20% of hospitalizations (*n* = 48,803) had a length of stay of more than 8 days.

Characteristics of 30-Day Readmissions

Of 247,680 index hospital discharges, 8584 patients (3.5%) died within 30 days of index hospital discharge (Figure 2). There were 83,209 index hospital discharges

that resulted in a 30-day readmission (33.6%). Of these, 59,045 were classified as potentially avoidable readmissions (70.1%), 18,461 were unplanned and unavoidable readmissions (22.2%), and 5703 readmissions (6.9%) were planned.

Table 3 shows the 5 most frequent causes for index hospitalization that resulted in a 30-day PAR, with corresponding 30-day PAR rates, and 5 most frequent causes of 30-day PAR (by single-level CCS category). Complication of a device, implant, or graft was the most frequent index hospital discharge that resulted

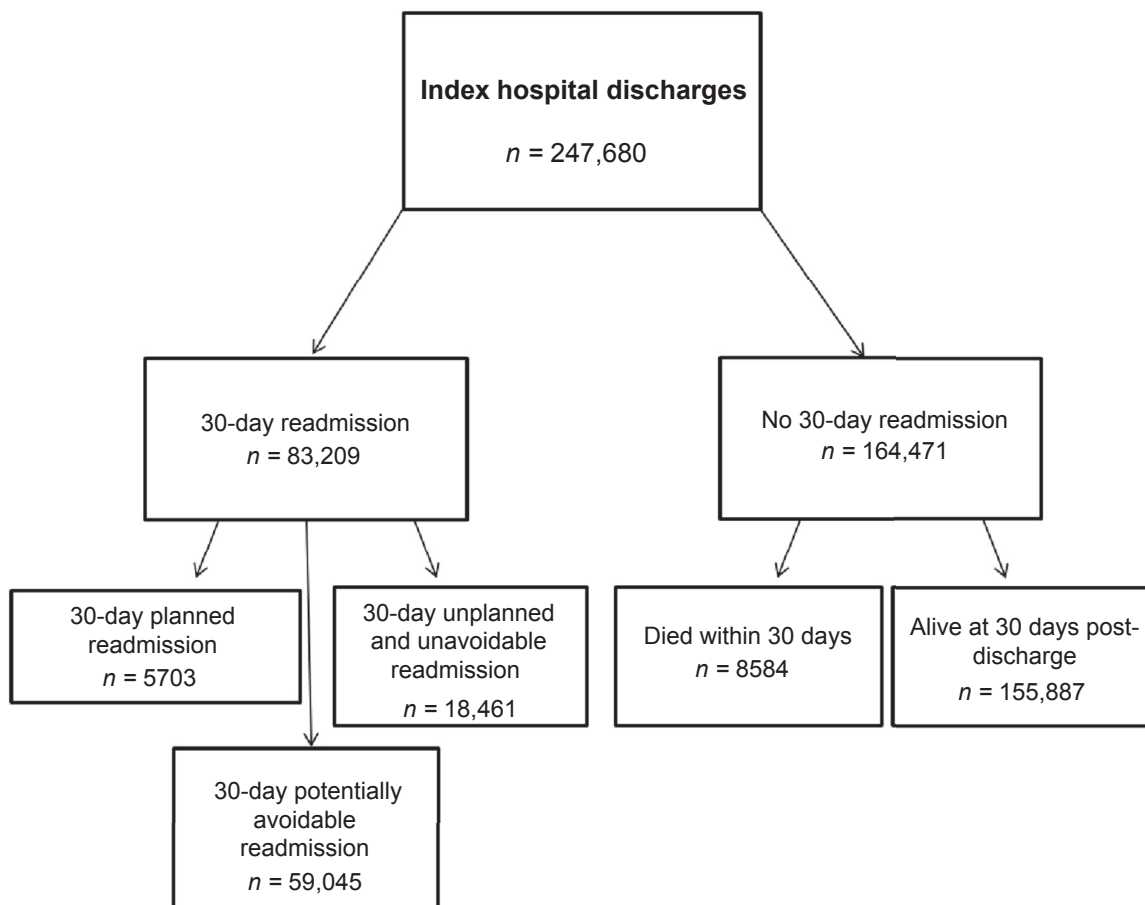


Figure 2. Index hospital discharge outcomes and frequencies.

Table 3. Most frequent causes of index hospitalizations resulting in potentially avoidable readmission^a

Index hospitalizations (<i>n</i>)	Five most frequent causes of index hospitalization resulting in a 30-d potentially avoidable readmission ^b	30-d potentially avoidable readmission rate, <i>n</i> (row %)	Five most frequent causes for potentially avoidable readmission ^b
36,032	Complication of device; implant or graft	8264 (22.9)	Complication of device; implant or graft
			Septicemia
			Hypertension with complications and secondary hypertension
			Congestive heart failure; nonhypertensive
			Complications of surgical procedures or medical care
19,072	Congestive heart failure; nonhypertensive	5290 (27.7)	Congestive heart failure; nonhypertensive
			Hypertension with complications and secondary hypertension
			Complication of device; implant or graft
			Fluid and electrolyte disorder
			Respiratory failure; insufficiency; arrest
15,824	Hypertension with complications and secondary hypertension	4018 (25.4)	Hypertension with complications and secondary hypertension
			Complication of device; implant or graft
			Congestive heart failure; nonhypertensive
			Fluid and electrolyte disorder
			Diabetes mellitus with complications
12,136	Diabetes mellitus with complications	3395 (28.0)	Diabetes mellitus with complications
			Complication of device; implant or graft
			Complications of surgical procedures or medical care
			Hypertension with complications and secondary hypertension
			Septicemia
12,472	Septicemia	3131 (25.1)	Septicemia
			Complication of device; implant or graft
			Congestive heart failure; nonhypertensive
			Hypertension with complications and secondary hypertension
			Diabetes mellitus with complications

^aIndex hospitalization causes listed are in order of decreasing total number of 30-day potentially avoidable readmission.

^bAs a percentage of index hospitalization, and identified by single-level Clinical Classification Software category as follows: Congestive Heart Failure: 108; Hypertension with Complications: 99; Fluid and Electrolyte Disorders: 55; Respiratory Failure, insufficiency or arrest: 131; Device Complications (Implant or Graft): 237; Septicemia: 2; Diabetes Mellitus with Complications: 50.

in a 30-day PAR, followed by congestive failure, and hypertension. The index hospital discharge cause with the highest 30-day PAR rate was diabetes mellitus with complications (28.0%), followed by congestive heart failure (27.7%). Causes of 30-day PAR are most commonly the same as reason for index hospital discharge; the most frequent 30-day PAR cause was identical to the corresponding index hospital discharge cause in all of our reported categories.

The geographic distribution of 30-day PAR varied by state, with percentages ranging from 12% to 31%, as a proportion of index hospital discharges (Figure 3). The highest 30-day PARs were in Nevada (30.6%), Washington, DC (28.3%), and Maryland (27.5%).

Multivariable 30-Day Potentially Avoidable Readmission

All baseline patient demographic characteristics were examined in unadjusted analysis, and the following were significantly associated with 30-day PAR ($P < 0.05$) and were included in the final multivariable model: age, length of stay, number of prior admissions,

HD vintage years, gender, race, ethnicity, ESKD primary cause, employment status, type of admission (surgical, medical with surgery, medical without surgery), dialysis facility, and comorbidity index. Geographic-level median income and index admission primary diagnosis were not significantly associated with 30-day PAR and therefore not included in the final multivariable model.

In adjusted analyses that controlled for patient comorbidities using a validated comorbidity index,³⁴ patient characteristics associated with increased odds of 30-day PAR included greater number of prior hospitalizations (odds ratio [OR] 1.40; 95% confidence interval [CI] 1.36–1.45 for >3 compared with none), black race (OR 1.06; 95% CI 1.03–1.08 compared with white race), unemployed status (OR 1.07; 95% CI 1.01–1.13 compared with employed/student), HD at a for-profit HD facility (OR 1.05; 95% CI 1.02–1.07 compared with nonprofit facility), and higher comorbidity index (OR 1.19; 95% CI 1.18–1.19 per 2-unit increase). Older age (OR 0.93; 95% CI 0.92–0.94 per 10-year age increase) and longer HD vintage (OR 0.77; 95% CI 0.75–0.80 for >3 years compared with <1 year) was associated with decreased risk of 30-day PAR (Table 4).

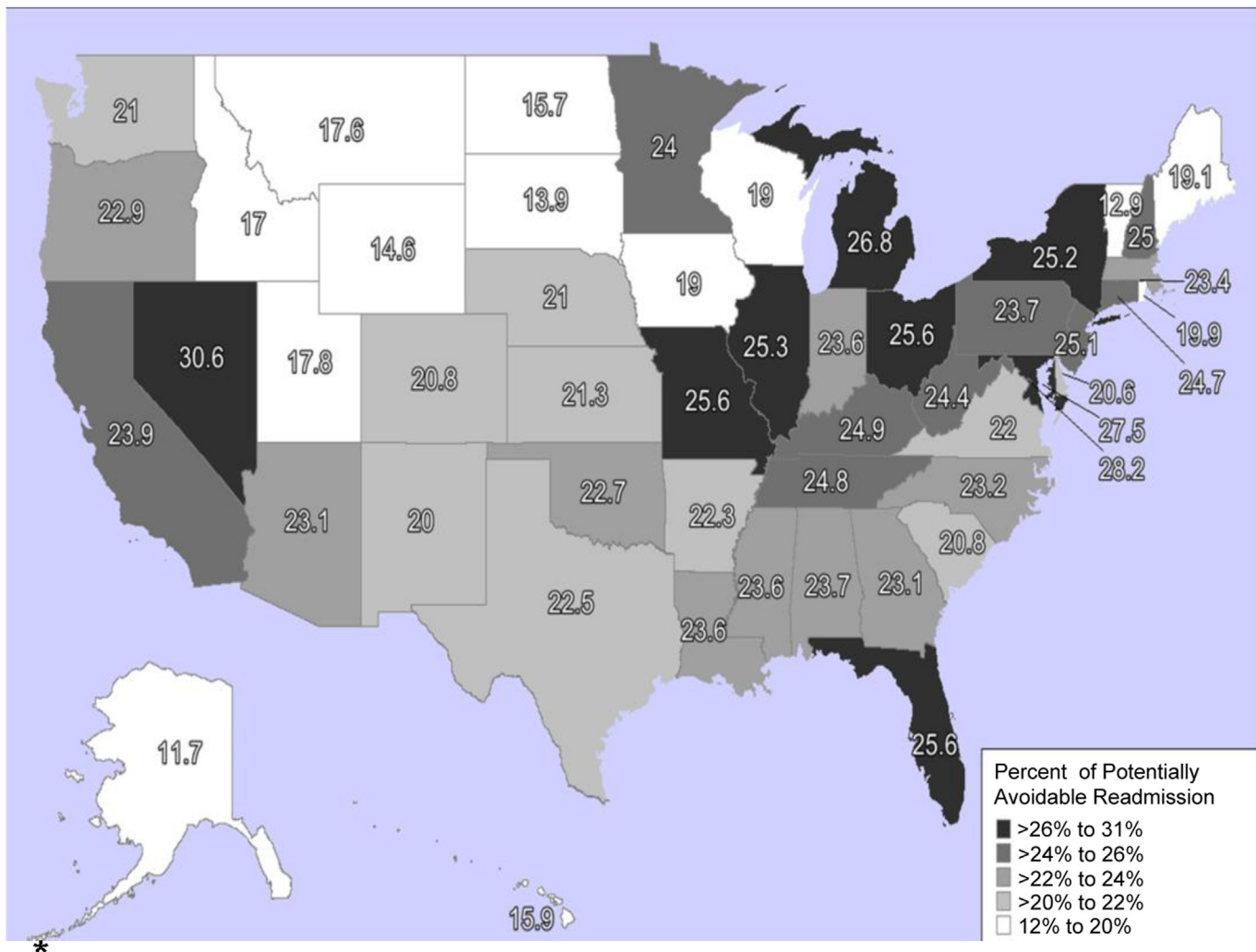


Figure 3. Geographic variation in 30-day potentially avoidable readmission. *Percentages of 30-day potentially avoidable readmission presented as proportion of index hospitalization. Reproduced with permission from Jonathan Amalfitano, Strategic Planning, Northwell Health, New Hyde Park, NY.

Index hospitalization characteristics associated with higher risk 30-day PAR included longer length of index hospital stay (OR 1.30; 95% CI 1.26–1.34 for >8 days compared with 0–4 days), and index hospitalizations that involved a surgical procedure. Compared with surgical index hospitalizations, medical index hospitalizations that did not involve surgery had a lower risk of 30-day PAR (OR 0.86; 95% CI 0.82–0.90) (Table 4). Additionally, medical admissions with a surgical procedure had greater odds of PAR as compared with medical admissions without a surgical procedure (OR 1.08, 95% CI 1.03–1.13).

To assess for unique risk factors for PAR, models were repeated using all readmission, all readmission + death and PAR + death as the main outcomes of interest (Supplementary Tables S1–S3). When comparing the original model with the “all readmission” model, findings were similar with the addition that geographic-level median income was now significant (OR 1.01; 95% CI 1.00–1.01; $P = 0.0110$) for every \$10,000 increase in income.

When comparing the original model to “all readmission + death,” findings were similar with the exception that age was no longer significant. When comparing the original model to PAR + death, findings are similar with the exception of increasing age associated with the increased risk of the composite outcome of PAR + death (OR 1.01; 95% CI 1.00–1.02; $P = 0.0110$). Finally, in our original analysis, surgical index admissions were associated with the highest risk of 30-day PAR. However, medical index admissions have the highest risk when death is included as a composite outcome with either the “all readmission” or “PAR” outcome.

Time to Potentially Avoidable Readmission

The cumulative incidence function was estimated with competing risks data. The 5-, 15-, and 30-day potentially avoidable readmission cumulative incidences were 6.0%, 15.1%, and 23.8%, respectively. Using standard survival analysis procedures (Kaplan-Meier product-limit method) the 5-, 15-, and 30-day failure

Table 4. Multivariable logistic regression model of association of potentially avoidable readmission association with patient and index hospitalization characteristics among prevalent patients with ESKD on hemodialysis in the United States

Characteristic	OR (95% CI)	P
Age, yr (unit = 10 yr)	0.93 (0.92–0.94)	<0.001
Length of stay of index hospitalization, d		
0–4	Ref	–
>4–8	1.12 (1.10–1.16)	<0.001
>8	1.30 (1.26–1.34)	<0.001
Number of prior admissions (12 months prior)		
None	Ref	–
1–3	1.03 (1.00–1.06)	0.02
>3	1.40 (1.36–1.45)	<0.001
Dialysis vintage, yr		
<1	Ref	–
1–3	0.84 (0.81–0.87)	<0.001
>3	0.77 (0.75–0.80)	<0.001
Gender		
Male	Ref	–
Female	1.03 (1.01–1.06)	0.003
Race		
White	Ref	–
Black	1.06 (1.03–1.08)	<0.001
Asian	1.07 (0.99–1.14)	0.05
Native American	0.88 (0.81–0.97)	0.01
Other	1.13 (0.98–1.31)	0.09
Unknown	1.12 (0.63–1.98)	0.70
Ethnicity		
Non-Hispanic	Ref	–
Hispanic	1.01 (0.97–1.04)	0.75
Unknown	0.84 (0.76–0.94)	0.0014
ESKD primary cause		
Glomerulonephritis/cystic kidney	Ref	–
Diabetes	0.99 (0.95–1.04)	0.81
Hypertension	1.05 (1.01–1.10)	0.01
Other	1.12 (1.07–1.18)	<0.001
Employment status		
Employed/Student	Ref	–
Homemaker	1.02 (0.95–1.10)	0.61
Retired – Disability/Medical LOA	0.98 (0.94–1.04)	0.67
Retired – Age	1.02 (0.96–1.08)	0.49
Unemployed	1.07 (1.01–1.13)	0.02
Unknown/Other	1.07 (0.98–1.17)	0.15
Type of index admission		
Surgical	Ref	–
Medical without surgery	0.85 (0.81–0.89)	<0.001
Medical with surgery	0.91 (0.89–0.94)	<0.001
Dialysis facility		
Nonprofit	Ref	–
Profit	1.05 (1.02–1.07)	0.0013
Unknown	0.99 (0.95–1.05)	0.85
Comorbidity Index (unit = 2)		
	1.19 (1.18–1.19)	<0.001

CI, confidence interval; ESKD, end-stage kidney disease; LOA, leave of absence; OR, odds ratio.

estimates of potentially avoidable readmission were 6.1%, 15.9%, and 25.8%, respectively. It is possible that the different methods yield similar results due to the relatively small number of deaths (3.5%), unplanned readmissions (7.5%), and planned readmissions (2.3%), representing only 13.2% of the total

index hospitalizations. The instantaneous hazard rate for potentially avoidable readmission varied with length of time from index hospital discharge. The estimated hazard rate increased for approximately the first week postdischarge then decreased until day 25 with a subsequent recurrent increase (Figure 4).

DISCUSSION

Using data from a national longitudinal database of US HD patients, this study explored the frequency, causes, predictors, and time to potentially avoidable readmission to hospital within 30 days of an index hospital discharge in patients with ESKD receiving HD treatment. Nearly three-quarters (70.1%) of all 30-day readmissions may have been potentially avoidable. Geographic frequency of 30-day PAR varied by state. The most common medical index hospital discharge condition that resulted in a 30-day PAR was heart failure. The most common surgical index hospital discharge condition that resulted in a 30-day PAR was a vascular procedure. In adjusted analysis, characteristics associated with higher 30-day PAR included younger age, shorter HD vintage, greater number of prior hospitalizations, black race, unemployed status, HD treatment at a for-profit center, and longer length of index hospital stay. Increasing age was associated with PAR + death, suggesting that older patients are more likely to die and younger patients are more likely to be readmitted for PAR. The estimated hazard rate for potentially avoidable readmission varied from day 0 to day 30 postdischarge.

Observational studies have described risk factors for readmission to hospital in patients with ESKD, including anemia,^{37,38} low serum albumin,^{37,39} and comorbid conditions, such as cerebrovascular accident, peripheral vascular disease, and depression.⁴⁰ Given the observational study designs and variable definitions of readmission, comparison across studies is

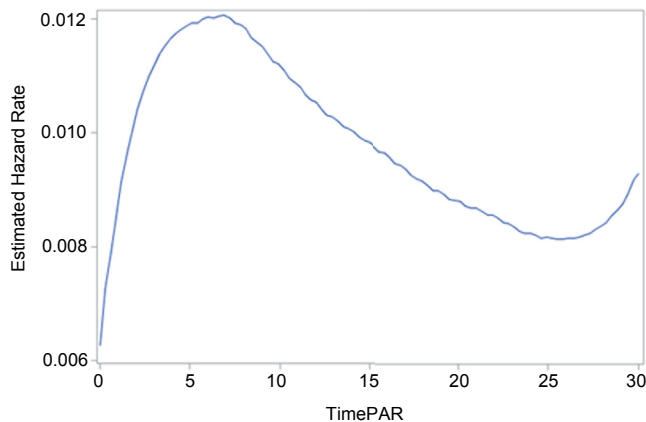


Figure 4. Hazard function for potentially avoidable readmission.

limited. A recent study by Harel *et al.*⁴¹ using administrative data from Ontario, Canada, reported 17% of in-center HD patients were readmitted, 27% visited the emergency department, and 7.5% died with 30 days of an index hospital discharge. Although this study extends the understanding of postdischarge resource utilization and patient outcomes to include emergency room visits, comparison with the current US in-center HD population is limited. The proportion of patients with 30-day readmission is substantially lower than observed in the United States since theUSRDS reports a 35.2% all-cause 30-day readmission risk.⁵ Harel *et al.*⁴¹ proposed several reasons for this observed difference in 30-day readmission risk between Canada and the United States, including variations in HD care provision, reimbursement policies, and HD unit location in hospitals versus free-standing units. Prospective studies are required to test these hypotheses in controlled trials. Another recent study by Flythe *et al.*⁴² assessed risk factors for 30-day readmission to hospital, and excluded scheduled readmissions for vascular access or other planned procedures (as determined by admission history and physical review). Unlike our study, Flythe *et al.*⁴² did not distinguish “unplanned but unavoidable” readmissions from potentially avoidable readmissions. Of 349 included patients, 32.1% had a 30-day readmission. Similar to our study, comorbid illness and greater number of hospitalizations in the prior 12 months were associated with 30-day readmission. Prescription medication changes (from higher to lower number at index hospital discharge), and weekend discharge day were identified by Flythe *et al.*⁴² as associated with 30-day readmissions, as possibly actionable risk factors for 30-day readmission. Unlike Flythe *et al.*,⁴² we identified several patient-related risk factors, including younger age, female gender, black race, and shorter dialysis vintage, which were not identified by those authors. These characteristics may be associated with patients who are particularly ill and/or disadvantaged and thus prone to potentially avoidable 30-day readmission. Although the computerized algorithm we used cannot perfectly distinguish avoidable from unavoidable readmissions, we created a cohort enriched with avoidable readmissions to better identify risk factors for potentially avoidable readmission in HD patients than would otherwise be possible. A future full validation study in HD patients should be performed, given that our results identify a potentially important performance gap.

Previous studies have described associations between interventions and lower risk of hospital readmission in HD patients. Chan *et al.*²⁴ reported that hemoglobin monitoring, erythropoietin dose adjustments, and

vitamin D administration after hospital discharge were associated with a 15% lower risk of readmission than others. Erickson *et al.*²⁵ reported a 3.5% reduction in the probability of readmission with one additional nephrologist provider visit in the month following a hospital discharge. These observational study results suggest that higher intensity of outpatient care in the period following a hospital discharge could reduce the risk of a subsequent readmission. However, the components of such a targeted intervention require characterization and study through prospective controlled trials.

The lack of evidence-based strategies to reduce readmission risk in HD patients is disquieting, in light of the Standardized Readmission Ratio component of the End-Stage Renal Disease Quality Incentive Program.⁴³ This program is a “pay-for-performance” program administered by the Centers for Medicare and Medicaid Services. Beginning in payment year 2017, a high Standardized Readmission Ratio rate could contribute to a total performance score that causes payment reductions to HD facilities. In other high-risk populations, such as skilled nursing facility residents, pay-for-performance readmission quality measures attempt to include only potentially avoidable readmissions¹⁶ to reduce the misaligned incentives to defer hospitalization of a skilled nursing facility resident for elective or beneficial care.

Our results provide the groundwork for several avenues of future research aimed at reducing avoidable readmissions in HD patients. First, we demonstrate a substantial difference in risk between readmissions considered potentially avoidable and those that were unplanned and also unavoidable. We show that the estimated hazard rate of 30-day PAR varies with a late rise at 25 days post hospital discharge, suggesting that the postdischarge 30-day window conventionally used to identify readmissions may be inappropriately short. Thus, research is required to develop a standardized measure of avoidable readmission tailored to HD patients with the appropriate time span after hospital discharge. This will facilitate comparison of results across research studies and provide a meaningful target for improvement through prospective interventional studies. Second, our study identifies several factors associated with increased risk of 30-day PAR in HD patients that can be used in subsequent patient-level studies for the derivation and validation of a clinical prediction model. This would benefit clinicians and policy makers by focusing intensive postdischarge care on patients at highest risk of readmission, and facilitate researchers in enrolling HD patients at highest risk into clinical trials testing interventions to reduce readmission risk. Third, our reported baseline risk

estimates of potentially avoidable readmission can be used in sample size calculations for future randomized controlled trials. Finally, the wide geographic variation we report across the United States implies that improvement in potentially avoidable readmission risk may be possible; however, more detailed study is required to elucidate the processes and practices which effectively reduce potentially avoidable readmissions that are nationally or regionally transferrable.

In this study, the outcome of 30-day PAR was determined using a computer algorithm for administrative data validated in a general medicine population. There are several reasons that rationalize the use of this algorithm in the HD population, including the following: (i) the proportion of potentially avoidable readmission we report is similar to studies of other patient populations. A MedPac report using 3M classification software identified 76% of all 30-day readmissions as potentially preventable from 2005 Medicare discharge claims data.⁴⁴ A single-center study of acute general medical hospitalizations deemed 71% of readmissions potentially avoidable.¹⁵ Finally, a recent systematic review of potentially avoidable readmissions found 8 studies with more than 50% of readmissions classified as potentially avoidable.¹⁰ (ii) Our analysis identifies several predictors of potentially avoidable readmission which are consistent with the algorithm developed by Halfon *et al.*,¹⁹ including previous hospitalizations, high comorbidity index, and long length of stay. (iii) Although this algorithm was originally derived and validated in Switzerland, it has been used with good to excellent discriminatory power and calibration in US general medical populations,²⁰ and in US populations with comorbid disease, including cancer⁴⁵ and chronic kidney disease.⁴⁶

Our study should be qualified by several potential limitations. (i) We underestimated the proportion of planned 30-day readmissions, as hospital discharges for rehabilitation, psychiatric reasons, cancer treatments, and renal transplants were excluded. Our study observed that 6.8% of all 30-day readmissions were planned, compared with approximately 10% in the general medicine population.⁶ (ii) Exclusion of these planned hospital stays slightly reduced the number of denominator index hospital discharges and thus modestly increased the reported proportion of 30-day PAR. Exclusion of these hospital discharges was an intentional component of our study design to limit the index cohort to acute hospitalizations of patients who were in a more homogeneous “at-risk” set for potentially avoidable readmission upon discharge. (iii) Data from 2008 were used for this analysis, and some trends in ESKD care may not reflect current practice. However, all-cause 30-day readmission risk has

remained relatively fixed since 2008, ranging from 35.2% to 36.3% as indicated in annual USRDS data reports,^{5,47,48} lending validity to our results in the present day. (iv) We are limited by the use of a national database, where medical evidence forms and claims-based data may have misclassified variables for medical conditions and encounters. In particular, the 2728 Medical Evidence report has very good to excellent specificity, but comorbid conditions are under-reported.⁴⁹ Given our use of administrative data, we did not have access to laboratory values and medication utilization, which would augment the risk predictors identified in this study.

ESKD patients on maintenance HD are at high risk for 30-day readmission, and a large proportion of these readmissions may have been prevented with optimized transitional care. The ESKD patient’s requisite follow-up in the outpatient HD unit provides a unique opportunity to streamline and facilitate hospital discharge processes and coordinate outpatient care. Given the high financial costs to health systems and emotional and societal costs to patients and their caregivers, future research should focus on developing and testing cost-effective interventions to reduce this high risk of readmission and improve patient outcomes.

DISCLOSURE

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in no way should be seen as an official policy or interpretation of the US government.

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SUPPLEMENTARY MATERIAL

Table S1. Multivariable logistic regression model of association of all readmission association with patient and index hospitalization characteristics among prevalent patients with end-stage renal disease on hemodialysis in the United States.

Table S2. Multivariable logistic regression model of association of all readmission + death association with patient and index hospitalization characteristics among prevalent patients with end-stage renal disease on hemodialysis in the United States.

Table S3. Multivariable logistic regression model of association of potentially avoidable readmission + death association with patient and index hospitalization characteristics among prevalent patients with end-stage renal disease on hemodialysis in the United States.

Supplementary material is linked to the online version of the paper at www.kireports.org.

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