Prior Hospitalization Burden and the Relatedness of 30-Day Readmissions in Patients Receiving Hemodialysis

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ABSTRACT

Background Thirty-day readmissions are common in patients receiving hemodialysis and costly to Medicare. Because patients on hemodialysis have a high background hospitalization rate, 30-day readmissions might be less likely related to the index hospitalization than in patients with other conditions.

Methods In adults with Medicare receiving hemodialysis in the United States, we used multinomial logistic regression to evaluate whether prior hospitalization burden was associated with increased 30-day readmissions unrelated to index hospitalizations with a discharge date from January 1, 2013 to December 31, 2014. We categorized a hospitalization, 30-day readmission pair as "related" if the principal diagnoses came from the same organ system.

Results The adjusted probability of unrelated 30-day readmission after any index hospitalization was 19.1% (95% confidence interval [95% CI] 18.9% to 19.3%), 22.6% (95% CI, 22.4% to 22.8%), and 31.2% (95% CI, 30.8% to 31.5%) in patients with 0–1, 2–4, and ≥5 hospitalizations, respectively. Cardiovascular index hospitalizations had the highest adjusted probability of related 30-day readmission: 10.4% (95% CI, 10.2% to 10.7%), 13.6% (95% CI, 13.4% to 13.9%), and 20.8% (95% CI, 20.2% to 21.4%), respectively. Renal index hospitalizations had the lowest adjusted probability of related 30-day readmission: 2.0% (95% CI, 1.8% to 2.3%), 3.9% (95% CI, 3.4% to 4.4%), and 5.1% (95% CI, 4.3% to 5.9%), respectively.

Conclusions High prior hospitalization burden increases the likelihood that patients receiving hemodialysis experience a 30-day readmission unrelated to the index hospitalization. Health care payers such as Medicare should consider incorporating clinical relatedness into 30-day readmission quality measures.

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Patients receiving hemodialysis shoulder a high 30-day readmission burden, with 35% of hospital discharges followed by a readmission within 30 days.[1] When avoidable, 30-day readmissions in patients receiving hemodialysis are failures that account for up to $1.3 billion of Medicare spending annually.[2]

Policy makers and clinicians have widely recognized 30-day readmissions as a marker of health care quality. The Centers for Medicare and Medicaid Services (CMS) has prioritized reducing 30-day

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readmissions through value-based purchasing initiatives such as the Readmissions Reduction Program,[3] publishing 30-day readmission rates on the Dialysis Facility Compare website[4] and adopting the Standardized Readmission Ratio (a National Quality Forum endorsed, risk-adjusted metric) in the ESRD Quality Incentive Program.[5]

These policies assume that providers can reasonably reduce 30-day readmissions by providing high-quality care. However, patients with a high background hospitalization rate, such as those receiving hemodialysis, might experience 30-day readmissions that are more likely due to underlying disease burden and less likely due to health care quality. All-cause 30-day readmissions may not be appropriate as a metric if a large proportion of readmissions is unrelated to index hospitalizations.

Although prior studies have identified major causes for 30-day readmission in patients undergoing hemodialysis,[1,6–8] few have assessed the "relatedness" between the index hospitalization and 30-day readmission. One study suggested in this population that the principal diagnoses of the index hospitalization and 30-day readmission were often discordant,[6] and none have investigated the association between background hospitalization rate and the relatedness of 30-day readmissions and index hospitalizations.

We investigated whether prior hospitalization burden was associated with 30-day readmissions unrelated to the index hospitalization in patients receiving hemodialysis. We defined relatedness between index hospitalizations and 30-day readmissions as having principal diagnoses in the same organ system.

Significance Statement

Patients receiving hemodialysis have a high 30-day readmission rate after hospitalization, and Medicare financially penalizes providers with rates that are higher than expected. However, quality measures currently do not account for whether 30-day readmissions are indeed related to the cause for the index hospitalization. This study demonstrates that Medicare patients receiving hemodialysis are significantly more likely to experience an unrelated 30-day readmission if they have a high baseline hospitalization rate, which itself is associated with having more comorbidities and Medicaid status. A related 30-day readmission is most likely to follow cardiac index hospitalizations and least likely to follow renal index hospitalizations. The authors suggest that Medicare consider incorporating prior hospitalization burden and clinical relatedness to improve the clinical meaningfulness of its 30-day readmission quality metrics.

METHODS

Population and Data Sources

Our primary data source was the US Renal Data System (USRDS),[9] a data registry that houses Medicare claims data on all patients with ESRD and Medicare Parts A and B in the United States (Supplemental Appendix 1). We linked patient zip codes to information about population density and local sociodemographics using the 2010 Census and 2012 American Community Survey.[10]

For adults receiving hemodialysis in the United States, we isolated inpatient hospitalizations by taking inpatient claims with a discharge date from January 1, 2013 to December 1, 2014 and grouping transfers using a previously defined algorithm.[2] The primary unit of analysis was index hospitalizations, and patients could contribute multiple hospitalizations. We limited our analysis to patients receiving hemodialysis because hospitalizations for patients on peritoneal dialysis are substantially different. To ensure capture of comorbidities, we required that patients have Medicare Parts A and B as their primary payer at least 365 days before the hospitalization. This restriction excluded incident patients receiving hemodialysis who did not have Medicare before initiating dialysis. We chose to exclude these patients because prior studies have indicated that the Medical Evidence Form has incomplete capture of comorbidities.[11] We still included incident patients who had Medicare for at least 365 days before the index hospitalization.

We excluded hospitalizations where the patient did not have 30 days of follow-up (died or lost Medicare coverage) or did not have dialysis treatment data, a Medical Evidence Form, or an associated dialysis facility. We excluded hospitalizations that CMS routinely excludes from its 30-day readmission programs: hospitalizations with a principal diagnosis of cancer, psychiatric illness, or rehabilitation for prosthesis; hospitalizations when the patient left against medical advice; and hospitalizations followed by a planned readmission (see Supplemental Appendix 1).[12]

Study Exposure

We had two primary exposures: (*1*) the number of hospitalizations (including 30-day readmissions) experienced by the patient in the 365 days before the index hospitalization, and (*2*) the organ system of the principal diagnosis for each index hospitalization. We mapped principal diagnosis codes to organ systems, using the Agency for Healthcare Research and Quality's (AHRQ) Clinical Classification Software (CCS).[13] We consolidated organ systems into an "other" category if they did not have a sufficient number of observations to analyze separately (see Supplemental Appendix 1). We modeled both exposures as categorical covariates and incorporated interaction terms between them.

Study Outcomes

Our primary outcomes were whether an index hospitalization was followed by a 30-day readmission related to the index hospitalization, a 30-day readmission unrelated to the index hospitalization, or no 30-day readmission. Readmissions were also included as index hospitalizations as long as they met our inclusion criteria and *vice versa*.

Assessing the relatedness between index hospitalizations and 30-day readmissions is challenging. Prior studies have either used retrospective chart review[14] or used a proxy for relatedness such as concordance between the principal diagnoses of the index hospitalization and 30-day readmission.[6] Although the latter strategy cannot definitively determine *clinical* relatedness, it has the advantage of being objective and scalable. In this study, if the organ systems of the principal diagnoses were identical between index hospitalization and 30-day readmission, we defined the pair as related. For index hospitalizations grouped in the "other" category, we used the originally mapped CCS organ system to determine relatedness.

Covariates

We controlled for patient demographics, Medicaid status, prior kidney transplant, total time with ESRD, dialysis vintage (time for the current course of hemodialysis), type of vascular access used for hemodialysis, comorbidities, dialysis facility characteristics, season and year, index hospitalization length of stay, whether the index hospitalization was "high risk," and local sociodemographics of the patient's dialysis facility's zip code (full list of covariates in Supplemental Appendix 2, Table B1).

To isolate comorbidities, we identified all diagnosis codes in Medicare claims 365 days before the index hospitalization and mapped them to CMS' Hierarchical Condition Categories.[15,16] We also applied AHRQ's Elixhauser Comorbidity Software to generate a comorbidity index score for 30-day readmissions, a metric that can be thought of as a patient's overall sickness.[17] We defined high-risk index hospitalizations as those for HIV, hepatitis and other liver diseases, cystic fibrosis, immunity disorders, sickle cell anemia, SLE and connective tissue disorders, and poisoning by nonmedicinal substances. This concurred with CMS' definition of high-risk hospitalizations in 30-day readmission measures for patients receiving hemodialysis (see Supplemental Appendix 1).[4]

We converted all continuous variables into categorical variables by first examining the distribution of patients at logical breakpoints (*e.g.*, age decades, dialysis vintage at half year and yearly intervals, *etc.*). When there were an insufficient number of index hospitalizations binned in each category, we combined categories. We performed a complete case analysis because only a small fraction of our population had missing data in census demographics (0.9%) or vascular access (1.9%).

Statistical Analyses

We produced descriptive statistics at an index hospitalization level and plotted the unadjusted proportion of hospitalizations leading to related or unrelated 30-day readmissions. Because we had a large sample size, even small differences in patient, facility, and hospitalization characteristics were statistically significant. Therefore, instead of computing *P* values, we calculated standardized mean differences (Supplemental Appendix 2, Table B2).[18] To adjust for covariates, we used multinomial logistic regression to model the probabilities of related and unrelated 30-day readmissions as functions of the exposures (prior hospitalization burden and type of index hospitalization) and potential confounders. To do this, we estimated two independent logit models with the base outcome set to "no 30-day readmission" and the comparison outcomes related and unrelated 30-day readmissions. The model assumes that the exposures and confounders varied linearly with the log of the ratio of probabilities between the comparison outcomes and the base outcome.

From these regression estimates, we estimated the predicted probability of each outcome as a function of prior hospitalization burden and organ system (see Supplemental Appendix 1). Specifically, for each index hospitalization, we estimated the predicted probabilities of related and unrelated 30-day readmissions under the following counterfactual scenarios: (*1*) 0–1 prior hospitalizations, (*2*) 2–4 prior hospitalizations, or (*3*) ≥5 prior hospitalizations. For each organ system, we used these counterfactual predicted probabilities to estimate the proportional increase in related and unrelated 30-day readmissions as the number of prior hospitalizations increased. We also estimated the average relative change in the proportion of 30-day readmissions related to the index hospitalization as the number of prior hospitalizations increased. Of note, these relative changes are not identical to the relative risk ratios routinely estimated by standard statistical software for multinomial logistic regression models. Therefore, we used a nonparametric bootstrap clustered at the patient level (250 samples) to estimate 95% confidence intervals (95% CIs) for these proportional changes.

Subgroup Analyses

In descriptive analyses, we observed that patients with more prior hospitalizations tended to be younger and nonwhite. We therefore performed subgroup analyses stratified by age (18–54, 55–64, 65–74, and ≥75 years old) and race (white and black). Patients who were Asian and Native American formed a small portion of our population, so we were unable to reliably produce separate estimates in these subgroups.

Sensitivity Analyses

We performed four sensitivity analyses to test the robustness of our results to changes in model specification. First, we included death within 30 days as a competing risk by modeling it as an additional outcome in our multinomial logistic regression. Second, we tested the effect of using a more stringent definition of relatedness. Instead of mapping principal diagnosis codes to organ systems, we used the CCS to map the diagnosis codes to condition categories, which define clinically homogeneous conditions. We considered an index hospitalization and 30-day readmission pair related if the condition categories were concordant. Third, we used continuous variables rather than converting continuous variables to categorical ones. Finally, we included interaction terms between key variables (age, sex, race, Medicaid status, time with ESRD, dialysis vintage, dialysis access, and Elixhauser readmission score) (see Supplemental Appendix 1 for full details).

RESULTS

Of 1,088,214 candidate hospitalizations in the USRDS database, we isolated 677,868 index hospitalizations from 231,330 patients that met our inclusion criteria (Supplemental Appendix 2, Figure B1).

Table 1. Index hospitalization characteristics, stratified by number of hospitalizations in the prior 365 days

Characteristic	Number of Hospitalizations in the Past 365 d					
	0–1 (*n*=283,231)		2–4 (*n*=229,844)		≥5 (*n*=138,311)	
	N or Mean[a]	% or SD	*N* or Mean	% or SD	*N* or Mean	% or SD
Age at index discharge, yr[b]	65.8	14.1	64.1	14.2	57.6	15.3
Sex						
Women	133,648	47.2%	116,556	50.7%	72,792	52.6%
Men	149,583	52.8%	113,288	49.3%	65,519	47.4%
Race						
Native American	3523	1.2%	2770	1.2%	1644	1.2%
Asian	10,978	3.9%	7292	3.2%	3176	2.3%
Black	98,408	34.7%	87,857	38.2%	63,303	45.8%
White	169,880	60.0%	131,572	57.2%	69,968	50.6%
Other	442	0.2%	353	0.2%	220	0.2%
Hispanic	39,941	14.1%	33,023	14.4%	19,191	13.9%
Medicaid at index discharge	130,135	45.9%	122,586	53.3%	92,061	66.6%
Prior transplant	18,198	6.4%	15,590	6.8%	10,404	7.5%
Total time with ESRD, yr[b]	4.6	5.1	5.2	4.9	5.4	4.6
Dialysis vintage, yr[b]	2.6	2.6	3.0	2.4	3.0	2.1
Dialysis access at index discharge						
Dialysis catheter	88,154	31.1%	59,177	25.7%	37,457	27.1%
AVF	145,008	51.2%	121,170	52.7%	68,870	49.8%
AVG	50,069	17.7%	49,497	21.5%	31,984	23.1%
Elixhauser: readmission score[b]	50	24	73	18	89	20
Length of stay, d[b]	6.3	8.4	5.9	5.7	5.7	5.7
High-risk index hospitalizations (by principal diagnosis)						
HIV infection	388	0.1%	393	0.2%	437	0.3%
Hepatitis	226	0.1%	359	0.2%	580	0.4%
Other liver diseases	1234	0.4%	1541	0.7%	1642	1.2%
SLE and connective tissue disorders	204	0.1%	183	0.1%	198	0.1%
Facility characteristics						
Large dialysis organization	203,113	71.7%	164,553	71.6%	99,561	72.0%
Dialysis facility, for profit	247,787	87.5%	201,909	87.8%	121,546	87.9%
Dialysis facility, hospital-based	13,200	4.7%	9974	4.3%	6017	4.4%
Patient: RN >7	126,500	44.7%	104,263	45.4%	63,843	46.2%
No. of patients at facility						
0–50	51,096	18.0%	39,052	17.0%	21,050	15.2%
>50–100	117,223	41.4%	95,412	41.5%	57,311	41.4%
>100–150	72,796	25.7%	60,331	26.2%	37,456	27.1%
>150	42,116	14.9%	35,049	15.2%	22,494	16.3%
Population in zip code[b]	31,390	17,008	31,815	17,221	32,441	17,281
Median household income in zip code[b]	$50,429	$19,931	$50,174	$19,944	$49,351	$19,517
Median household rent in zip code[b]	$891	$286	$896	$283	$901	$274
% Below poverty line in zip code[b]	18%	10%	18%	10%	19%	10%
% Unemployed in zip code[b]	10%	5%	11%	5%	11%	5%
% Less than high school education in zip code[b]	16%	10%	16%	10%	17%	10%
Urban zip code	253,086	89.4%	208,889	90.9%	129,150	93.4%

This table has been truncated for readability. See Supplemental Appendix 2, Table B1 for the full table. See Supplemental Appendix 2, Table B2 for standardized mean differences. AVF, arteriovenous fistula; AVG, arteriovenous graft; RN, registered nurse.

[a]For categorical variables, we show the number (*N*) and column percentage. For continuous variables, we show the mean and SD.

[b]Continuous variable. Although we show continuous summary statistics here, our primary model converted all continuous variables into categorical variables (Supplemental Appendix 2, Table B1 shows the break points).

A substantial proportion of index hospitalizations (21%) came from patients with at least five hospitalizations in the prior year. In general, younger patients, women, black patients, patients with Medicaid, patients with longer dialysis vintage and total ESRD time, patients using arteriovenous grafts, patients with more comorbidities, and patients receiving dialysis in urban zip codes had higher prior hospitalization burden (Supplemental Appendix 2, Tables B1 and B2, and Table 1).

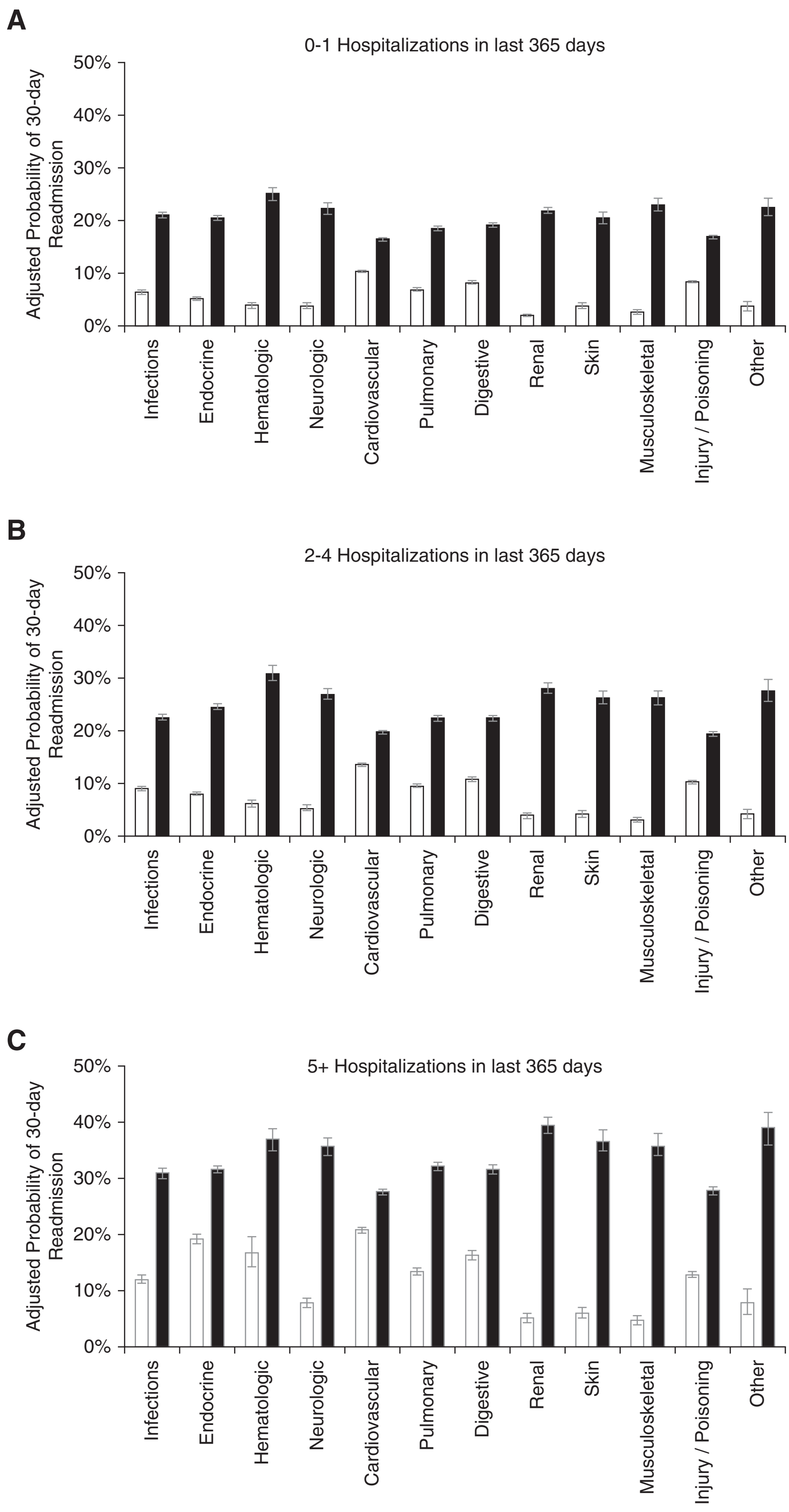

Figure 1. High proportion of index hospitalizations followed by an unrelated 30-day readmission, by organ system. We depict the predicted probability of related 30-day readmissions in white patients and unrelated readmissions in black patients. We stratify by number of hospitalizations in the prior 365 days: (A) 0–1, (B) 2–4, and (C) ≥5. Predicted probabilities were adjusted for patient, facility, geographic, seasonal, and hospital characteristics. 95% CIs were computed using nonparametric, bootstrap clustered at the patient level.

General Characteristics of Index Hospitalizations and Readmissions

Cardiovascular causes of hospitalization were most common, followed by injury and poisonings, pulmonary, and endocrine causes (Supplemental Appendix 2, Table B3). When subdividing patients by the number of hospitalizations in the prior year (0–1, 2–4, and ≥5), cardiovascular hospitalizations remained the most common. The unadjusted proportion of index hospitalizations followed by any 30-day readmission was 22.7% for patients with 0–1 hospitalizations in the prior year, 31.6% for those with 2–4 hospitalizations, and 50.5% for those with ≥5 hospitalizations (Supplemental Appendix 2, Figure B2). After controlling for confounders, the predicted probability of index hospitalizations followed by a 30-day readmission was 26.4% (95% CI, 26.2% to 26.7%), 32.3% (95% CI, 32.1% to 32.6%), and 46.2% (95% CI, 45.7% to 46.6%), respectively. We show the most common 30-day readmission diagnoses by organ system in Supplemental Appendix 2, Tables B4–B14.

Unrelated 30-Day Readmissions

In unadjusted analysis, unrelated 30-day readmissions occurred after 16.2%, 22.2%, and 34.3% of index hospitalizations for patients with 0–1 hospitalizations, 2–4 hospitalizations, and ≥5 hospitalizations in the prior year, respectively (Supplemental Appendix 2, Figure B2). When adjusting for confounders, the predicted probability of an unrelated 30-day readmission was 19.1% (95% CI, 18.9% to 19.3%), 22.6% (95% CI, 22.4% to 22.8%), and 31.2% (95% CI, 30.8% to 31.5%), respectively (Figure 1). For all organ systems, unrelated 30-day readmissions were more common than related 30-day readmissions. Cardiovascular and injury/poisoning index hospitalizations were the least likely to have an unrelated 30-day readmission in the entire population (cardiovascular: 19.1% unadjusted, 20.2% [95% CI, 20.0 to 20.4%] adjusted; and injury/poisoning: 19.7% unadjusted, 20.4% [95% CI, 20.2% to 20.7%] adjusted). On the other hand, hematologic and renal index hospitalizations were the most likely to have an unrelated 30-day readmission (hematologic: 29.3% unadjusted, 29.7% [95% CI, 28.9% to 30.5%] adjusted; and renal: 24.2% unadjusted, 28.1% [95% CI, 27.5% to 28.8%] adjusted).

As the number of hospitalizations in the prior 365 days increased, the likelihood of an unrelated 30-day readmission also increased. Relative to patients with 0–1 prior hospitalizations, index hospitalizations for patients with 2–4 and ≥5 prior hospitalizations were 1.19 (95% CI, 1.18 to 1.21) and 1.67 (95% CI, 1.64 to 1.70) times more likely to be followed by an unrelated 30-day readmission respectively (Figure 2). Index hospitalizations for renal causes had the highest relative increase in probability of unrelated 30-day readmissions (1.29; 95% CI, 1.23 to 1.35; and 1.84; 95% CI, 1.76 to 1.93, respectively), whereas index hospitalizations for infections had the lowest relative increase (1.07; 95% CI, 1.03 to 1.10; and 1.49; 95% CI, 1.42 to 1.55, respectively).

Related 30-Day Readmissions

Conversely, related 30-day readmissions remained comparatively low, and the likelihood of a related 30-day readmission was lower than the likelihood of an unrelated 30-day readmission for all categories of index hospitalizations (Figure 1). The probability of a related 30-day readmission was 6.5%, 9.4%, and 16.2% unadjusted in patients with 0–1, 2–4, and ≥5 hospitalizations in the prior 365 days, respectively, and 7.3% (95% CI, 7.2% to 7.5%), 9.7% (95% CI, 9.6% to 9.9%), and 15.0% (95% CI, 14.7% to 15.2%) when adjusting for confounders. Cardiovascular index hospitalizations had the highest adjusted probability of a related 30-day readmission: 10.4% (95% CI, 10.2% to 10.7%), 13.6% (95% CI, 13.4% to 13.9%), and 20.8% (95% CI, 20.2% to 21.4%), respectively. In contrast, renal index hospitalizations had the lowest adjusted probability of a related 30-day readmission: 2.0% (95% CI, 1.8% to 2.3%), 3.9% (95% CI, 3.4% to 4.4%), and 5.1% (95% CI, 4.3% to 5.9%), respectively.

We also examined the change in proportion of readmissions related to the index hospitalization. Index hospitalizations in patients with 2–4 and ≥5 prior hospitalizations (compared with patients with 0–1 prior hospitalizations) had a significant relative increase in proportion of 30-day readmissions that were related: 1.08 (95% CI, 1.06 to 1.11) and 1.15 (95% CI, 1.12 to 1.18) times, respectively (Figure 3). With the exception of endocrine, hematologic, and renal index hospitalizations, the relative change in the proportion of 30-day readmissions related to the index hospitalization was <1.3 for all organ systems.

Subgroup Analyses

We performed subgroup analyses because patients who were younger and black were more likely to have higher numbers of hospitalizations in the prior 365 days. None of our findings materially changed in each of the subgroups. The relative increase in unrelated readmissions for patients with 2–4 and ≥5 prior hospitalizations relative to patients with 0–1 prior hospitalizations appeared more pronounced in younger patients (Figure 4). For instance, white patients aged 18–54 years old had a relative risk of 1.27 (95% CI, 1.22 to 1.32) and 1.91 (95% CI, 1.84 to 2.01), respectively, whereas white patients aged ≥75 years had a relative risk of 1.13 (95% CI, 1.09 to 1.16) and 1.49 (95% CI, 1.43 to 1.46), respectively. Similarly, black patients aged 18–54 years old had a relative risk of 1.29 (95% CI, 1.24 to 1.36) and 2.02 (95% CI, 1.92 to 2.13), respectively, whereas black patients aged ≥75 years had a relative risk of 1.14 (95% CI, 1.08 to 1.19) and 1.40 (95% CI, 1.31 to 1.51), respectively.

When assessing the change in the proportion of readmissions related to the index hospitalization, the relative change remained <1.3 for all subgroups (Figure 5). Black patients aged 18–54 years old with ≥5 prior hospitalizations had the highest relative increase of 1.22 (95% CI, 1.14 to 1.30) when compared with those with 0–1 prior hospitalizations.

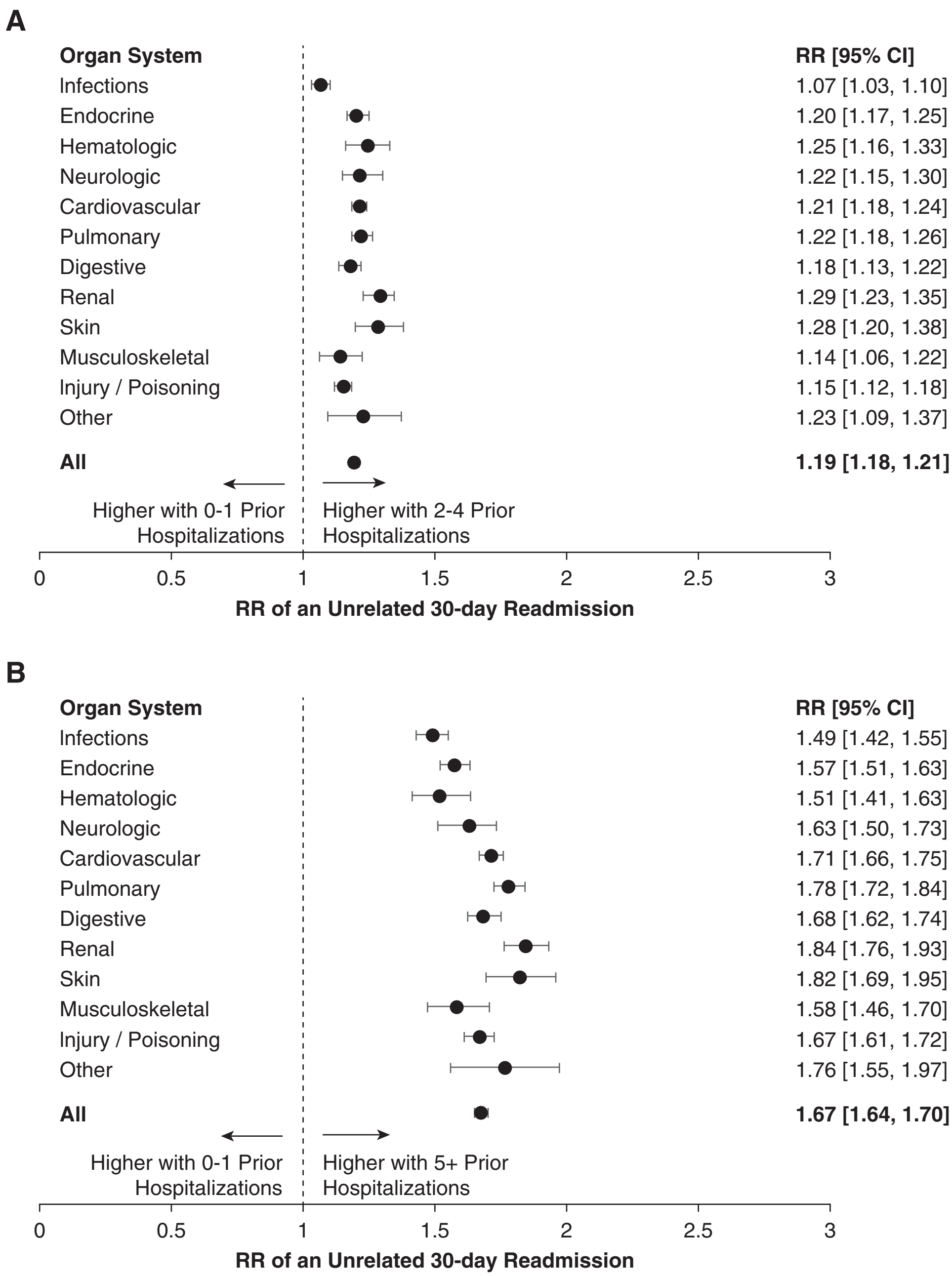

Figure 2. Higher probability of unrelated 30-day readmissions with more hospitalizations in the prior year. We show the adjusted relative risk of an unrelated 30-day readmission when having (A) 2–4 or (B) ≥5 hospitalizations in the prior year as compared with 0–1. We stratify by the organ system of the index hospitalization. Relative risks were adjusted for patient, facility, geographic, seasonal, and hospital characteristics. 95% CIs were computed using nonparametric, bootstrap clustered at the patient level. RR, relative risk.

Sensitivity Analyses

Our results did not materially change when we incorporated death as a competing risk (Supplemental Appendix 3). Unsurprisingly, when we used the more stringent definition of relatedness, we found a lower probability of related 30-day readmissions. However, the relative increase in probability of an unrelated 30-day readmission or proportion of 30-day readmissions related to the index hospitalization remained similar. In the analyses where we changed the specifications of confounding variables, our results did not substantively change.

DISCUSSION

In patients receiving hemodialysis, higher prior hospitalization burden is associated with increased 30-day readmissions unrelated

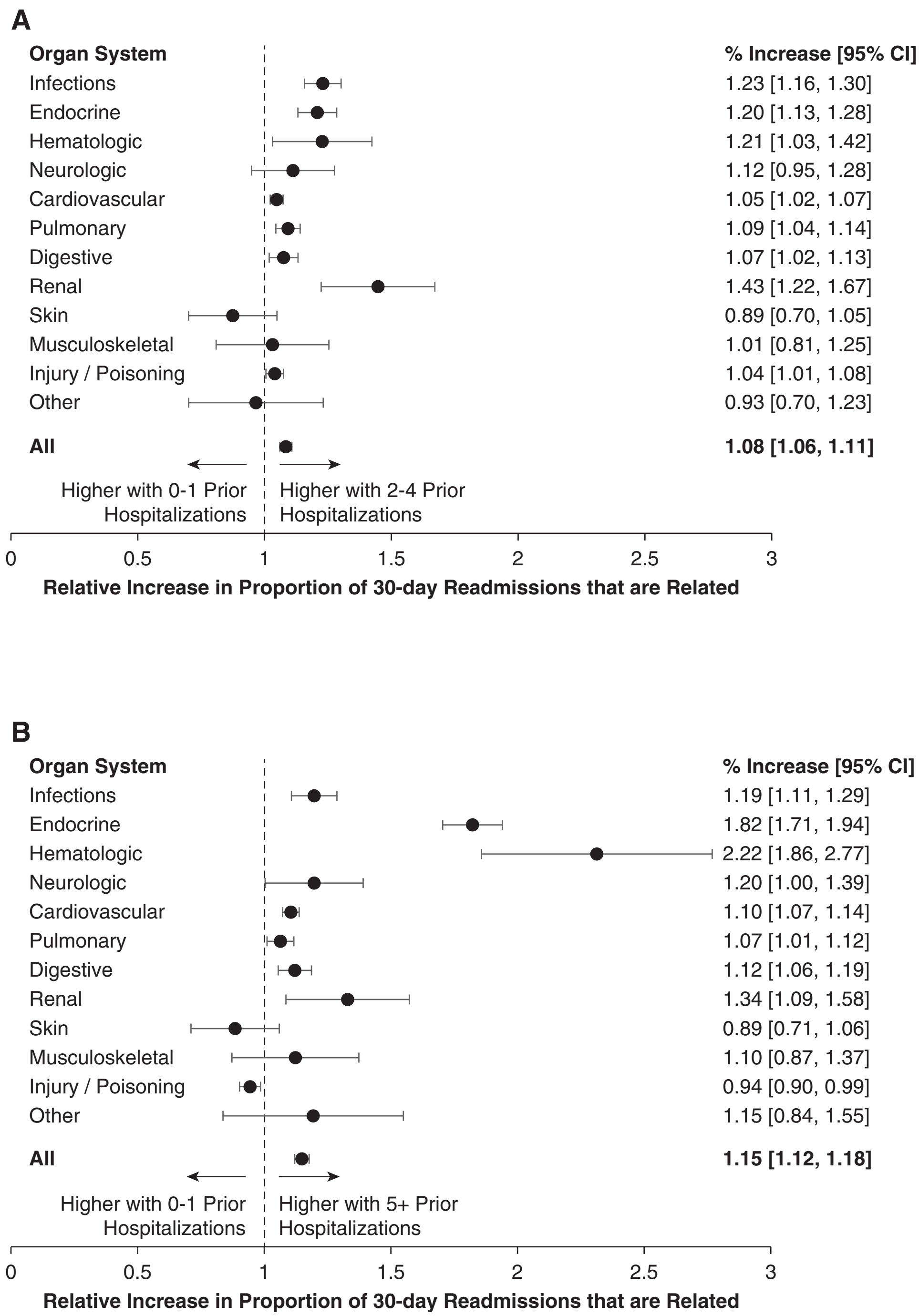

Figure 3. Small increase in proportion of 30-day readmissions related to the index hospitalization with more hospitalizations in the prior year. We show the adjusted change in the proportion of 30-day readmissions related to the index hospitalization when having (A) 2–4 or (B) ≥5 hospitalizations in the prior year as compared with 0–1. We stratify by the organ system of the index hospitalization. Estimates were adjusted for patient, facility, geographic, seasonal, and hospital characteristics. 95% CIs were computed using non-parametric, bootstrap clustered at the patient level.

to the index hospitalization. Additionally, higher prior hospitalization burden was associated with a small (but significant) increase in the proportion of 30-day readmissions related to the index hospitalization. Together, these findings suggest that the large increase in 30-day readmissions associated with background hospitalization burden is mostly attributable to an increase in unrelated 30-day readmissions. Indeed, in this population as a whole, unrelated 30-day readmissions are more common than related ones irrespective of prior hospitalization rate.

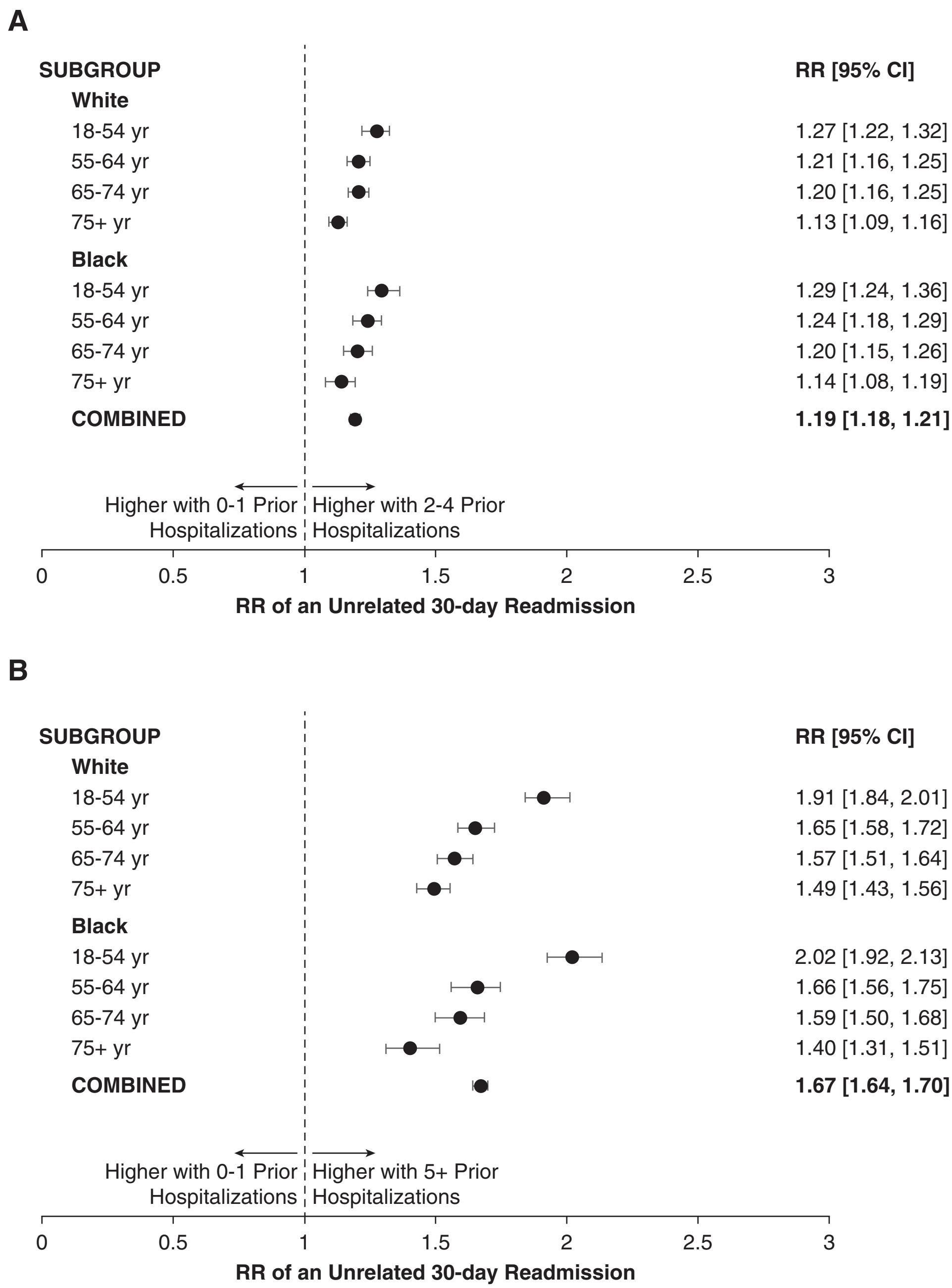

Figure 4. Higher probability of unrelated 30-day readmissions with more hospitalizations in the prior year, subgroup analysis by race and age. We show the adjusted relative risk of an unrelated 30-day readmission when having (A) 2–4 or (B) ≥5 hospitalizations in the prior year as compared with 0–1. Relative risks were adjusted for patient, facility, geographic, seasonal, and hospital characteristics. 95% CIs were computed using nonparametric, bootstrap clustered at the patient level. RR, relative risk.

The relatedness of a 30-day readmission was partially dependent on the organ system of the index hospitalization. Related 30-day readmissions were more common after a cardiovascular, pulmonary, endocrine, and injury or poisoning hospitalization, and less common after a renal hospitalization. Because the most common hospitalizations in patients undergoing hemodialysis are cardiovascular,[9] our findings suggest real opportunities to reduce 30-day readmissions. For example, careful titration of the target postdialysis ("estimated dry") weight, judicious use of afterload reduction, and extra sessions of isolated ultrafiltration could prevent readmission due to heart failure. In contrast, dialysis providers may have limited influence over readmissions related to a renal hospitalization. This may reflect the high burden of illness in patients with ESRD and the high likelihood of readmission due to one of many comorbid conditions. Additionally, these

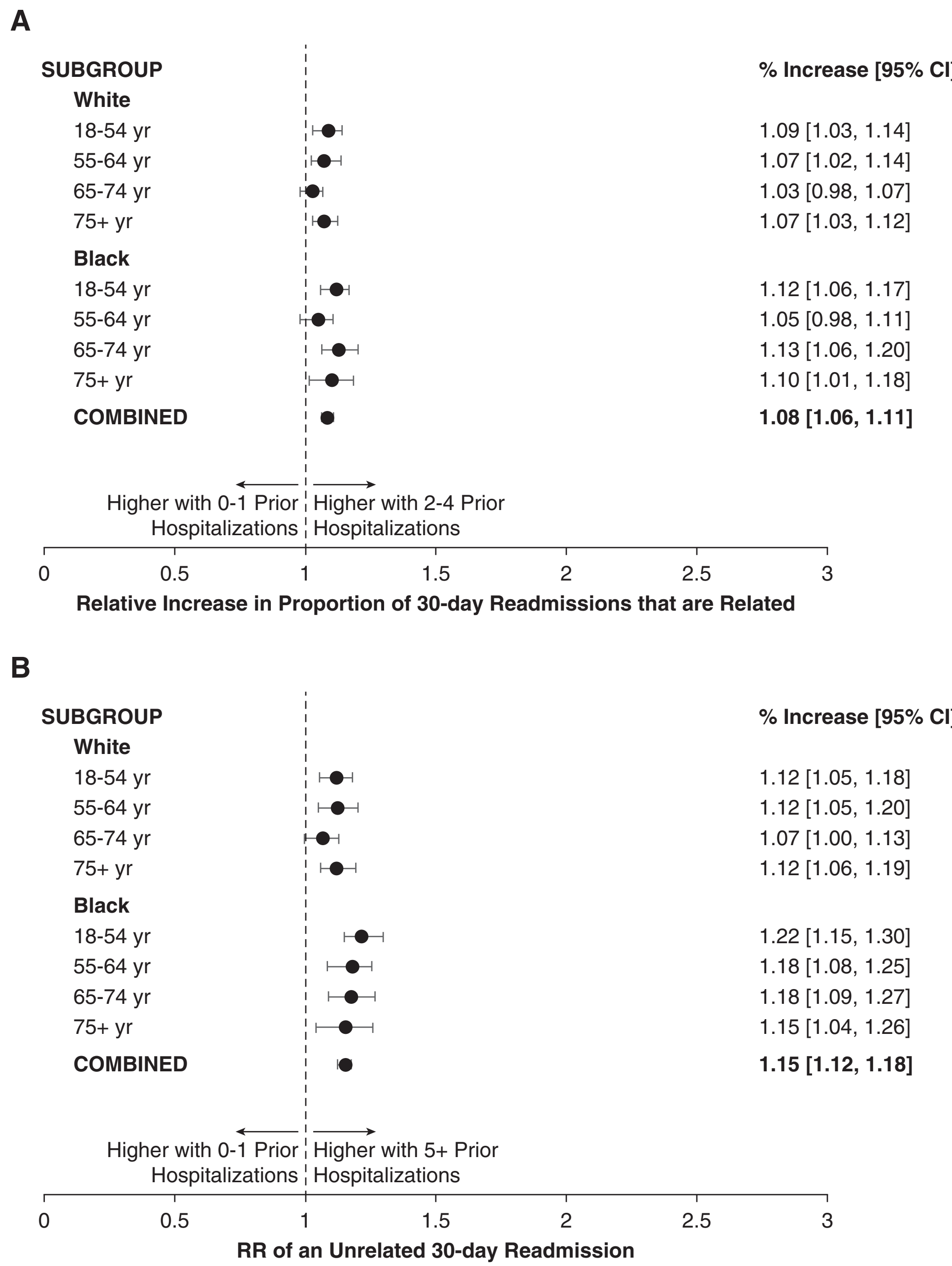

Figure 5. Small increase in proportion of 30-day readmissions related to the index hospitalization with more hospitalizations in the prior year, subgroup analysis by race and age. We show the adjusted change in the proportion of 30-day readmissions related to the index hospitalization when having (A) 2–4 or (B) ≥5 hospitalizations in the prior year as compared with 0–1. Estimates were adjusted for patient, facility, geographic, seasonal, and hospital characteristics. 95% CIs were computed using nonparametric, bootstrap clustered at the patient level. RR, relative risk.

findings may underscore poor coding practices, where providers record a nonspecific diagnosis code of "ESRD" because the patient requires dialysis, regardless of the true reason for admission. Nevertheless, our results may help healthcare providers focus their efforts on preventing 30-day readmissions after index hospitalizations of "higher risk," such as cardiovascular hospitalizations.

This study also highlights prior hospitalization burden as an important risk factor for future 30-day readmissions over and above other markers of illness, including comorbid conditions, reason for index hospitalization, and length of stay. Our results are concordant with other studies in the non-ESRD population, suggesting that the number of hospitalizations in the prior year are predictive of subsequent 30-day readmission.[19] Inpatient and outpatient providers alike could use these findings to focus care-coordination efforts on patients with high prior hospitalization burden. Using prior hospitalization burden as a global measure of illness might substantially augment our ability to capture unobserved markers of patient health. Still, even if providers are more effective in identifying at-risk patients, it does not address the challenge of preventing unrelated readmissions that are likely inevitable and a consequence of poor patient health.

As currently formulated, quality measures do not account for the relatedness of 30-day readmissions, and using all-cause 30-day readmissions as a quality benchmark might lead policy makers and providers to conflate poor-quality care with care for sicker and socioeconomically disadvantaged patients. High prior hospitalization burden was associated with more comorbidities and Medicaid. We also found that younger patients had higher hospitalization burden, a finding corroborated in previous studies.[6] In line with our other findings, higher hospitalization burden in younger patients was associated with an increase in unrelated 30-day readmissions. Even after controlling for confounders, we found that high prior hospitalization burden was associated with a substantial increase in unrelated 30-day readmissions and 30-day readmissions overall. A measure that does not discriminate between related and unrelated 30-day readmissions could promote facilities to cherry-pick healthier patients, leaving the sickest patients to seek care from safety-net providers or lose access to dialysis services entirely. Physicians and nurses have reported that cherry-picking is common among dialysis facilities.[20] Financial penalties through value-based purchasing programs could also unfairly penalize safety-net providers, precipitating a cycle of worse health care for the most vulnerable patients. Studies have shown that safety-net providers are disproportionately affected by high 30-day readmission rates.[21–23]

Refining 30-day readmission metrics to emphasize relatedness could help providers more effectively identify poor quality care. A large proportion of related 30-day readmissions are likely preventable with improved care coordination and more effective follow-up. In the hemodialysis setting, early physician follow-up may play an important role in preventing 30-day readmissions, particularly if a patient's treatment or medications require adjustments.[24] Ensuring prompt resumption of outpatient medications may also reduce 30-day readmissions.[25] Likewise, studies in heart failure,[26,27] chronic obstructive pulmonary disease,[28] and other diseases,[29] suggest that early follow-up may help mitigate 30-day readmission risk.

The CMS has already begun developing measures utilizing clinical relatedness. The Medicare Access and CHIP Reauthorization Act of 2015 (MACRA) mandated the creation of episode-based cost-measures that hold providers accountable for costs that are clinically related to an episode of care.[30,31] Parallel quality measures that incorporate similar clinical logic could substantially improve value-based purchasing umbrella policies such as the Quality Payment Program (established by MACRA) and the ESRD Quality Incentive Program.

Measures that account for clinical relatedness should be thoroughly tested before being operationalized in the entire Medicare population. Recent studies suggest that the Hospital Readmission Reduction Program may have been associated with fewer readmissions but higher mortality in the heart failure population.[32] Additionally, limiting readmission metrics to related readmissions might introduce an incentive to "game" the measure through sophisticated coding practices.[33,34] Any changes to these measures must weigh the trade-off between making a clinically more precise (and thus meaningful) measure and its susceptibility to provider manipulation. Nevertheless, our study adds to the growing body of evidence suggesting that the current iteration of readmission metrics may require adjustments to more effectively evaluate provider performance.

A major difficulty of these efforts stem from developing an objective and scalable definition of relatedness. A clinical gold-standard, such as chart review with clinical adjudication, may be reasonable when auditing a small provider. However, policy makers could not effectively scale chart review into a national program, and such a standard would likely suffer from subjectivity. In our study, we used a simple method for defining relatedness, principal diagnoses stemming from the same organ system. We also explored the effect of using more stringent criteria, such as concordance between condition categories. The latter is more likely to ensure that the 30-day readmission is related to the index hospitalization, but would identify fewer related readmissions overall (the trade-off between sensitivity and specificity). Although we chose a simple definition of clinical relatedness, our results provide impetus for policy makers and researchers to revisit 30-day readmission measures. Future studies, perhaps through convening expert panels, should explore more sophisticated algorithms that incorporate related 30-day readmissions that come from different organ systems (*e.g.*, new atrial fibrillation after pneumonia or gastrointestinal bleeds after an ST-elevation myocardial infarction). Such a measure could account for complications unique to a particular index hospitalization. Furthermore, these algorithms could alleviate ambiguities in classifying diagnoses on the basis of organ system (*e.g.*, admissions for volume overload could be classified as cardiovascular or renal, depending on coding preferences).

In addition to limitations stemming from our definition of relatedness, our study could have been confounded by unobserved characteristics not present in administrative claims. However, our results likely still have policy relevance because we attempted to construct a metric that could easily be replicated by a payer using claim-based variables. Residual confounding is also unlikely to completely account for the large magnitude of our results. As we note earlier, this study provides an impetus for incorporating prior hospitalization burden as a proxy for overall illness into already existing risk-adjustment models. Because we used administrative data, our results may have been biased by limitations in claims-based variables and miscoding errors, particularly for renal index hospitalizations. These coding issues also make it difficult to equate related readmissions with preventable ones. Still, this study is important because current and future value-based purchasing policies are generally limited to administrative data. Our findings may also have limited generalizability to other patient populations, such as those receiving peritoneal dialysis or those with other illnesses that have high hospitalization burden. We chose to focus on patients receiving hemodialysis because they have a unique set of reasons for hospitalization. Future studies should extend our results to patients receiving peritoneal dialysis or other populations where hospitalizations occur frequently. Finally, we excluded a sizeable fraction of incident patients, specifically those who did not have at least 365 days of Medicare. This limits our generalizability to patients with incident ESRD.

Although many studies have highlighted the importance of preventability in 30-day readmissions, most require a tedious adjudication process requiring subjective clinical judgement.[35–37] Ours is one of the first to propose a claims-based approach that addresses a surrogate of preventability, relatedness. The algorithm could be easily replicated in the Medicare population more broadly. This is especially important in the hemodialysis population where the 30-day readmission rate is high and the health of the average patient is poor. As far as we know, no other studies have investigated the clinical relatedness of 30-day readmissions in patients receiving hemodialysis. Likewise, no other studies have explored using prior hospitalization rate as a measure for underlying illness in patients receiving dialysis.

Focusing provider efforts on reducing related 30-day readmissions could improve patient health and reduce health care costs. Although CMS' attempts to reduce 30-day readmissions are laudable, it is imperative that performance measures do not cause providers to avoid caring for sicker or otherwise more vulnerable patients. Our findings suggest that CMS, and other health care payers, should consider refining 30-day readmission metrics to account for clinical relatedness. The challenge lies in constructing a metric that requires no additional data, could be operationalized objectively, and is scalable. Such a policy change could reduce the impetus for cherry-picking, avoid unfair penalties for safety-net providers, and improve the overall health of patients receiving hemodialysis.

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DISCLOSURES

None.

SUPPLEMENTAL MATERIAL

This article contains the following supplemental material online at http://jasn.asnjournals.org/lookup/suppl/doi:10.1681/ASN.2018080858/-/DCSupplemental.

Supplemental Appendix 1. Technical specifications.

Supplemental Appendix 2. Supplementary results.

Supplemental Appendix 3. Results of sensitivity analyses.

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See related editorial, "Readmissions Metrics in Hemodialysis: Do the Specifics Matter?," on pages 184–186.