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Authors
Chen, Yanjun
Rhee, Connie
Senturk, Damla
et al.

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Association of US Dialysis Facility Staffing with Profiling of Hospital-Wide 30-Day Unplanned Readmission

Yanjun Chen[a] Connie Rhee[b] Damla Senturk[c] Esra Kurum[d] Luis Campos[e]
Yihao Li[c] Kamyar Kalantar-Zadeh[b] Danh Nguyen[f]

[a]Institute for Clinical and Translational Science, University of California, Irvine, CA, USA; [b]Harold Simmons Center for Chronic Disease Research and Epidemiology, University of California Irvine School of Medicine, Orange, CA, USA; [c]Department of Biostatistics, University of California, Los Angeles, CA, USA; [d]Department of Statistics, University of California, Riverside, CA, USA; [e]Department of Statistics, Harvard University, Cambridge, MA, USA; [f]Department of Medicine, University of California Irvine, Orange, CA, USA

Abstract

Background: Unplanned hospital readmissions are a major source of morbidity among dialysis patients, in whom the risk of hospital readmission is exceptionally high. The contribution of dialysis facility staffing to hospital readmission has been largely overlooked. ***Methods:*** Using annual data of dialysis patients from the United States Renal Data System from 2010 to 2013, we assessed dialysis facilities with a significantly worse (SW) and facilities with a nonsignificant (NS) standardized readmission ratio (SRR). SRR estimates were risk adjusted for patient factors, past year comorbidities, and index hospitalization characteristics. Facility staffing variables were compared between 2 exposure groups: facilities with SW and NS SRRs. Four measures of staffing, including patient-to-staffing ratio, were compared between SW and matched NS facilities. ***Results:*** About 136,000–148,000 dialy-sis patients with 269,000–319,000 index hospital discharges were used to identify facilities with SW and facilities with NS SRR annually. Approximately 3–4% of facilities were identified as having SW SRR among >5,000 facilities annually. The percent of nurses-to-total staff was significantly lower in 2010 for SW facilities than in matched NS facilities (42.5 vs. 45.6%, $p = 0.012$), but this disparity was attenuated by 2013 (44.8 vs. 44.7%, $p = 0.949$). There was a higher patient-to-nurse ratio for SW facilities than for NS facilities (mean 16.4 vs. 15.2, $p = 0.038$) in 2010 as well, and the disparity was reduced by 2013. The trends were similar for patient-to-total staff and patient-to-registered nurse, but not statistically significant. ***Conclusions:*** This study found that dialysis facilities with SW 30-day readmission rates had lower proportions of nurses-to-total staff and higher patient-to-nurse ratios, but this disparity improved in recent years. Additional research is warranted focusing on how evidence-based staffing at dialysis facilities can contribute to reduction of hospital readmission, and this knowledge is needed to inform clinical practice guidelines and policy decisions regarding optimal dialysis patient staffing.

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Danh V. Nguyen, MS, PhD
Department of Medicine, University of California Irvine
333 City Blvd. West, Suite 400
Orange, CA 92868-3298 (USA)
E-Mail danhvn1@uci.edu

Introduction

Compared to most other morbid populations, dialysis patients have a substantially higher level of mortality and morbidity, particularly with respect to hospital readmissions [1, 2]. Dialysis patients were admitted to the hospital twice each year on average [1, 3]. Furthermore, about 30% of hospitalized dialysis patients had an unplanned readmission within 30 days [1], with substantial implications on patient morbidity burden, health-related quality of life, and costs [4].

In recent years, the Center for Medicare and Medicaid Services (CMS) have implemented quality of care measures for 30-day readmission based on *profiling models* [5–10], which compare the performance of a specific health-care provider, such as a hospital or dialysis facility, to the national average rate of readmission. The performance metric used was 30-day standardized readmission ratio (SRR). Profiling models provide dialysis facility-specific SRR estimates that are risk adjusted for patient factors, past year comorbidities, and index hospitalization characteristics [11, 12]. In this work, we conducted the first study that examined US dialysis patients from the United States Renal Data System (USRDS) across multiple years (2010–2013) to compare dialysis facilities' staffing, including the proportion of registered nurses (RNs)-to-total staff and ratios of patient-to-nurse and patient-to-total staff, between facilities identified as having a significantly worse (SW) and a nonsignificant (NS) 30-day SRR. Indeed, there is a current debate in the US among stakeholders, including policy makers, to mandate specific patient-to-staff ratios in dialysis facilities [13], although rigorous studies to form the evidence base are sparse.

We note that potential strategies to reduce the risk of readmission for dialysis patients are multifaceted. For example, care coordination strategies are important for postdischarge assessment and early intervention at the dialysis facility [14]. Coordination between hospital and outpatient dialysis units [15] and communication between dialysis staff, hospital staff, and physicians across both settings at the time of a patient's discharge have been discussed as target areas for improvement [16–18]. Our work here focuses on another modifiable factor, namely the patient care staffing at dialysis facilities. Indeed, staffing ratios and composition vary substantially across dialysis facilities [19]. We use a rigorous 2-stage analysis to identify SW and NS facilities in stage 1 and an independent comparative analysis of facility staffing characteristics between SW and NS facilities in stage 2.

Methods

Study Cohort and Data Source

The source data for the study was from the USRDS, a national registry that includes nearly all patients receiving care for end-stage renal disease (ESRD) in the US [20] from the years 2010–2013 (January 1, 2010, to December 31, 2013). Annual study cohort sizes are provided in online supplementary Figure 1 (see www.karger.com/doi/10.1159/000496147 for all online suppl. material). Patient-level data were collected from patient profile, payer history, Medical Evidence Form (CMS-2728), transplant, patient treatment history files, institutional claims files, and hospitalization standard analytic files. Facility-level data, including staffing and the number of patients receiving care, were obtained from the ESRD facility survey (CMS-2744). The study was approved by the University of California Irvine Institutional Review Board.

Index Discharges and Inclusion/Exclusion Criteria

Hospital data through December 31, 2013, were available for analysis. Hospitalizations with admission dates from January 1 through December 31 of each year were used. Index discharges were restricted to Medicare-covered hospitalization events at acute care hospitals. Index discharges were restricted to patients who were covered by Medicare as primary payer at day 91 from start of dialysis, because USRDS hospitalization data are incomplete for non-Medicare patients and for patients classified as Medicare as secondary payer [20]. Each hospital index discharge date was linked to the dialysis facility under which the patient was receiving dialysis care.

Exclusion criteria for index discharge included the following. Hospitalizations with length of stay longer than 365 days were excluded (unusual cases), and duplicate hospitalizations (identified as the same patient admitted to the same hospital with the same admission and discharge date) were removed. If a patient had more than 12 inpatient stays within 1 year, hospitalizations that occurred after the patient's 12th hospital admission within each year were excluded [11]. This cap in the readmission has been advocated to address concerns that allowing >12 discharges per person would unfairly affect smaller facilities [11]; however, because there were <1% of these cases, the impact was small [11]. Since index discharges are hospitalizations at acute care hospitals, discharges from skilled nursing facilities, long-term care hospitals, rehabilitation hospitals, and hospice were excluded. Hospitalizations for patients who were discharged against medical advice or transferred to another acute care facility were excluded as these do not capture unplanned readmission. In-hospital deaths were excluded as well because there would be no readmission. In addition, hospitalizations where patients were admitted for cancer, primary psychiatric diagnosis, and rehabilitation were excluded [11] as these events are not eligible as unplanned readmission. Also, a hospitalization was excluded if the patient died within 30 days from discharge because there was no opportunity for 30-day readmission.

An extremely small facility with several patients is not appropriate for profiling analysis to assess the facility's readmission rate; therefore, facilities with <10 index discharges were excluded. Also, when a facility's raw readmission rate (calculated as the percentage of 30-day readmission among all index discharges) equaled 1 (i.e., all index hospitalizations resulted in readmissions within 30 days), the facility was excluded. This occurred for extremely small facili-

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ties with 1–4 patients. Dialysis facility exclusion is documented in online supplementary Table 1.

Outcomes

The outcome was all-cause unplanned readmission to an acute care hospital within 30 days after the date of an index hospitalization discharge in stage 1. A readmission was designated as planned or unplanned following CMS methodology for all-cause 30-day readmission [8, 11]. Planned readmissions were defined as readmissions that were either nonacute or for a maintenance care/therapy. More specifically, a prespecified list of 32 planned procedures was defined using the full Agency for Healthcare Research and Quality Clinical Classification System procedure category (see online suppl. Table 2A) [8]. Admissions for an acute illness or for complications of care were not "planned." Discharge condition categories considered as acute or complications of care were listed in supplementary Table 2B [8]. Only admissions during which at least 1 of the 32 listed procedures were performed, and concerning patients who were not admitted for an acute illness or complications of care, were considered "planned," otherwise they were considered unplanned.

Four patient care staffing outcomes were considered in stage 2 analysis, which compared dialysis facilities' staffing between facilities with SW and NS 30-day readmissions: (1) percent of nurses-to-total staff, (2) patient-to-nurse ratio, (3) patient-to-RN ratio, and (4) patient-to-total staff ratio. The number of RNs included the number of full-time RNs plus part-time RNs, but a part-time RN was counted as one-half RN. The number of nurses was defined to be the number of RNs and licensed practical nurses, and total staff included RNs, licensed practical nurses, and patient care technicians. The number of patients was defined as the number of dialysis outpatients at the end of the year.

Covariates and Exposure

Profiling analysis in stage 1 aims to estimate the facility-specific SRR, adjusted for patient risk factors/covariates. The rationale for the categories of risk adjustment for 30-day hospital-wide readmission and their development has been reported [8, 9, 11]. Similarly, in profiling models here we adjusted for age at hospitalization, sex, body mass index, diabetes as the cause of ESRD, years on dialysis, length of index hospitalization, high-risk index hospitalization, and past-year comorbidities (online suppl. Table 3). Past-year comorbidities were created by defining unique ICD-9 diagnosis codes from institutional claims within 1 year before admission dates. Five claim sources were used: inpatient, outpatient, skilled nursing facility, hospice, and home health claims. These diagnosis codes were grouped by using the Department of Health and Human Services' hierarchical condition categories [21]. Past-year comorbidities are listed in online supplementary Table 3. Finally, high-risk diagnosis was defined as any diagnosis area that was extremely rare but had a 30-day readmission rate of at least 40% using 11 Clinical Classification System areas identified as high risk [21] (online suppl. Table 2C). In stage 2 analyses (facility level), the exposure groups were SW and NS facilities.

Statistical Analysis

Stage 1

Profiling models that provide effective risk adjustment include random effects (RE) [8, 10] and fixed effects (FE) [11, 12, 22] hierarchical logistic regression models (HLRMs). In stage 1 analysis, HLRMs were used to profile dialysis facilities using 30-day readmissions as the outcome, adjusted for patient risk factors. The HLRM was used to estimate the risk-adjusted SRR for each dialysis facility. SRR is the ratio of the number of readmissions for a specific facility to the expected number of readmissions assuming a national average and adjusted for patient-level risk factors. We considered both RE and FE models. For FE models, we examined 2 FE models, FE1 and FE2, where FE2 adds a RE to the FE1 model to account for additional variation in discharging hospitals [12]. Each profiling model was used to flag SW and NS facilities. For the RE model, a bootstrap based on 500 resampling of facilities with replacement was used to obtain 95% confidence intervals (CIs) for SRRs [8, 10]. For FE models, inference was based on testing the null hypothesis that SRR = 1 through 500 resampling under the null with empirical null adjustment [22, 23].

Stage 2

To allow for risk adjustment required in stage 1 and to avoid confounding of the patient care process variables with patient risk factors and outcome (readmission), facilities that have SW and NS readmissions were independently identified by profiling models in stage 1. However, a direct comparison of patient care staffing variables between SW and NS facilities is not appropriate because of differences in patient case-mix characteristics, including comorbidities. Therefore, in stage 2, we first matched facilities with NS readmissions to facilities with SW readmissions with respect to average patient risk factors as well as facility size (number of patients). Matching was achieved using the propensity score [24, 25], and adequacy of matching was assessed by checking the balances of covariates before and after matching using the absolute standardized difference criteria [26]. Comparisons of patient staffing variables between matched sets of SW and NS facilities were based on multiple linear regression models (to doubly adjust for average patient risk factors). Finally, a secondary analysis to assess changes in patient staffing over time was based on linear mixed effects models. SAS/STAT® version 9.4 was used for all analyses [27], except for RE and FE profiling models which were implemented in R version 3.4 [28].

Results

Study Cohorts

The study cohort for each year comprised about 146,000–148,000 patients with raw unplanned 30-day readmission rates of about 30% among approximately 310,000–319,000 index discharges (online suppl. Table 4). For each year, over 5,000 dialysis facilities were included for profiling analysis.

Characteristics of patient risk factors prior to index hospitalization are summarized in online supplementary Table 3. For example, the 2013 cohort comprised 63% of patients aged 45–75 years and 48% females. Approximately 24, 15, 12, 25, and 23% of patients were on ESRD for <1, 1–2, 2–3, 3–6, and >6 years, respectively. Diabetes was the cause of ESRD in about 43% of patients. High-risk index hospitalizations accounted for about 1% of hospi-
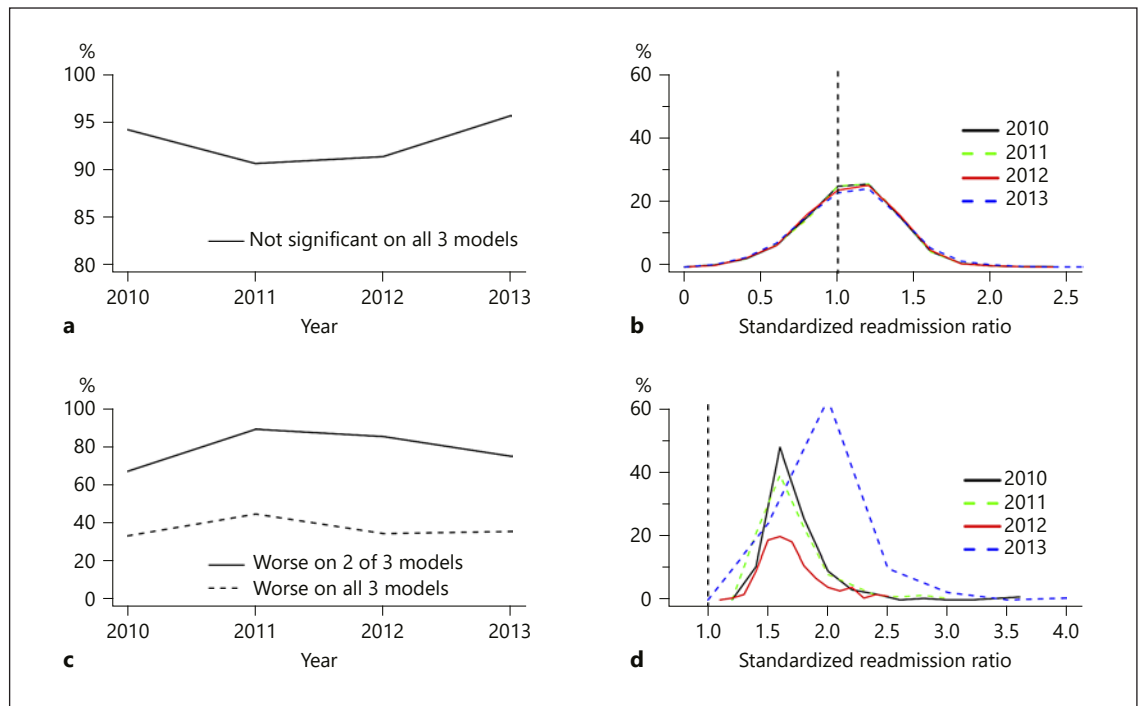
Fig. 1. Dialysis facilities flagged by profiling models in 2010–2013. **a** Dialysis facilities flagged as nonsignificant (denominator is the total number of facilities in each year from 2010 to 2013: N_F = 5,346, 5,579, 5,637, and 5,628). **b** Among facilities flagged as significantly worse (SW) by at least 1 model (2010–2013: N_F = 222, 211, 176, and 171); the percentage flagged as SW by all 3 models is presented. Distribution of estimated standardized readmission ratio for facilities flagged as nonsignificant (**c**) and SW (**d**).
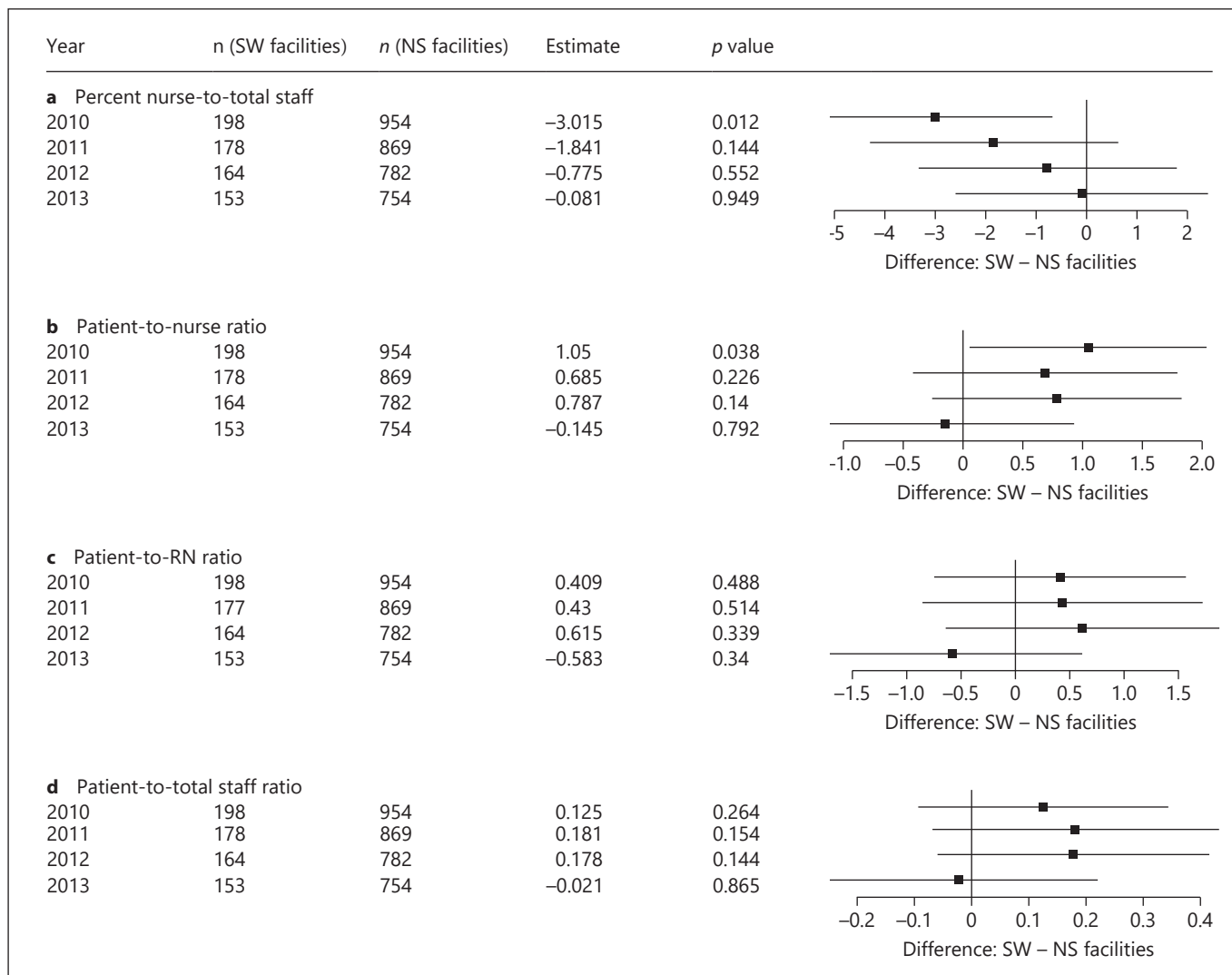
talizations, and 47, 22, and 31% of hospitalizations were for <5, 5 or 6, and >6 days in duration, respectively. Past-year comorbidities prior to index hospitalization are also summarized in online supplementary Table 3. The most common past-year comorbidities were chronic obstructive pulmonary disease (26%), cardiorespiratory failure/shock (22%), coagulation defects and other specified hematological disorders (16%), other infectious disease and pneumonias (41%), septicemia/shock (17%), and psychiatric comorbidity (29%).

Stage 1: Identifying Dialysis Facilities with SW SRR
Profiling models identified facilities with SW and NS risk-adjusted SRRs. Profiling results for the 2010 cohort are summarized in online supplementary Table 5. Approximately 94–96% of all facilities were flagged as NS by all 3 models across years; i.e., 94–96% of facilities had SRRs not different from the national average. Highlighted in online supplementary Table 5 are the flagging results for the 2010 cohort with 94% (N_F = 5,043) NS facilities and N_F = 222 facilities flagged as having SW SRRs by at least 1 of the 3 models. Figure 1a, b shows the results

over time with respect to facilities flagged as NS (Fig. 1a) and SW (Fig. 1b). We note that the overall rate of facilities flagged as SW by at least 1 model was similar for 2010–2013: 4.2% (222/5,346), 3.8% (211/5,579), 3.1% (176/5,637), and 3.0% (171/5,628), respectively. The estimated SRRs for facilities that were NS and SW are displayed in Figure 1c and d, respectively. For SW facilities, the 5th and 95th percentiles of the estimated SRRs were 1.3 and 2.1 in 2010, respectively, and the distributions of SW SRRs were similar across years.

Trends in the adjusted odds ratio (OR) and associated 95% CIs for patient risk factors are summarized in online supplementary Figure 2 for the 2011 cohort. Most past-year comorbidities were associated with significantly higher odds of 30-day readmission, except for 4 comorbid groups: hip fracture, transplant, respiratory dependence, and rheumatoid arthritis/inflammatory connective tissue disease. Significant risk factors associated with 9% (OR 1.09, 95% CI 1.05–1.13), 27% (OR 1.27, 95% CI 1.26–1.29), and 40% (OR 1.40, 95% CI 1.35–1.45) higher odds of readmission were motor impairment, other infectious disease, and drug or alcohol disorders (online suppl. Fig. 2A).

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Year	n (SW facilities)	n (NS facilities)	Estimate	p value
a Percent nurse-to-total staff				
2010	198	954	−3.015	0.012
2011	178	869	−1.841	0.144
2012	164	782	−0.775	0.552
2013	153	754	−0.081	0.949
b Patient-to-nurse ratio				
2010	198	954	1.05	0.038
2011	178	869	0.685	0.226
2012	164	782	0.787	0.14
2013	153	754	−0.145	0.792
c Patient-to-RN ratio				
2010	198	954	0.409	0.488
2011	177	869	0.43	0.514
2012	164	782	0.615	0.339
2013	153	754	−0.583	0.34
d Patient-to-total staff ratio				
2010	198	954	0.125	0.264
2011	178	869	0.181	0.154
2012	164	782	0.178	0.144
2013	153	754	−0.021	0.865

Fig. 2. Comparison of patient staffing characteristics in dialysis facilities with significantly worse (SW) readmission versus facilities with nonsignificant (NS) readmission in the years 2010–2013 (*n* = number of facilities). RN, registered nurses.

Females, younger age groups (<25 and 25–45 years) relative to the 45–60 years reference group, diabetes as the cause of ESRD, high-risk index discharge, and longer index hospitalization were associated with higher risk of readmission (online suppl. Fig. 2B). These trends in the adjusted ORs were similar for the 2012 through 2013 cohorts (results not shown).

Stage 2: Comparison of Dialysis Facility Patient Care Staffing

In stage 2 analysis, we compared dialysis facilities' staffing levels and patient-to-staff composition between SW and NS facilities. The numbers of facilities with SW SRRs identified from stage 1 were 222, 211, 176, and 171 for the years 2010–2013, respectively. We removed extreme outlier facilities. Specifically, facilities with nurses, total staff, and patient-to-total staff ratios greater than the 99.5th percentile, or with patient-to-total staff ratios that were smaller than the 0.5th percentile, which appeared to include database errors, were excluded. Also, similar to previous work [19], facilities with 0 nurses were not included. This resulted in N_F = 198, 178, 164, and 153 SW facilities (years 2010–2013, respectively) used in stage 2 analysis. As described above, a large number of facilities with NS SRR were identified (>5,000 facilities); however, patient case-mix characteristics, including comorbidities,

Table 1. Summary statistics of staffing variables for a matched set of significantly worse facilities and nonsignificant facilities for the 2010–2013 cohorts

Year	Variable	Significantly worse facilities			Nonsignificant facilities		
		n	mean	SD	n	mean	SD
2010	patient-to-RN ratio	198	18.61	7.18	954	18.11	7.85
	patient-to-nurse ratio	198	16.36	6.38	954	15.24	6.63
	patient-to-total staff ratio	198	6.28	1.45	954	6.15	1.45
	percent of nurses-to-total staff	198	42.50	14.56	954	45.60	15.92
2011	patient-to-RN ratio	177	18.51	7.79	869	17.97	8.36
	patient-to-nurse ratio	178	16.30	6.99	869	15.51	7.18
	patient-to-total staff ratio	178	6.34	1.69	869	6.15	1.59
	percent of nurses-to-total staff	178	43.38	15.22	869	45.45	16.49
2012	patient-to-RN ratio	164	17.50	7.14	782	16.82	7.82
	patient-to-nurse ratio	164	15.25	6.61	782	14.44	6.34
	patient-to-total staff ratio	164	6.09	1.31	782	5.93	1.52
	percent of nurses-to-total staff	164	45.43	16.01	782	46.35	15.98
2013	patient-to-RN ratio	153	16.66	6.56	754	17.29	7.26
	patient-to-nurse ratio	153	14.87	6.08	754	15.04	6.40
	patient-to-total staff ratio	153	5.96	1.33	754	5.98	1.44
	percent of nurses-to-total staff	153	44.83	15.41	754	44.75	15.07

SD, standard deviation; RN, registered nurses.

in these NS facilities differed from SW facilities (online suppl. Fig. 3 – before matching). Thus, we first matched NS facilities to SW facilities on average patient age, facility size, percent of high-risk discharges, frequencies of past-year comorbidities, and all other risk factors presented in online supplementary Table 3. A maximum of 5 NS facilities was matched with each SW facility. In 93% of cases, the SW:NS match was 1 SW:5 NS facilities, while for the remaining 7%, the match was 1 SW:1–4 NS facilities. Online supplementary Figure 3 shows the adequacy of matching results with absolute standardized differences <0.1.

Patient staffing level and ratios between matched SW and NS facilities are summarized in Table 1. In 2010, the average (SD) percent of nurses-to-total staff was 42.5% (14.6%) for SW facilities and 45.6% (15.9%) for NS facilities ($p = 0.012$; Fig. 2a), and the model-based estimate of the average percentage of nurses-to-total staff was 3.0% lower for SW facilities (Fig. 2a). The observed disparity in the average percentage of nurses-to-total staff between SW and NS facilities was reduced in the year 2011 and was nearly equalized by 2013: mean 44.8% (15.4%) for SW facilities and 44.8% (15.1%) for NS facilities ($p = 0.949$; Table 1; Fig. 2a).

The average (SD) patient-to-nurse ratio was higher by 1.1 for SW than for NS facilities: mean 16.4 (6.4) versus 15.2 (6.6) ($p = 0.038$; Table 1; Fig. 2b). The average (SD) patient-to-nurse ratios in SW and NS facilities were similar in 2011 and 2012, although in 2013 the difference between SW and NS facilities was negligible: mean 14.9 (6.1) for SW facilities versus 15.0 (6.4) for NS facilities ($p = 0.792$; Table 1; Fig. 2b). For patient volume relative to RNs, the overall pattern of results was similar between SW and NS facilities, although not statistically significant. For example, the average (SD) patient-to-RN ratio was 17.5 (7.1) for SW facilities versus 16.8 (7.8) for NS facilities by 2012 ($p = 0.339$; Fig. 2c) and was also similar in 2013.

A trend of SW facilities having a higher average patient-to-total staff ratio, based on the pattern of 95% CIs (Fig. 2d), was also observed in 2010–2012. In 2013, the difference in patient-to-staff ratio between SW and NS facilities was negligible.

Finally, in a secondary analysis we assessed the facility staffing characteristics' longitudinal trend using linear mixed effects models. We found that relative to 2010, there has been an overall significant decline in patient-to-RN, patient-to-nurse, and patient-to-staff ratios, while

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Table 2. Linear mixed effects model for facility staffing characteristics assessing longitudinal trend within matched sample

Outcome	Comparison	Estimate	Standard error	p value
Patient-to-RN ratio	2011 versus 2010	−0.33	0.11	0.003
	2012 versus 2010	−1.19	0.11	<0.001
	2013 versus 2010	−1.24	0.11	<0.001
Patient-to-nurse ratio	2011 versus 2010	−0.08	0.08	0.352
	2012 versus 2010	−0.66	0.08	<0.001
	2013 versus 2010	−0.68	0.08	<0.001
Patient-to-total staff ratio	2011 versus 2010	−0.05	0.02	0.037
	2012 versus 2010	−0.21	0.02	<0.001
	2013 versus 2010	−0.21	0.02	<0.001
Percent of nurses-to-total staff	2011 versus 2010	0.01	0.16	0.947
	2012 versus 2010	0.26	0.16	0.099
	2013 versus 2010	0.32	0.16	0.041

RN, registered nurses.

there was an increase in the percent of nurses relative to total patient care staff (Table 2).

We note that the main interest in profiling analysis centers on identifying SW facilities compared to NS facilities. However, although typically not considered, we also examined dialysis facilities identified with *significantly better* (SB) hospital readmission rates (i.e., readmission rates significantly lower than the national average). The results show that staffing characteristics for SB facilities were not different from NS facilities (online suppl. Fig. 4). Thus, the pattern of results described above was observed in SW facilities only and not in SB facilities.

Discussion

Unplanned hospital readmissions are a major health burden to patients and cost to the health-care system, and even more so for dialysis patients given the substantially higher rate of 30-day unplanned readmission compared to the general population [3]. Using the national data and rigorous patient-level profiling models, we identified dialysis facilities that had SW and NS annual readmission rates. After matching to eliminate differences in patient characteristics (and facility size) between SW and NS facilities, we found that SW facilities had higher ratios of patient-to-nurse and lower nurses-to-total staff, particularly in earlier years (e.g., 2010). These disparities appeared to have been attenuated by 2013. As national pa-

tient-level data are released in the coming years, it would be of interest to monitor these encouraging trends in patient staffing ratios.

Also, although qualitative, we note that the average ratios of patient-to-RN, patient-to-nurse, and patient-to-total staff all declined from 2010 to 2013 (Table 1, 2), similar to the decline in the overall rate of SW facilities (from 4.2, 3.8, and 3.1 to 3.0% from 2010 to 2013, respectively). Furthermore, during these years, there was an increase in the percent of nurses-to-total staff (from 42.5 to 44.8%) as well.

Preventing recurrent hospitalizations in dialysis patients is a complex process that involves multiple areas, including (1) managing patients' medical issues before, during, and after hospitalization (e.g., anemia, malnutrition, volume overload, mineral metabolism disorders, and infection) [17]; and (2) timely communication and coordination of care between hospital and ambulatory dialysis facility staff and physicians. Patients may be prescribed new therapies or undergo changes in their health parameters over the course of their hospitalization that require monitoring and/or adjustment to their prior management approaches upon returning to their outpatient dialysis facility. Furthermore, given their frequency of interaction, ambulatory dialysis staff and physicians may be the first providers to assess patients following hospital discharge, including medication reconciliation [18, 29, 30]. Also, critical health parameters, including patients' anemia (e.g., hemoglobin), serum albumin, and

mineral bone disease (e.g., calcium, phosphorus, and parathyroid hormone) as well as dry weights may have substantially changed over the course of hospitalization, and in prior studies of dialysis patients these parameters were found to be significantly decreased after hospitalization [14]. Therefore, care coordination and discharge planning are paramount for timely implementation of posthospitalization care, optimization of health status, and early identification and intervention for recurrent illness immediately following discharge. Improved patient care coordination and intervention to reduce readmission has also been examined extensively in the non-ESRD populations [31–37]. Thus, adequate dialysis facility staffing is critical.

Our work here systematically examined a largely overlooked factor, specifically the dialysis patient staffing ratio and infrastructure within dialysis facilities, as a contributor to unplanned hospital readmissions. Staffing levels and composition in dialysis facilities are ultimately modifiable factors that can be optimized and thereby improve patient outcomes [38, 39]. Structural staffing issues, specifically inadequate nurse staffing in acute care hospitals, have been linked to heightened risk of infection [40], mortality [41], and other adverse consequences [42–45]. Adequacy of dialysis clinic staffing and quality of care are linked [46], although what constitutes "adequate" staffing at dialysis facilities has not yet been defined, particularly with respect to ameliorating hospitalization risk [47]. Indeed, there is urgent need for further study of the optimal dialysis patient-to-staffing ratios given recent controversy with respect to legislation regarding mandated dialysis staffing ratios in ambulatory facilities. For example, in the state of California serving 63,000 dialysis patients across 560 freestanding dialysis clinics, there has been a proposal of a State Senate Bill, the "Dialysis Patient Safety Act" (SB 349 [48, 49]), which would mandate dialysis patient-to-nurse ratios of 8:1, as well as patient-to-technician and patient-to-social worker ratios of 3:1 and 75:1, respectively. While this would be the first US law to mandate dialysis staffing ratios, other states have set minimum staffing requirements via administrative regulations. Hence, rigorous studies are needed to determine adequate dialysis facility staffing ratios associated with optimal patient outcomes in order to guide stakeholders, including policy makers, regulatory bodies, patients, and dialysis facility providers [13].

Our study utilized a 2-stage analysis to avoid confounding of the patient care process (staffing) variables with patient risk factors and the outcome, 30-day readmissions. In the first stage, a profiling model (hierarchical logistic regression) was used to estimate facility effects (contribution of a facility total process to hospital readmission of patients at that facility). We note that a common misunderstanding in profiling analysis centers on the intuition to include (adjust for) factors related to the process of care, such as the effect of nephrologist or nephrology care or other facility-level factors, including management strategies (e.g., infection control policies). No facility-level factors or no factors on the "causal pathway" after the start of follow-up for a patient (e.g., level of nephrologist care) should be included as a basis to assess SRR [10–12, 50] because doing so would explain away variation in outcomes presumably attributable to dialysis facilities. However, there are several limitations. A limitation of our study is the quality of the self-reported data from the annual facility survey due to potential reporting errors or data entry errors. Additionally, we did not examine potential contributions of dietitians and social workers employed at dialysis facilities because >75% of dialysis facilities did not report or reported ≤1 dietitian or social worker. Also, lack of data precluded an examination of factors such as patient-to-nephrologist ratio and dialysis nurses' level of experience in stage 2 analysis.

Our study focused on SRR and associated staffing ratios in the US dialysis population. Similar analyses in other populations, such as other countries/regions, would facilitate interesting comparative studies. Towards this objective, establishment of appropriate population registries that include hospitalization is needed.

In summary, this study found that dialysis facilities with SW 30-day hospital readmissions have lower proportions of nurses-to-total staff and higher patient-to-nurse ratios. However, the disparities in staffing characteristics between SW and NS facilities were attenuated by 2013. Although there were trends of higher patient-to-RN and higher patient-to-total staff ratios in facilities with SW SRRs, these were not statistically significant. Annual monitoring/profiling analysis, as described here, is a useful tool to see whether this trend continues or reverses over time as data become available. Finally, the evidence from this study does not definitely support or not support mandated staffing ratios. Rather, it highlights the critical need to develop the evidence base of how patient care staffing at dialysis facilities can contribute to a reduction of hospital readmissions, and this knowledge is needed to inform clinical practice guidelines and policy decisions regarding optimal dialysis patient staffing, which currently are lacking.

Statement of Ethics

The study was approved by the University of California Irvine Institutional Review Board.

Disclosure Statement

K.K.-Z. has served as a medical director of FMC and Davita dialysis clinics. The other authors declare that they have no other relevant financial interests.

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