Predictors of 30-Day Hospital Readmission among Maintenance Hemodialysis Patients: A Hospital's Perspective

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Abstract

Background and objectives Over 35% of patients on maintenance dialysis are readmitted to the hospital within 30 days of hospital discharge. Outpatient dialysis facilities often assume responsibility for readmission prevention. Hospital care and discharge practices may increase readmission risk. We undertook this study to elucidate risk factors identifiable from hospital-derived data for 30-day readmission among patients on hemodialysis.

Design, setting, participants, & measurements Data were taken from patients on maintenance hemodialysis discharged from University of North Carolina Hospitals between May of 2008 and June of 2013 who received inpatient hemodialysis during their index hospitalizations. Multivariable logistic regression models with 30-day readmission as the dependent outcome were used to identify readmission risk factors. Models considered variables available at hospital admission and discharge separately.

Results Among 349 patients, 112 (32.1%) had a 30-day hospital readmission. The discharge (versus admission) model was more predictive of 30-day readmission. In the discharge model, malignancy comorbid condition (odds ratio [OR], 2.08; 95% confidence interval [95% CI], 1.04 to 3.11), three or more hospitalizations in the prior year (OR, 1.97; 95% CI, 1.06 to 3.64), ≥10 outpatient medications at hospital admission (OR, 1.69; 95% CI, 1.00 to 2.88), catheter vascular access (OR, 1.82; 95% CI, 1.01 to 3.65), outpatient dialysis at a nonuniversity–affiliated dialysis facility (OR, 3.59; 95% CI, 2.03 to 6.36), intradialytic hypotension (OR, 3.10; 95% CI, 1.45 to 6.61), weekend discharge day (OR, 1.82; 95% CI, 1.01 to 3.31), and serum albumin <3.3 g/dl (OR, 4.28; 95% CI, 2.37 to 7.73) were associated with higher readmission odds. A decrease in prescribed medications from admission to discharge (OR, 0.20; 95% CI, 0.08 to 0.51) was associated with lower readmission odds. Findings were robust across different model–building approaches.

Conclusions Models containing discharge day data had greater predictive capacity of 30-day readmission than admission models. Identified modifiable readmission risk factors suggest that improved medication education and improved transitions from hospital to community may potentially reduce readmissions. Studies evaluating targeted transition programs among patients on dialysis are needed.

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Introduction

United States patients on hemodialysis (HD) have disproportionately high hospitalization and 30-day readmission rates compared with the general Medicare population. In 2012, patients on dialysis had a 35% 30-day readmission rate, almost double that of nondialysis Medicare beneficiaries (1). This high hospital utilization comes at great expense. In 2010, inpatient care constituted 38% of the $30 billion Medicare budget for ESRD care (1). The planned introduction of a standardized hospital readmission ratio to the Centers for Medicaid and Medicare Services Quality Incentive Program in payment year 2017 has further sharpened the focus on readmissions (2).

Undoubtedly, 30-day hospital readmission rates of patients on dialysis are too high, but evidence regarding modifiable risk factors and effective readmission prevention strategies is limited. The responsibility of rehospitalization prevention often falls to the outpatient dialysis facility. Previous studies have shown that timely, more frequent, and targeted posthospitalization follow-up reduces readmissions among patients on dialysis (3,4). Hospital-based strategies for readmission reduction have received less scrutiny. Patients on dialysis are at increased risk for in–hospital medication errors, infections, and hemoglobin and albumin declines, rendering inpatient care and discharge practices relevant to readmission risk (4–6). Hospital data–derived readmission prediction models have been developed in nondialysis populations and are helpful for resource allocation (7,8). Targeted discharge care coordination programs have been shown to reduce readmissions in some populations (9). To our knowledge, hospital–based risk factors for readmissions among patients on HD have not been evaluated.

We undertook this study to elucidate risk factors identifiable from hospital-derived data for 30-day readmission among patients on HD. Because risk assessment is often performed at hospital admission, we sought to investigate the comparative 30-day readmission risk prediction of a model generated at admission and a model generated at hospital discharge.

Materials and Methods

Study Design, Population, and Outcome

This observational cohort study included adult patients on maintenance HD discharged from University of North Carolina (UNC) Hospitals (Chapel Hill, NC) between May 1, 2008 and June 27, 2013. UNC Hospitals is a public academic medical center with >800 inpatient beds and >35,000 acute discharges per year. Study data were obtained from the Carolina Data Warehouse for Health, a central data repository containing clinical, research, and administrative data sourced from the UNC Health Care System. HD treatment data and complete medications were not electronically captured before 2014 and are not available in the database. In–hospital HD treatment data and hospital admission and discharge medications were abstracted from the scanned medical record by a trained abstractionist. A nephrologist (S.L.K.) performed repeat abstractions for patients with missing data. The principal investigator (J.E.F.) randomly sampled 15% of abstracted charts to confirm accuracy. The UNC Institutional Review Board approved this study.

The cohort consisted of patients discharged from UNC Hospitals medical and surgical services who met the following inclusion criteria: (*1*) age ≥18 years old, (*2*) ESRD designation before index hospital admission, and (*3*) receipt of inpatient HD during the index admission. Exclusion criteria included (*1*) patients on peritoneal dialysis, (*2*) observation stays, (*3*) discharges from psychiatric or inpatient rehabilitation services, (*4*) receipt of kidney transplant during index hospitalization, (*5*) declaration of ESRD during index hospitalization, (*6*) death during index hospitalization, (*7*) recovery of kidney function during index hospitalization, and (*8*) missing data (medication or select laboratory). We excluded scheduled readmissions for vascular access or other planned procedures (determined by admission history and physical review). We required at least one in–hospital HD treatment to allow consideration of HD treatment–related variables for model inclusion.

Patients were eligible to contribute a single index admission and 30-day readmission. Multiple admissions per patient were not considered because of the burden of chart abstraction associated with data collection from all hospitalizations during the 5-year period (n=867). We randomly selected each patient's index admission from all available admissions during the study period. The study index date was the index hospitalization discharge date. The study outcome was rehospitalization at UNC Hospitals within 30 days of index discharge. Because death is a competing risk for readmission, we confirmed vital status among patients without 30-day readmissions. Using UNC Hospitals and outpatient dialysis data, we confirmed vitality of all but three patients.

Predictor Variables

We collected administrative data (demographics, comorbidities, and previous health care utilization) and clinical data (diagnoses, hospital procedures, laboratory results, and vital signs). Hospitalization primary diagnosis was determined by inpatient administrative codes. Comorbid conditions were determined by administrative codes associated with prior UNC ambulatory and hospital encounters and the electronic medical record problem list. Operational definitions are available in Supplemental Table 1. Admission vital signs were considered as the first nonmissing values within 6 hours of admission, and discharge vital signs were considered as the last nonmissing values in the 12 hours before discharge. Admission laboratory values were considered as the first nonmissing values within 12 hours of admission, and discharge laboratory values were considered as the last nonmissing values in the 24 hours before discharge. Serum albumin (grams per deciliter) was considered as any value obtained during the hospitalization. When more than one value was available, the last albumin level was used. We collected HD variables from the first in–hospital HD treatment during the index admission. Considered variables are presented in Tables 1 and 2. Variables were chosen *a priori* on the basis of existing literature and their plausible associations with outcome (7,10,11).

Statistical Analyses

Data are presented as means and SDs for continuous variables and frequencies and percentages for categorical variables. We excluded variables with missing data from consideration for multivariable model inclusion (dialysis vintage, pre- and post-HD weights, discharge temperature, sodium, potassium, hemoglobin, white blood cell count, and platelet count). Baseline comparisons were made using chi-squared tests and independent samples t tests on the basis of distributions.

Prediction models were developed using univariate and multivariable binary logistic regressions, with 30-day readmission to UNC Hospitals as the dependent outcome. Models considered only variables with a univariate P value <0.20 and were constructed using backward selection with an elimination threshold of 0.10. Multivariable model 1 considered qualifying variables available at hospital admission. Model 2 considered model 1 variables and qualifying variables available at hospital discharge. Model goodness of fit was assessed *via* Hosmer and Lemeshow testing. The receiver operating characteristic curve and the area under the receiver operating characteristic curve (AUC) with 95% confidence intervals (95% CIs) were derived for each model. Model 1 and 2 AUCs were tested for equality using the method by DeLong *et al.* (12) for calculating the AUC SEM and the difference between model AUCs. Internal model validation was assessed using bootstrap resampling of the full cohort with 1000 iterations.

Given the modest sample size, sensitivity analyses evaluating variable selection and model stability were performed. First, least absolute shrinkage and selection operator adapted for logistic regression was used for model variable selection (13,14). Second, because the primary analysis considered 14 variables in the setting of 112

Table 1. Cohort characteristics at index hospitalization admission across 30-day hospital readmission status

Characteristic	Total, *n*=349	With 30-d Readmission, *n*=112	Without 30-d Readmission, *n*=237	*P* Value[a]
Administrative data				
Age, yr				0.81
≤49	99 (28.4%)	33 (29.5%)	66 (27.8%)	
50–59	86 (24.6%)	24 (21.4%)	62 (26.2%)	
60–69	94 (26.9%)	31 (27.7%)	63 (26.6%)	
≥70	70 (20.1%)	24 (21.4%)	46 (19.4%)	
Women	163 (46.7%)	50 (44.6%)	113 (47.7%)	0.60
Black	219 (62.7%)	67 (59.8%)	152 (64.1%)	0.44
Marital status				0.47
Single	189 (54.2%)	60 (53.6%)	129 (54.4%)	
Married	100 (28.6%)	36 (32.1%)	64 (27.0%)	
Other[b]	60 (17.2%)	16 (14.3%)	44 (18.6%)	
Medicare as primary insurance payer	261 (74.8%)	88 (78.6%)	173 (73.0%)	0.26
Diabetes	132 (37.8%)	45 (40.2%)	87 (36.7%)	0.53
Heart failure	166 (47.6%)	58 (51.8%)	108 (45.6%)	0.28
Arterial disease[c]	162 (46.4%)	60 (53.6%)	102 (43.0%)	0.06
Hypertension	249 (71.3%)	84 (75.0%)	165 (69.6%)	0.30
Ischemic stroke	58 (16.6%)	20 (17.9%)	38 (16.0%)	0.67
Malignancy	25 (7.2%)	14 (12.5%)	11 (4.6%)	0.01
Hospital admission data				
Hospitalizations in the prior year ≥3	80 (22.9%)	37 (33.0%)	43 (18.1%)	0.002
Outpatient medications ≥10	186 (53.3%)	67 (59.8%)	119 (50.2%)	0.05
Outpatient use of warfarin	28 (8.0%)	14 (12.5%)	14 (5.9%)	0.04
Outpatient use of antibiotics	56 (16.1%)	17 (15.2%)	39 (16.5%)	0.76
Outpatient use of narcotics	97 (27.8%)	35 (31.3%)	62 (26.2%)	0.32
Surgery admitting service	86 (24.6%)	35 (31.2%)	51 (21.5%)	0.05
Temperature ≥37.8°C	18 (5.2%)	6 (5.4%)	12 (5.1%)	0.91
Systolic BP, mmHg				0.10
≤110	54 (15.5%)	24 (21.4%)	30 (12.7%)	
111–175	236 (67.6%)	71 (63.4%)	165 (69.6%)	
≥176	59 (16.9%)	17 (15.2%)	42 (17.7%)	
Heart rate, bpm				0.52
≤60	19 (5.4%)	8 (7.1%)	11 (4.6%)	
61–99	294 (84.2%)	91 (81.2%)	203 (85.6%)	
≥100	36 (10.3%)	13 (11.6%)	23 (9.7%)	
Hemodialysis data				
Dialysis vintage, yr				0.38
<1	49 (14.0%)	12 (10.7%)	37 (15.6%)	
1–5	30 (8.6%)	7 (6.3%)	23 (9.7%)	
>5	76 (21.8%)	27 (24.1%)	49 (20.7%)	
Missing	194 (55.6%)	66 (58.9%)	128 (54.0%)	
Vascular access				0.06
Fistula	161 (46.1%)	44 (39.3%)	117 (49.4%)	
Graft	63 (18.0%)	18 (16.1%)	45 (19.0%)	
Catheter	125 (35.8%)	50 (44.6%)	75 (31.6%)	
Non–UNC–affiliated outpatient dialysis facility	176 (50.4%)	68 (60.7%)	108 (45.6%)	<0.01

UNC, University of North Carolina.
[a]Significance was assessed by chi-squared testing.
[b]Includes separated, divorced, and widowed.
[c]Includes ischemic heart disease, myocardial infarction, and peripheral vascular disease.

readmission events, analyses using a restricted model–building approach were performed. In these analyses, variables with univariate *P* values ≤0.05 were considered for model inclusion (*n*=12 variables). Third, primary hospitalization diagnosis, age, sex, race, and primary insurer did not meet the established univariate significance threshold in primary or sensitivity analyses. These clinically relevant variables were tested in expanded logistic models. Fourth, analyses excluding the three patients who died in the 30-day period after index discharge and thus, were not eligible for readmission were performed. Results were analogous to those of the primary analyses and are not shown. Analyses were performed using STATA 12.0MP (StataCorp., College Station, TX).

Table 2. Cohort characteristics during hospitalization across 30-day hospital readmission status

Characteristic	Total, *n*=349	With 30-d Readmission, *n*=112	Without 30-d Readmission, *n*=237	*P* Value[a]
Admission laboratory values				
Sodium ≤135 mmol/L	60 (17.2%)	20 (17.9%)	40 (16.9%)	0.82
Potassium, mEq/L				0.22
<4	78 (22.4%)	29 (25.9%)	49 (20.7%)	
4–5.4	204 (58.4%)	67 (59.8%)	137 (57.8%)	
≥5.5	67 (19.2%)	16 (14.3%)	51 (21.5%)	
Hemoglobin, g/dl				0.88
<9.5	90 (25.8%)	30 (26.8%)	60 (25.3%)	
9.5–12	198 (56.7%)	64 (57.1%)	134 (56.5%)	
>12	61 (17.5%)	18 (16.1%)	43 (18.1%)	
White blood cell count $>10\times10^3$ μl	101 (28.9%)	30 (26.8%)	71 (30.0%)	0.54
Platelet count <150	89 (25.5%)	32 (28.6%)	57 (24.0%)	0.37
First hospital HD treatment data				
Pre–HD systolic BP, mmHg				0.87
<120	95 (27.2%)	32 (28.6%)	63 (26.6%)	
120–160	190 (54.4%)	61 (54.5%)	129 (54.4%)	
>160	64 (18.3%)	19 (17.0%)	45 (19.0%)	
Nadir intradialytic systolic BP <90 mmHg	50 (14.3%)	22 (19.6%)	28 (11.8%)	0.05
Pre-HD weight, kg	83.3±22.2 (*n*=289)	83.3±22.2 (*n*=96)	83.4±19.7 (*n*=193)	0.48
Post-HD weight, kg	81.9±20.8 (*n*=286)	80.8±21.9 (*n*=95)	82.5±20.3 (*n*=191)	0.26
Ultrafiltration volume, L	1.9±1.4	1.9±1.4	2.0±1.4	0.26
Ultrafiltration volume ≥3 L	90 (25.8%)	27 (24.1%)	63 (26.6%)	0.62
Hospitalization characteristics				
Primary admission diagnosis[b]				0.81
Cardiovascular	78 (22.3%)	25 (22.3%)	53 (22.4%)	
Infection	76 (21.8%)	26 (23.2%)	50 (21.1%)	
Other	195 (55.9%)	61 (54.5%)	134 (56.5%)	
Length of stay ≥4 d	209 (59.9%)	69 (61.6%)	140 (59.1%)	0.65
Intensive care unit–level care	117 (33.5%)	40 (35.7%)	77 (32.5%)	0.55
Weekend discharge	73 (20.9%)	28 (25.0%)	45 (19.0%)	0.19
Discharge destination[c]				0.30
Home	277 (79.4%)	86 (76.8%)	191 (80.6%)	
Nursing facility	58 (16.6%)	23 (20.5%)	35 (14.8%)	
Other	14 (4.0%)	3 (2.7%)	11 (4.6%)	
Hospitalization medication changes				
Medication no. change				0.004
None	42 (12.0%)	18 (16.1%)	24 (10.1%)	
Decrease	87 (25.0%)	16 (14.3%)	71 (30.0%)	
Increase	220 (63.0%)	78 (69.6%)	142 (59.9%)	
Narcotic start	78 (22.4%)	27 (24.1%)	51 (21.5%)	0.59
Antibiotic start	71 (20.3%)	25 (22.3%)	46 (19.4%)	0.53
Warfarin start	20 (5.7%)	4 (3.6%)	16 (6.8%)	0.24
Discharge vital signs				
Temperature, °C				0.01
<37.8	319 (91.4%)	95 (84.8%)	224 (94.5%)	
≥37.8	13 (3.7%)	7 (6.3%)	6 (2.5%)	
Missing	17 (4.9%)	10 (8.9%)	7 (3.0%)	
Systolic BP, mmHg				0.04
≤110	44 (12.6%)	19 (17.0%)	25 (10.6%)	
111–175	278 (79.7%)	89 (79.5%)	189 (79.7%)	
≥176	27 (7.7%)	4 (3.6%)	23 (9.7%)	
Heart rate, bpm				0.69
≤60	12 (3.6%)	5 (4.7%)	7 (3.1%)	
61–99	282 (83.9%)	90 (84.1%)	192 (83.8%)	
≥100	42 (12.5%)	12 (11.2%)	30 (13.1%)	
Discharge laboratory values				
Sodium, mmol/L				0.06
≤135	78 (22.4%)	33 (29.5%)	45 (19.0%)	
>135	230 (65.9%)	67 (59.8%)	163 (68.8%)	

Table 2. (Continued)

Characteristic	Total, *n*=349	With 30-d Readmission, *n*=112	Without 30-d Readmission, *n*=237	*P* Value[a]
Missing	41 (11.7%)	12 (10.7%)	29 (12.2%)	
Potassium, mEq/L				0.55
<4	67 (19.2%)	18 (16.1%)	49 (20.7%)	
4–5.4	219 (62.7%)	76 (67.9%)	143 (60.3%)	
≥5.5	23 (6.9%)	6 (5.3%)	18 (7.6%)	
Missing	39 (11.2%)	12 (10.7%)	27 (11.4%)	
Hemoglobin, g/dl				0.94
<9.5	143 (41.0%)	46 (41.1%)	97 (40.9%)	
9.5–12	172 (49.3%)	55 (49.1%)	117 (49.4%)	
>12	24 (6.9%)	7 (6.2%)	17 (7.2%)	
Missing	10 (2.9%)	4 (3.6%)	6 (2.5%)	
White blood cell count $>10\times10^3$ μl	47 (15.3%; *n*=308)	17 (17.0%; *n*=100)	30 (14.4%; *n*=208)	0.56
Platelet count <150	85 (28.0%; *n*=304)	37 (37.4%; *n*=99)	48 (23.4%; *n*=205)	0.003
Albumin <3.3 g/dl[d]	213 (61.0%)	86 (76.8%)	127 (53.6%)	<0.001

Values are shown as mean±SD or *n* (percentage). *n*=349 unless otherwise noted. HD, hemodialysis.
[a]Significance was assessed by chi-squared tests or independent samples *t* tests depending on data distribution.
[b]Relevant administrative codes (Supplemental Table 1) in the first position. Each index admission had a single primary admission diagnosis.
[c]Nursing facility includes skilled nursing facilities, rehabilitation facilities, and long–term care facilities. Other includes home of family or friends or a temporary housing location.
[d]Albumin was considered any time during the hospitalization. When more than one value was available, the last available value during the hospitalization was selected.

Results

Characteristics of the Cohort

Figure 1 displays the flow diagram of study cohort selection. During the study period, 583 patients on dialysis had 1753 admissions to medical or surgical services at UNC Hospitals. After selection criteria were applied, 349 index admissions remained. Cohort characteristics at index hospitalization across 30-day readmission status are displayed in Tables 1 and 2. Of the 349 patients, 163 (46.7%) were women, the mean age was 57±15 years old, and 219 (62.7%) were black. Approximately one half (49.6%) dialyzed at UNC–affiliated outpatient dialysis facilities, 125 (35.8%) dialyzed *via* catheter, and 261 (74.8%) had Medicare as the primary insurance payer. The principal index admission diagnosis was cardiovascular related in 78 (22.3%) patients and infection related in 76 (21.8%) patients. The median length of index hospitalization was 4 days (quartiles 1–3, 3–9 days).

The cumulative 30-day readmission rate was 27.5%. Considering only the index hospitalization, the 30-day readmission rate was 32.1%. The median time from index discharge to 30-day readmission was 10 days (quartiles 1–3, 6–21 days), with 14 (12.5%) patients readmitted within 3 days of discharge and 3 (2.7%) patients readmitted within 2 days of discharge. Of the 78 patients with an index hospitalization primary cardiovascular diagnosis, 25 (32.1%) had 30-day readmissions, and 60% of these readmissions were for diagnoses similar to those of the index hospitalization. Primary 30-day readmission diagnoses among patients with cardiovascular and infection index admission diagnoses are shown in Supplemental Figure 1. Among other differences, patients with 30-day readmissions were more likely to have a malignant comorbid condition, be hospitalized at UNC Hospitals three or more times in the prior year, dialyze at a non–UNC–affiliated outpatient dialysis facility, and be admitted to a surgical service compared with patients without readmissions.

Hospital Readmission Predictors

In univariate analyses, malignancy comorbid condition, three or more hospitalizations in the prior year, use of ≥10 medications at the time of admission, outpatient use of warfarin, admission to a surgical service, catheter vascular access, dialysis at a non–UNC–affiliated facility, admission systolic BP ≤110 mmHg, nadir intradialytic systolic BP <90 mmHg, and serum albumin <3.3 g/dl were associated with higher readmission odds (*P* value ≤0.05 for all). Discharge systolic BP ≥176 mmHg and a decrease in prescribed outpatient medications were associated with lower readmission odds (*P* value <0.05 for both).

Results of the two multivariable logistic regression models for 30-day readmission are presented in Table 3. In the admission model (model 1), malignancy comorbid condition, three or more hospitalizations in the prior year, admission to a surgical service, catheter vascular access, dialysis at a non–UNC–affiliated facility, and admitting systolic BP ≤110 mmHg were associated with greater 30-day readmission odds (*P* value <0.05 for all). Model performance as characterized by the AUC was moderate: 0.68 (95% CI, 0.60 to 0.77).

Consideration of data available at discharge improved model performance. The discharge model (model 2) AUC of 0.79 (95% CI, 0.73 to 0.85) was significantly greater than the admission model AUC (test for equality [12]; *P*<0.01) (Figure 2). In model 2, malignancy comorbid condition (odds ratio [OR], 2.08; 95% CI, 1.04 to 3.11), three or more hospitalizations in the prior year (OR, 1.97; 95% CI,

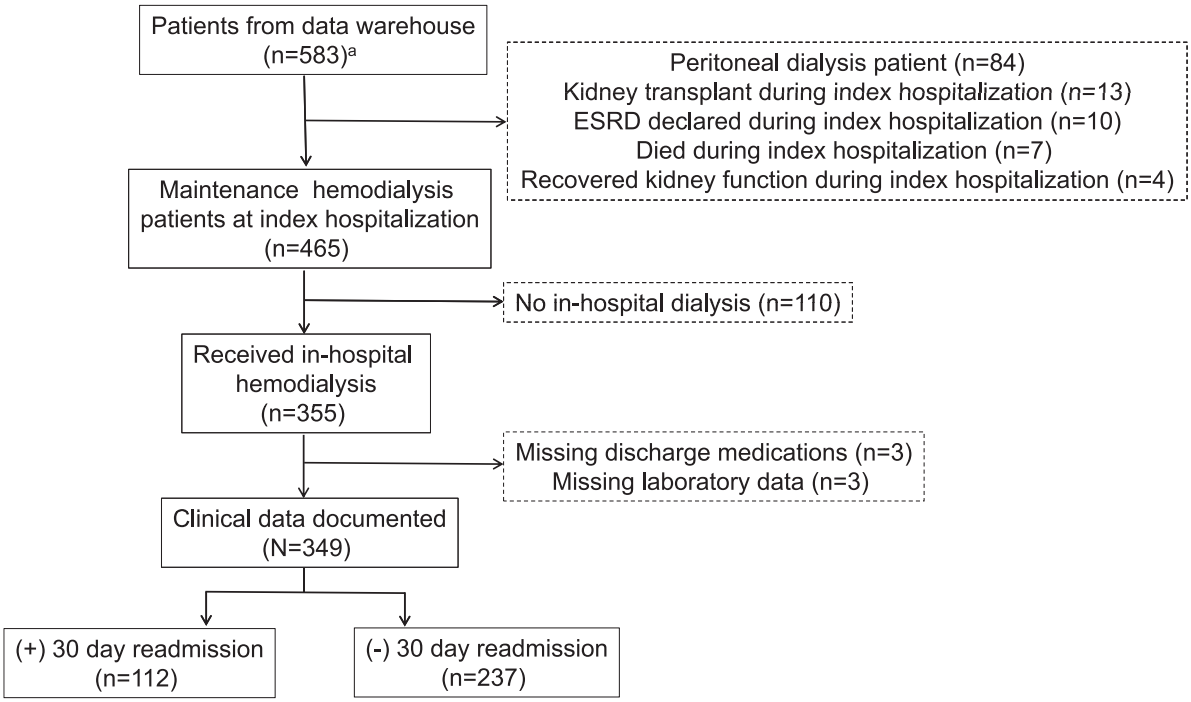

Figure 1. | **Flow diagram of study cohort patient selection.** [a]Patients discharged from medical or surgical services were considered for cohort inclusion. Patients were excluded from consideration on the basis of discharge from the inpatient psychiatry service, discharge from the inpatient rehabilitation service, and discharge from an observation stay before compilation of the 583 patient source cohort.

1.06 to 3.64), ≥10 outpatient medications at hospital admission (OR, 1.69; 95% CI, 1.00 to 2.88), catheter vascular access (OR, 1.82; 95% CI, 1.01 to 3.65), outpatient dialysis at a nonuniversity–affiliated dialysis facility (OR, 3.59; 95% CI, 2.03 to 6.36), intradialytic hypotension (OR, 3.10; 95% CI, 1.45 to 6.61), weekend discharge day (OR, 1.82; 95% CI, 1.01 to 3.31), and serum albumin <3.3 g/dl (OR, 4.28; 95% CI, 2.37 to 7.73) were associated with higher readmission odds. A decrease in prescribed outpatient medications from admission to discharge (OR, 0.20; 95% CI, 0.08 to 0.51) was associated with lower readmission odds. Model goodness of fit was adequate (P=0.35). Results of the bootstrap resampling validation were similar with an AUC of 0.78 (95% CI, 0.70 to 0.90).

To assess whether the readmission risk associated with outpatient dialysis at nonuniversity facilities was attributable to case mix differences, we compared patients dialyzing at university-affiliated clinics with those dialyzing at nonuniversity-affiliated clinics. University-associated patients were more likely to have heart failure compared with nonuniversity-associated patients (P=0.04), but the two groups were otherwise similar in terms of demographic, comorbid, and dialysis characteristics (Supplemental Table 2).

Sensitivity Analyses

We performed sensitivity analyses to test the robustness of our predictive models under different model–building paradigms. Analyses using least absolute shrinkage and selection operator for variable selection yielded similar results to backward selection (Supplemental Table 3). A more restrictive approach to model building considering 12 (versus 14) variables also produced analogous findings (Supplemental Table 4). Finally, an expanded multivariable model incorporating the clinically important variables of age, sex, race, primary insurer, and primary admission diagnosis was also consistent with primary findings (Supplemental Table 5).

Discussion

To our knowledge, this is the first study investigating 30-day hospital readmission predictors identifiable from hospital-derived data among patients on maintenance HD. Our single-center analysis shows that predictive models with hospital discharge data are more predictive of readmission than admission-based models. Factors associated with higher 30-day readmission odds were malignancy comorbid condition, three or more hospitalizations in the prior year, ≥10 outpatient medications at hospital admission, catheter vascular access, outpatient dialysis at a nonuniversity–affiliated dialysis facility, intradialytic hypotension, weekend discharge day, and serum albumin <3.3 g/dl. A decrease in prescribed medications from admission to discharge was associated with lower readmission odds. Our results show the potential for transition services focused on medication management and communication between care settings to reduce hospital readmissions.

Prior studies have identified older age, greater comorbidity burden, and anemia as risk factors for hospital readmission among United States patients on dialysis (15,16). Harel *et al.* (17) recently reported that older age, higher comorbidity index, higher prior health care utilization, and receipt of mechanical ventilation during hospitalization were associated with readmission in Ontario,

Table 3. Logistic regression models for 30-day hospital readmission

Characteristic	Univariate Associations		Model 1: Admission Data[a]		Model 2: Discharge Data[a]	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value
Arterial disease comorbid condition[b]	1.53 (0.98 to 2.40)	0.06				
Malignancy comorbid condition	2.93 (1.29 to 6.69)	0.01	2.75 (1.13 to 6.70)	0.03	2.08 (1.04 to 3.11)	0.03
Hospitalizations in the prior year ≥3	2.23 (1.33 to 3.72)	0.002	2.24 (1.26 to 3.99)	<0.01	1.97 (1.06 to 3.64)	0.02
Outpatient medications ≥10	1.48 (1.00 to 2.33)	0.05			1.69 (1.00 to 2.88)	0.05
Outpatient use of warfarin	2.28 (1.05 to 4.95)	0.04	2.08 (0.90 to 4.80)	0.08		
Surgery admitting service	1.66 (1.00 to 2.75)	0.05	1.75 (1.01 to 3.01)	0.04	1.74 (0.91 to 3.14)	0.07
Access						
Fistula	1.00 (reference)		1.00 (reference)		1.00 (reference)	
Graft	1.06 (0.56 to 2.03)	0.85	1.01 (0.51 to 2.12)	0.85	1.09 (0.62 to 2.43)	0.77
Catheter	1.77 (1.08 to 2.92)	0.02	1.78 (1.03 to 2.96)	0.03	1.82 (1.01 to 3.65)	0.04
Non–UNC–affiliated outpatient dialysis unit	1.85 (1.17 to 2.92)	<0.01	2.11 (1.28 to 3.47)	0.003	3.59 (2.03 to 6.36)	<0.001
Admission systolic BP, mmHg						
≤110	1.86 (1.02 to 3.40)	0.04	2.13 (1.12 to 4.06)	0.02		
111–175	1.00 (reference)		1.00 (reference)			
≥176	0.94 (0.50 to 1.76)	0.85	1.03 (0.53 to 2.00)	0.92		
Nadir intradialytic systolic BP <90 mmHg	1.82 (1.00 to 3.36)	0.05			3.10 (1.45 to 6.61)	0.003
Weekend discharge day	1.42 (0.83 to 2.43)	0.19			1.82 (1.01 to 3.31)	0.04
Discharge systolic BP, mmHg						
≤110	0.96 (0.57 to 1.60)	0.87				
111–175	1.00 (reference)					
≥176	0.49 (0.24 to 0.98)	0.04				
Albumin <3.3 g/dl[c]	2.86 (1.72 to 4.76)	<0.001			4.28 (2.37 to 7.73)	<0.001
Medication no. change						
None	1.00 (reference)				1.00 (reference)	
Decrease	0.30 (0.13 to 0.68)	0.004			0.20 (0.08 to 0.51)	0.001
Increase	1.12 (0.88 to 2.47)	0.35			1.07 (0.75 to 2.29)	0.41
Model *c* statistic			0.68		0.79	
AUC (95% CI)			0.68 (0.60 to 0.77)		0.79 (0.73 to 0.85)	

Variables listed are those variables with complete data and a univariate *P* value <0.20; *n*=349 for all models. OR, odds ratio; 95% CI, 95% confidence interval; UNC, University of North Carolina; AUC, area under the receiver operating characteristic curve.

[a]Models were constructed by considering variables with a univariate *P* value <0.20 and using backward selection with an elimination threshold of 0.10. Model 1 considered only admission variables with univariate *P* values <0.20, and model 2 considered both admission and discharge variables with univariate *P* values <0.20.

[b]Includes ischemic heart disease, myocardial infarction, and peripheral vascular disease.

[c]Albumin was considered any time during the hospitalization. When more than one value was available, the last available value during the hospitalization was selected.

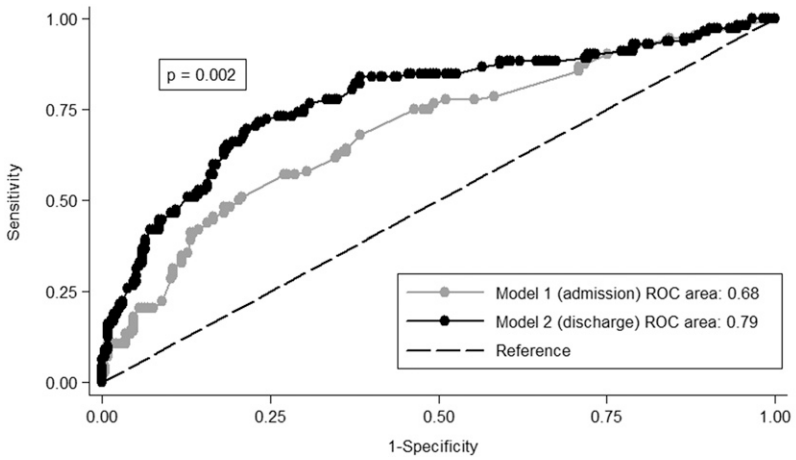

Figure 2. | The areas under the receiver operator characteristic curves (AUCs) for the admission data and discharge data multivariable logistic regression models for 30-day hospital readmission differed significantly. Prediction models were developed using univariate and multivariable binary logistic regressions, with 30-day readmission to University of North Carolina Hospitals as the dependent outcome. Models considered only variables with a univariate *P* value <0.20 and were constructed using backward selection with an elimination threshold of 0.10. Multivariable model 1 considered qualifying variables available at hospital admission. Model 2 considered model 1 variables and qualifying variables available at hospital discharge. Models 1 and 2 AUCs were tested for equality using the method by DeLong *et al.* (12) for calculating the AUC SEM and the difference between model AUCs. ROC, receiver operating characteristic curve.

Canada. A Dialysis Outcomes and Practice Patterns Study analysis found that readmissions were more common after shorter hospital stays (18). Together, these findings underscore the importance of in-hospital care to readmission risk. Despite the plausible importance of in-hospital management to readmission among patients on dialysis, the burden of rehospitalization prevention typically falls on the ambulatory dialysis facility. Little attention has been paid to modifiable hospital risk factors.

We evaluated 30-day readmission risk factors from a discharging hospital perspective. Our study cohort's index readmission rate of 32.1% is on par with the national rate (1). Consistent with prior studies, we found that greater health care utilization was associated with greater odds of readmission. Similarly, factors related to illness burden, including outpatient medication number and a cancer comorbid condition, predicted readmission. Not surprisingly, low serum albumin was a powerful predictor of 30-day readmission. Catheter vascular access and intradialytic hypotension, two important prognostic factors in the outpatient setting, were also predictive of readmission (19,20). Intradialytic hypotension is associated with end organ ischemia of the heart, gut, and brain and plausibly places patients at risk for conditions leading to hospital readmission (21–23). However, low BP is often associated with poor nutritional status, rendering it a potential risk marker as opposed to a risk factor (20).

Importantly, we identified several potential actionable readmission risk factors. We found that weekend discharge day, prescription medication changes, and outpatient HD at a nonuniversity-affiliated facility were associated with higher readmission odds. Patient demographic, comorbid, and dialysis characteristics were similar across patients dialyzing at nonuniversity- and university-affiliated clinics, suggesting that patient acuity did not explain the observed difference between clinic types. Although we cannot account for other practice differences across units, better communication between care settings is one potential explanation for the difference in readmission risk across facility affiliations. Interestingly, we did not observe a difference in readmission risk among patients discharged to nursing facilities (versus home), which has been reported in other populations (24,25). This finding should be evaluated in larger multicenter cohorts. Overall, our observations that discharge day, medication changes, and affiliation of outpatient dialysis unit affect readmission risk raise the possibility that improved communication between hospitals and dialysis facilities may reduce readmissions.

Prior studies of readmission prevention have focused on the ambulatory dialysis unit. Posthospitalization hemoglobin monitoring, erythropoietin–stimulating agent dose adjustment, and more frequent provider visits have been shown to reduce readmissions (3,4). Ultimately, hospital readmission prevention must be a shared responsibility among the outpatient dialysis facility, the treating nephrologist, and the discharging hospital. Care transitions across health care settings represent ideal opportunities to optimize these critical collaborations. Our findings indicate the potential for redesign of the discharge process to incorporate clinical pharmacy activities with a focus on medication regimen consolidation and patient education to be helpful. Although our analyses showed benefit from streamlined medication regimens, we cannot exclude the possibility that this finding may be attributable to less sick patients requiring fewer medications as opposed to more effective medication management. However, pharmacy discharge interventions have proven effective in other populations, making medication management a potential target for readmission reduction among patients on dialysis (26). Hospital discharge day also influenced readmission risk. Many hospitals, including our own, have reduced weekend case management services. Additionally, medical team continuity is often disrupted on weekends. These issues in combination with our finding that patients from

nonuniversity–affiliated dialysis facilities had greater readmission odds underscore the critical importance of communication between hospitals and ambulatory dialysis facilities. Augmented case management services and formalized information transfer across care settings represent feasible opportunities to possibly improve readmission rates among patients on dialysis.

Readers must consider our results in the context of study limitations. First, we used data from a single center. Our population has a high proportion of black patients, and >50% of patients receive outpatient HD at university-affiliated facilities. Also, we considered patients discharged from medical or surgical services. Our results may not generalize to other centers and may not generalize to patients discharged from inpatient psychiatry or rehabilitation services. Our prediction models should be externally validated. Sample size precluded use of separate development and validation cohorts. Second, we did not consider multiple outcomes per patient. We randomly selected a single hospitalization as the index hospitalization to facilitate data abstraction. However, use of a single index hospitalization is consistent with the operational environment in which the model will be used. Third, we were unable to consider readmissions that occurred outside our hospital network; however, patients dialyzing at UNC-affiliated facilities typically receive inpatient care from our system. Fourth, we were not able to consider all variables potentially associated with readmission in prediction model development. Unmeasured factors, such as health literacy, social support, and functional status, may influence readmission risk and were not included in the model. However, these factors are not typically measured in clinical care, and we sought to develop a prediction model from routinely available data. Additionally, our sample size was modest, and our outcome number prevented consideration of more variables because of model stability concerns. However, our prediction model AUC was moderately strong, and the model was robust to multiple model–building approaches, providing reassurance regarding our findings. Fifth, because of sample size limitations, we were unable to perform subgroup analyses to investigate risk factors for readmission among patients readmitted for diagnoses similar to index hospitalization primary diagnoses. This important subgroup should be considered in future larger studies.

In conclusion, we evaluated risk factors associated with 30-day hospital readmission among patients on maintenance dialysis from the hospital perspective and identified feasible, relatively low–cost strategies that may potentially reduce readmissions. Our findings of an association between 30-day readmission and dialysis at a nonuniversity–affiliated outpatient facility, changes in prescribed medications, and weekend discharge day raise the possibility that improved communication and care coordination between the hospital and ambulatory settings may reduce readmissions. Intervention studies evaluating targeted transition programs among patients on dialysis are needed.

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Disclosures

None.

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