Report for the

Standardized Readmission Ratio

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Introduction

In 2013, the Centers for Medicare and Medicaid Services (CMS) rolled out a new approach to ensuring safe and adequate health care delivery to its patients: the CMS Quality Strategy (CMS, 2013). The CMS strategy is designed to align with the six goals of the Department of Health and Human Services' (HHS) National Quality Strategy. The CMS strategy is framed in the following way: "To improve, a broad-based and seamless reform approach is necessary to address challenges in our healthcare system—escalating costs, inadequate coverage and inefficient care of variable quality" (CMS, 2013).

Dialysis patients are a population particularly affected by such issues. Relative to the general population, they experience much higher levels of mortality (de Jager et al., 2009) and morbidity (e.g., hospital readmission; MedPAC, 2007). Both hospitalization and readmission rates reflect morbidity and quality of life of dialysis patients as well as medical costs. For example, in 2011 dialysis patients were admitted to the hospital twice on average and spent an average of 12 days in the hospital, accounting for approximately 38% of Medicare expenditures for ESRD patients (USRDS, 2013). Furthermore, 36% of hemodialysis patients discharged from the hospital had an unplanned readmission within 30 days (USRDS, 2013). In other settings (e.g., cardiovascular disease, cancer), some studies show that about 25% of unplanned readmissions are preventable, that preventability vary widely across diagnoses, and that readmissions were more likely to be preventable for patients with more severe conditions (van Walraven et al., 2011).

In the dialysis setting, care coordination strategies, including appropriate hand-off and timely pre- and post-discharge communication among care providers, have emerged as a potentially effective means to reduce unplanned readmission among the ESRD patients. A recent study in the ESRD population found that certain post-discharge assessments and changes in treatment at the dialysis facility may be associated with a reduced risk of readmission (Chan et al., 2009). A recent multi-unit qualitative study by Reilly et al. (2013) found that a lack of care coordination between in- and outpatient dialysis units post-discharge is associated with increased readmission rates. Other articles concerning the dialysis setting (e.g. Castner,2011; Wish, 2014; Plantinga and Jarr, 2009) discuss the importance of dialysis facility and physician communication with the discharging hospital in order to ensure appropriate coordination of care such as reconciliation of post-discharge medications and treatment orders.

Clinical studies in the non-ESRD populations have also demonstrated that improved care coordination and discharge planning can reduce readmission rates (e.g., Dunn, 1994; Bostrom, 1996; Dudas, 2001; Azevedo, 2002; Coleman, 2004; Coleman, 2006; Balaban, 2008; Braun, 2009) or a combination of pre- and post-discharge interventions (e.g., Naylor, 1994; McDonald, 2001; Creason, 2001; Ahmed, 2004; Anderson, 2005; Jack, 2009; Koehler, 2009; Parry, 2009). Readmission measures have been developed in various care settings, including hospitals and skilled nursing facilities.

With the U.S. healthcare system moving toward a paradigm of shared accountability across providers from different care settings, a readmission measure that is particularly applicable to ESRD patients will not only encourage improvement in transition of care across various settings, but will also serve as a

strong motivation for facilities to coordinate treatment with the discharging hospital to reduce readmission rates. Such a measure should also encourage facilities to review readmission practices and identify potential problems. Moreover, measures of the frequency of unplanned readmissions are essential for controlling escalating medical costs in that they can help facilities identify problems and potentially improve care and reduce costs.

In 2011, a measure of 30-day readmission was added to the Dialysis Facility Reports, which have been used by dialysis facilities and ESRD Networks for quality improvement, and by ESRD state surveyors for monitoring and surveillance of dialysis facilities.

Methods

Overview

We developed the risk-adjusted Standardized Readmission Ratio (SRR), a measure of 30-day unplanned hospital readmission for dialysis patients discharged from any acute care hospital in the U.S. (He et al., 2013). The event of interest is an unplanned readmission within 30 days following an initiating hospitalization, termed an *index hospital discharge*, identified through the Medicare administrative data. To properly adjust for patient characteristics that may make unplanned readmission more likely, we used Medicare administrative data to characterize each patient's comorbidity history, which we derived from inpatient, outpatient institutional, home health, hospice and skilled nursing facility claims.

The SRR reflects the number of readmission events for the patients at a facility, relative to the number of readmission events that would be expected based on overall national rates and the characteristics of the patients at that facility as well as the number of discharges. Specifically, the SRR is calculated as the ratio of two numbers; the numerator ("observed") is the actual number of readmission events over a specified time period, and the denominator ("expected") is the number of readmission events that would be expected if patients at that facility experienced readmission events at the national median rate for patients with similar characteristics. Where it was considered appropriate, the SRR was developed to be consistent with the (NQF# 1789) Hospital-Wide Readmission Measure (HWR) for hospitals, and incorporates a number of similar elements, including planned readmissions exclusions (YNHHSC/CORE, 2013 [Appendix E]) as well as similar denominator exclusion criteria. Taken in concert, the SRR and HWR are intended to bring excess readmissions to the attention of both the dialysis facility and the hospital of discharge.

As the denominator of the SRR estimates the expected number of readmissions given the observed number of discharges, the SRR may suggest a very high rate of readmissions even though the facility in question has a relatively low overall hospitalization rate. To avoid this situation, it has been suggested that the SRR should take as a reference the set of all patients in the facility rather than the set of hospital discharges. The Standardized Hospitalization Ratio (SHR) is an overall measure of hospital usage by patients at a dialysis facility and evaluates the overall rate of hospitalizations taking account of the number and characteristics of patients in the facility. Consideration of the SHR and the SRR together

may prove useful in this respect. They measure two distinct aspects of the hospital usage by patients at a dialysis facility. As indicated, the SHR measures the effectiveness of care for chronically ill patients who frequently have multiple comorbidities, whereas the SRR focuses on communication and care coordination as patients return from acute hospitalization. A facility with a low SHR and high SRR is one where the overall frequency of hospitalization is relatively low, but where there may still be advantage in reviewing the processes associated with hospital discharge and readmission.

Measure Development

In April 2012, a CMS Technical Expert Panel (TEP) reviewed a preliminary version of the measure and suggested refinements. In response to suggestions, several changes were made to the SRR, which then was released for public comment in April 2013. However, some TEP members expressed concern about the measure, mainly regarding the lack of adjustment for physician(s) associated with the discharge and the readmission, and a related concern regarding facilities' not having full control over the implementation of changes that would address readmissions. CMS' position on both issues is detailed in the Risk Adjustment section of this document. Another concern raised during the TEP meeting was the use of index discharges, instead of patients, as defining the denominator. This is commented on briefly in the previous paragraph. As of June 2014, the SRR is under review by the National Quality Forum (NQF) for measure endorsement.

Data Sources

Data are derived from an extensive national ESRD patient database, which is primarily based on the CMS Consolidated Renal Operations in a Web-enabled Network (CROWN) system. The CROWN data include the Renal Management Information System (REMIS), CROWNWeb facility-reported clinical and administrative data (including CMS-2728 Medical Evidence Form, CMS-2746 Death Notification Form, and CMS-2744 Annual Facility Survey Form data), the historical Standard Information Management System (SIMS) database (formerly maintained by the 18 ESRD Networks until replaced by CROWNWeb in May 2012), the National Vascular Access Improvement Initiative's Fistula First project (in CROWNWeb since May 2012), Medicare dialysis and hospital payment records, transplant data from the Organ Procurement and Transplant Network (OPTN), the Nursing Home Minimum Dataset, the Quality Improvement Evaluation System (QIES) Workbench, which includes data from the Certification and Survey Provider Enhanced Report System (CASPER), the Dialysis Facility Compare (DFC) and the Social Security Death Master File. The database is comprehensive for Medicare patients. Non-Medicare patients are included in all sources except for the Medicare payment records. CROWNWeb provides tracking by dialysis provider and treatment modality for non-Medicare patients. Information on hospitalizations is obtained from Part A Medicare Inpatient Claims Standard Analysis Files (SAFs), and past-year comorbidity is obtained from multiple Part A types (inpatient, home health, hospice, skilled nursing facility claims) and Part B outpatient types of Medicare Claims SAFs.

Outcome Definition

The event is defined to be an unplanned readmission to an acute care hospital for any cause within 30 days of the discharge date for the index hospitalization.

Cohort Definition and Inclusion/Exclusion

Index discharges are restricted to Medicare-covered hospitalizations for inpatient care at short-term acute care hospitals and critical access hospitals. Discharges from skilled nursing facilities (SNFs), long-term care hospitals (LTCHs), rehabilitation hospitals and PPS-exempt cancer hospitals—as well as those from separate dedicated units for hospice, rehabilitation and psychiatric care—are excluded. To be counted as an index discharge, the patient must be receiving dialysis treatment for ESRD at the time of discharge. If the patient is not on dialysis at discharge or is not discharged to a dialysis facility, the hospitalization is not included as an index discharge.

In addition, index discharges exclude hospitalizations:

- for patients who died during the hospitalization (because there was no opportunity for readmission);
- for patients who were discharged against medical advice (AMA);
- that are followed in 30 days by the patient's death (and no readmission);
- that ended in a transfer to another acute care facility (for patients who are transferred between one acute care hospital and another, the measure considers these multiple contiguous hospitalizations as a single acute episode of care, and readmission for transferred patients is attributed to the hospital that ultimately discharges the patient to a non-acute care setting);
- that took place at Prospective Payment System (PPS)-exempt cancer hospitals;
- that occur after a patient's 12th hospital admission in the time period; and
- where the patient was admitted for medical treatment of cancer, primary psychiatric diagnoses or rehabilitation.

Index discharges are assigned to the dialysis provider to which the patient is discharged at the end of the hospital stay. In other words, the facility to which the patient is discharged is held responsible for any unplanned readmissions occurring within 30 days of the index discharge, regardless of whether the patient is still being treated at the facility associated with the index discharge.

Capping Readmissions

Facility size is a major factor in the decision to restrict "frequent flyers" from the measure. During the TEP's review of the measure, members were concerned that, especially for small facilities, allowing a patient at high risk of readmission (e.g., an HIV-positive patient) to contribute without limit to the denominator and numerator could unfairly skew that facility's measure. In response to this concern, we removed hospitalizations following an individual patient's 12th discharge in the time period. Sensitivity analyses excluding this cap (representing 0.8% of 2012 hospital discharges) led to only small changes in the flagging rate for smaller facilities.

Early Readmissions

During CMS' public comment period for the measure, several commenters suggested excluding readmissions occurring within the first few days following discharge. This suggestion was motivated by

the fact that the dialysis facility may not have an opportunity to see the patient before he/she is readmitted.

As indicated in Figure1, about 16% of dialysis patient hospital readmissions occur in the first 3 days after index discharge. This is the most vulnerable period after a patient is discharged from the hospital. As most dialysis facilities presently operate, they typically do not see patients after hospital discharge until the patient comes for the first post discharge dialysis session, often two or three days later; as mentioned, the concern is expressed that dialysis facilities may have no way to address these early readmissions to the hospital.

On the other hand, including readmissions within the first few days after discharge would encourage closer cooperation between the dialysis facility and the hospital in the process of hospital discharge. One concern is that some hospitals may not be as cognizant of ESRD care as are dialysis facilities, and patients are sometimes discharged having received inadequate ESRD care. This would be an extension of the paradigm of measures being constructed to affect processes and encourage coordination of care, with the aim of developing a new norm. It should also be noted that adjusting for hospital effects avoids full attribution of the readmission to a dialysis facility in situations where care cannot be coordinated.

Figure 2 illustrates the change in SRR if the first three days post-discharge are dropped from the measure. The correlation between the two versions of the measure is 0.96. Table 1 also describes flagging rates for the SRR with and without readmissions over the first three days. The percentage agreement between the two versions of the measure is 97.3%. Approximately 0.8% of dialysis facilities were classified as “As Expected” when early readmissions were included and “Worse than Expected” when early readmissions were removed; 0.7% of dialysis facilities moved in the other direction. These changes are relatively small but significant for the affected facilities.

Given its aim of encouraging care coordination between dialysis facilities and hospitals even for early readmissions, CMS decided to include all readmissions, both early and later, in the measure.

Figure 1. Distribution of days between index discharge and readmission, 2012.

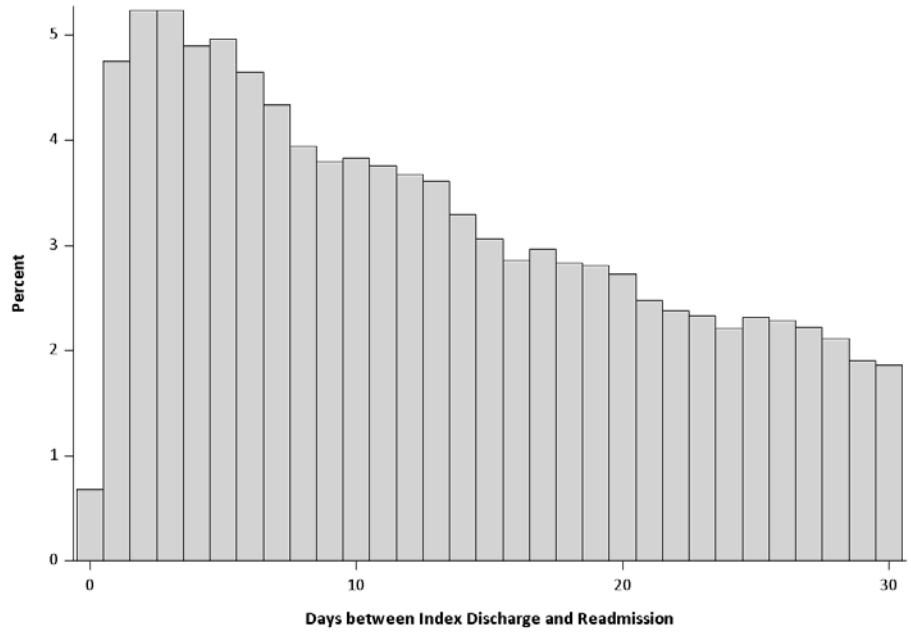
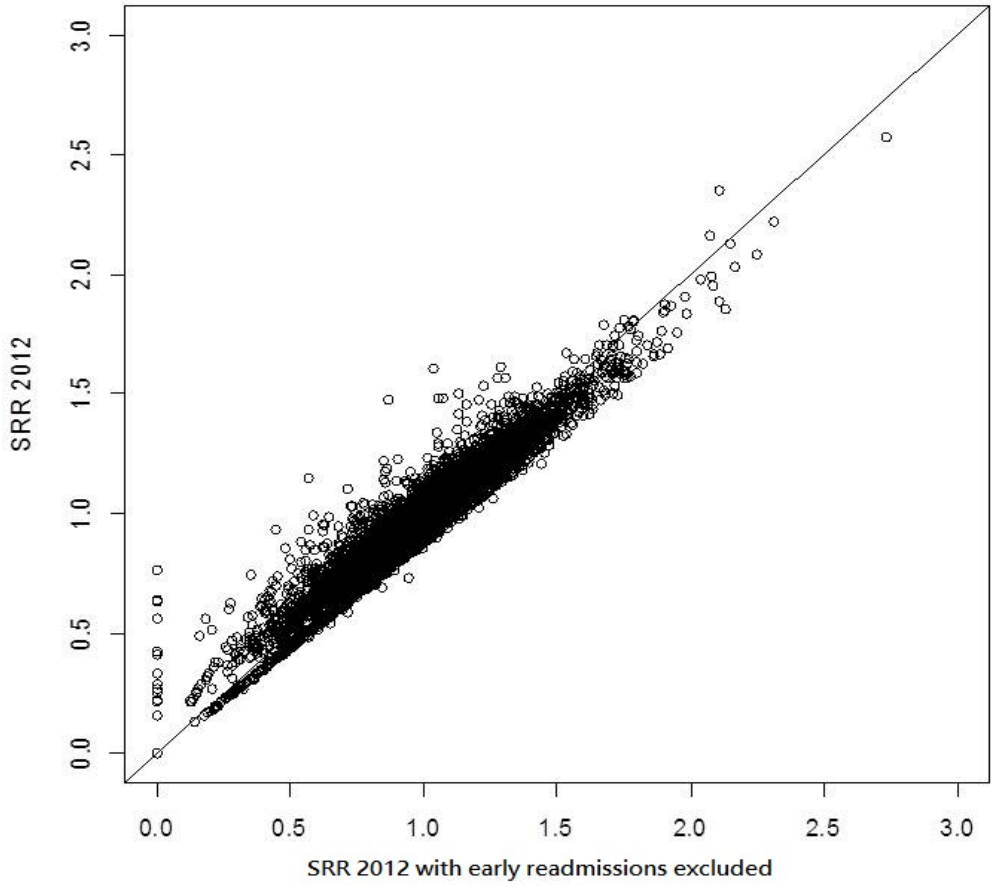


Figure 2. Comparison of SRRs when readmissions in the first 3 days are excluded versus included, 2012.



Note. Dialysis facilities with fewer than 11 discharges in the year are excluded.

Table 1. Change in Dialysis Facility Categorization when Readmissions in the First 3 Days Are Excluded versus Included, 2012

	Early readmissions excluded			
Early readmissions included	**Significantly worse**	**Non-significant**	**Significantly better**	**Total**
Significantly worse	154 (2.7%)	32 (0.6%)	0	**186 (3.2%)**
Non-significant	50 (0.9%)	5370 (93.4%)	45 (0.8%)	**5465 (95.0%)**
Significantly better	0	31 (0.5%)	70 (1.2%)	**101 (1.8%)**
Total	**204 (3.5%)**	**5433 (94.5%)**	**115 (2.0%)**	**5752**

Risk Adjustment

Approach to Risk Adjustment

Consistent with current NQF guidelines, CMS policy recommends the adjustment of outcome measures for clinical factors, such as severity of illness and co-morbidities, and requires careful consideration of adjustment for sociodemographic factors, such as race, sex and ethnicity. CMS has adopted this policy in an effort to ensure that risk adjustment does not occlude disparities in care provided to patients of different racial/ethnic identities or varying levels of socioeconomic status. NQF is currently reconsidering its policy guidelines with regard to risk adjusting for sociodemographic factors, and is expected to release a final report with recommendations later this year. This reconsideration reflects concern that, in some instances, not including such adjustments may result in misleading or inappropriate assessments about quality of care. This could have the unintended consequence of leading to greater disparities in care and reducing already limited resources and support to safety net providers that care for disadvantaged populations. We discuss these issues with respect to possible risk adjustment of the SRR for sex, race and socioeconomic status. At the completion of the NQF's final report, CMS will consider the attendant arguments and implications for its policy. The SRR risk model presented here is consistent with current NQF guidelines (http://www.qualityforum.org/docs/measure_evaluation_criteria.aspx) and CMS policy.

Adjustment in SRR

We adapted the risk adjustment approach used in the model for CMS' Standardized Hospitalization Ratio (SHR) in the calculation of the SRR. The regression model used to compute a facility's "expected" number of readmissions for the SRR measure contains many factors thought to be associated with readmission event rates. Specifically, the model adjusts for age, sex, diabetes, duration of end-stage renal disease (ESRD), body mass index (BMI) at start of dialysis, past-year comorbidities, length of the index hospital stay, and the presence of a high-risk diagnosis at index discharge. In addition, the model adjusts for the effect of the discharging hospital (via random effects).

CMS decided to adjust for hospital since the dialysis facilities have relatively little control over hospitals, and this adjustment helps avoid the possibility of cherry picking in accepting hospital referrals at discharge. Adjustment using ESRD data also accounts for hospital outcomes in the population that includes patients covered by Medicare and who are younger than 65 years of age. There is also a natural association between a unique hospital and a dialysis facility at the time of discharge. The adjustment using random effects avoids technical issues arising when a dialysis facility is associated with a unique hospital, and also retains an incentive for the dialysis facility to seek coordination of care with the hospital with the aim of reducing readmission rates. Additionally, the companion Hospital-Wide Readmission measure is not reported for patients under the age of 65, which has the potential of limiting the responsiveness of hospitals to the information needs of dialysis facilities when patients are discharged.

Among the dialysis patient population, the total variance in readmission rates attributable to the dialysis facility is comparable to the variance attributable to the hospital, which suggests a strong shared accountability between dialysis facility and the discharging hospital (Turenne et al., 2012; He et al., 2013). The inclusion of hospitals as random effects in the SRR model is consistent with the HWR measure for hospitals, but here the purpose is to adjust the measure for facilities, taking into account the overall distribution of hospital effects, and not to identify individual extreme outcomes for hospitals. By including an adjustment for discharging hospital, we aim to determine the true effect of a facility, despite the quality of the hospital from which it receives patients. Adding this adjustment to the model has a relatively small effect on the distribution of SRRs. The inclusion of the random effect for hospital does not greatly alter the overall categorization of facilities as worse than expected, as expected or better than expected, although it does affect the categorization of some facilities.

Below are details on the SRR's risk adjustors:

- **Sex**: We determine each patient's sex from his/her CMS Form 2728.
- **Age**: We determine each patient's age from the birth date provided in the SIMS and REMIS databases.
- **Years on ESRD**: We determine each patient's length of time on dialysis using the first service date from his/her CMS 2728, claims history (all claim types), the SIMS database and the SRTR database.
- **Diabetes as cause of ESRD**: We determine each patient's primary cause of ESRD from his/her CMS 2728.
- **BMI at incidence**: We calculate each patient's BMI based on the height and weight provided on his/her CMS 2728.
- **Days hospitalized during index admission**: Each admission's length is determined by taking the difference between the date of admission and the date of discharge available on the inpatient claim.
- **Past-year comorbidities (risk variables):** We identify all unique ICD-9 diagnosis codes from each patient's prior year of Medicare claims, using six available claim types: inpatient, outpatient, skilled nursing facility [SNF], hospice and home health claims. We group these

diagnosis codes by diagnosis area using HHS' Hierarchical Condition Categories (CCs; see https://www.cms.gov/Research-Statistics-Data-and-Systems/Research/HealthCareFinancingReview/downloads/04summerpg119.pdf). The HWR measure has determined that a subset of these diagnosis areas is appropriate to use in accounting for case mix; the Appendix II provides a detailed list of the CCs included in these areas.

- **Discharged with high-risk condition**: We define a *high-risk* diagnosis as any diagnosis area (grouped by the AHRQ Clinical Classification Software (CCS)) that was extremely rare in our population but had a 30-day readmission rate of at least 40%. Note that high risk diagnosis groups related to cancer or mental health are not index discharges and so such diagnoses are not included. The CCS areas identified as high-risk are:
    - CCS 5: HIV infection
    - CCS 6: Hepatitis
    - CCS 56: Cystic fibrosis
    - CCS 57: Immunity disorders
    - CCS 61: Sickle cell anemia
    - CCS 190: Fetal distress and abnormal forces of labor
    - CCS 151: Other liver diseases
    - CCS 182: Hemorrhage during pregnancy; abruptio placenta; placenta previa
    - CCS 186: Diabetes or abnormal glucose tolerance complicating pregnancy; childbirth; or the puerperium
    - CCS 210: Systemic lupus erythematosus and connective tissue disorders
    - CCS 243: Poisoning by nonmedicinal substances

In summary, the SRR indicates whether a facility experienced higher or lower readmission rates than the national average after accounting for differences that could be attributed to the patient characteristics listed above, as well as the discharging hospital. It should also be noted that the process of identifying comorbidities using ICD-9 codes over the past year could introduce some biases in that comorbidities will be more frequently found among patients who are more frequently hospitalized or are using the health system in other ways. This is a larger problem when using current comorbidities for the SHR, but for the SRR, the comorbidities in the index hospitalization always provide some information on a patient's health status. Finally, we acknowledge that during the Technical Expert Panel meeting and the public comment period, there was interest voiced in incorporating an adjustment for nephrologist or other physician. The SRR does not include such an adjustment for reasons that are detailed in the next section.

Adjustor Selection

We developed the model to align with CMS's existing measures of hospitalization currently used for public reporting: the National Quality Forum (NQF)-endorsed Hospital-Wide Readmission (HWR) measure, NQF# 1789, (YNHHSC/CORE, 2013)—and of hospitalization amongst dialysis patients—the NQF-endorsed SHR, NQF# 1463 (Liu, Schaubel and Kalbfleisch, 2012). The first iteration of the SRR included the following adjustors:

- To align with the HWR measure:
  - at index discharge, patient age
  - at index discharge, comorbidity status—that is, 36 separate indicators for a select set of comorbidities in the year leading up to the index discharge
- To align with the SHR measure:
  - patient sex
  - hypertension as the primary cause of ERSD
  - diabetes mellitus as the primary cause of ESRD
  - at incidence of ESRD, comorbidity status
  - at incidence of ESRD, BMI
  - at index discharge, time on dialysis

In addition to the patient- and discharge-level adjustors used in the SHR and HWR measures, we include two variables as adjustors in the SRR model that are not included in either the SHR or HWR measure: 1) an indicator for whether a patient was discharged with a "high-risk" diagnosis using the AHRQ CCS grouping described above; and 2) the length of stay for the index discharge. Consistent with CMS policy, the model does not include any adjustment for patient ethnicity, race, socioeconomic status or physician.

Sex

Several NQF-endorsed readmission measures include an adjustment for sex, including CMS' all-cause readmissions following hospitalization for acute myocardial infarction (NQF #0505), heart failure (NQF #0330), pneumonia (NQF #0506) and elective primary total hip arthroplasty and/or total knee arthroplasty (NQF #1551). In the dialysis setting, there is currently adjustment for sex of the patient in both the NQF-endorsed Standardized Hospitalization Ratio (SHR; NQF #1463) and the SRR. These adjustments in the latter two measures, in general, reflect observed higher hospital use of females. Adjustment for sex in these models has received broad support through the measure development and assessment process (TEPs and NQF). We document here the observations and arguments that led to the inclusion of sex as an adjuster in the model.

An adjustment for sex in any measure is most appropriate when the sex of the patient affects the measure in ways outside of the control of the health care provider (dialysis facility, hospital, and physician). For convenience, we call such effects "physiological". If the physiology of females is such that they are more likely to experience health conditions resulting in higher hospital use, failure to adjust the measure for sex would have the effect of unfairly penalizing providers caring for relatively high proportions of females. Further, unfairly penalizing providers for caring for females can cause providers to attempt to avoid caring for females at the margin, thereby potentially reducing their access to care.

An adjustment for sex would be less appropriate and perhaps wholly inappropriate if the provider can influence the likelihood of hospitalization for females differentially from males. For convenience, we call such causes of hospitalization "care-related". If the differential hospitalization rate for females is care-related, at worst the adjustment for sex could have the effect of justifying differential treatment of

females. It could also fail to provide optimal incentive to the provider to find and adopt care protocols specific to females that might reduce disparities in outcomes.

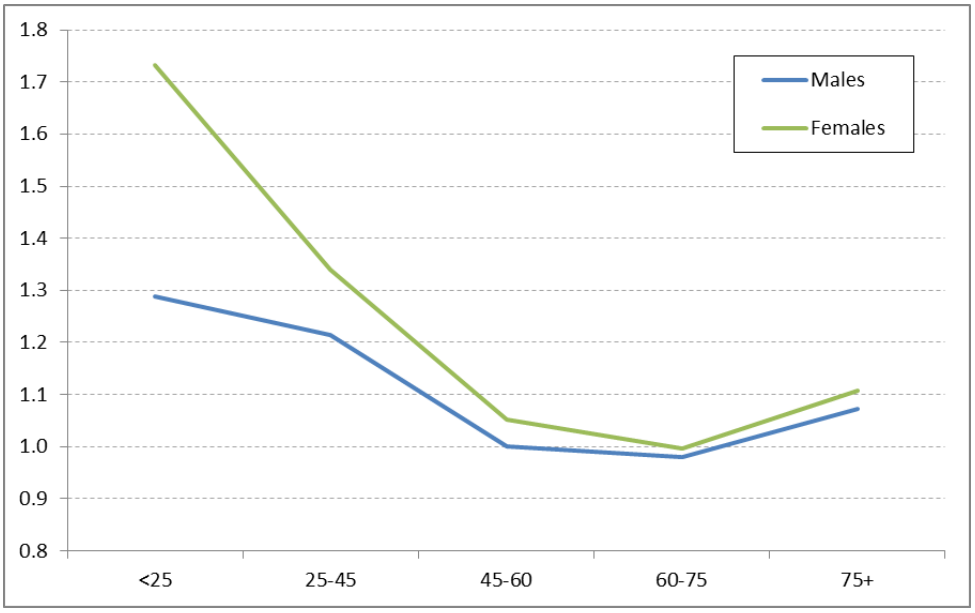
There is a higher rate of readmission among female patients. Table 1 looks further at the effect of sex on readmission rates. The interaction terms for age and sex indicate that the effect of sex on readmission depends substantially on patient age. In particular, females in child-bearing years are more likely to be readmitted than very young females and old females. Therefore, women in the 15-45 age range face a greater risk of experiencing an unplanned readmission, as compared to men of the same age with similar risk profiles. This does not appear to be a consequence of facility performance, however, because the disparity is not generally applicable to women, but only to a limited age group. It is therefore important to risk adjust for sex to ensure that facilities with larger numbers of women aged 15 to 45 are not inappropriately disadvantaged.

Table 2. Results of a model examining the Effects of Age and Sex on Readmission Rates, 2012

Risk Adjustor	**β**	***p***
Age at Index Discharge (y)		
<25	0.253	< .0001
25-45	0.194	< .0001
45-60 *(ref)*	0.000	—
60-75	-0.027	.03
75+	0.070	< .0001
(Age <25) * (Female)	0.550	< .0001
(Age 25–45) * (Female)	0.293	< .0001
(Age 45–60) * (Female)	0.033	.01
(Age 60–75) * (Female)	0.023	.25
(Age 75+) * (Female)	0.087	.42

Figure 3 gives a graphical view of the interaction of the effects of age and sex in the SRR model. The figure makes clear that, for both male and female patients, readmission is strongly associated with young age. Further, the male-female difference is concentrated in the younger age categories. Beyond age 45, where the readmission rates are generally quite low, there is little difference between males and females. The figure demonstrates that high readmission rates for females reflect readmission of younger females, suggesting a physiologic effect rather than a systematic difference in care by sex.

Figure 3. Relative odds of readmission, by sex and age groups (reference is 45- to 60-year-old males).



Our analysis of medical evidence and claims data is generally supportive of the current approach to sex adjustment in the SRR. It is consistent with the consensus opinion that adjustment for sex is appropriate, in that there is some evidence of physiological cause for higher hospitalization rates among females.

A review of the literature reveals recent evidence of some differences by sex in potentially important areas of care provision, such as dialysis adequacy, fluid management, and vascular access (Wasse et al., 2007; Arneson et al., 2010; Ramirez et al., 2012). However, there is as yet no demonstrated connection between differences in care processes by sex and hospitalization rates. We also know of no practice patterns that would be differentially applied to younger women and so explain the marked difference in risk in the 15- to 25-year-old age group especially. These differences, if not adjusted for, would tend to disadvantage facilities with larger numbers of younger females.

High-Risk Diagnoses at Index Discharge

As shown in Table 3, including this adjustment in the 2009 testing model had only relatively small effects on the identification of outlier (worse than expected) facilities. Nonetheless, the inclusion of this variable recognizes the very high readmission rates associated with these diagnoses.

Table 3. Flagging Rates for ESRD Facilities when Adjusting for High-Risk Discharge Diagnoses, 2009

	With adjustment		
Without adjustment	**Non-flagged**	**Flagged**	**Row Total**
Non-flagged	4997 (96.7%)	15 (0.3%)	5012 (97.0%)
Flagged	11 (0.2%)	146 (2.8%)	157 (3.0%)
Column Total	5008 (96.9%)	161 (3.1%)	5169 (100.0%)

Note. Flagging rates in this table are based on an empirical null test with a one-sided *p*-value of 2.5% or lower.

Hospital Length of Stay

We selected this adjustor initially because it has face validity from the clinical perspective and is supported in the literature (e.g., Chan et al., 2009 found a negative relationship between length of stay and hemoglobin levels, albumin levels and weight among hemodialysis patients). In the 2012 model, this factor has an effect comparable to other adjustors. More specifically, the estimated regression coefficients for quartiles 2, 3 and 4 were β = 0.08, 0.14 and 0.27, respectively; these results correspond to respective odds ratios of 1.08 (95% interval = 1.06–1.10), 1.16 (95% interval = 1.14–1.18) and 1.31 (95% interval = 1.29–1.34) when compared to the quartile with the shortest hospital stays.

As shown in Table 4, the variable has a relatively small effect on flagging rates in the 2012 dataset, and most facilities did not change flagging status. Finally, it should be noted that the dialysis facility has less ability to affect the patient's length of index hospital stay than does the hospital, which provides justification to include the variable here even if it were not deemed appropriate for use in the hospital models. Similar to the comorbidity adjustment, the length of the index hospital stay is a baseline measure of the severity of the patient's condition at the time of discharge.

Figure 4. Distribution of 2012 SRRs for U.S. dialysis facilities, by average length of index hospitalization.

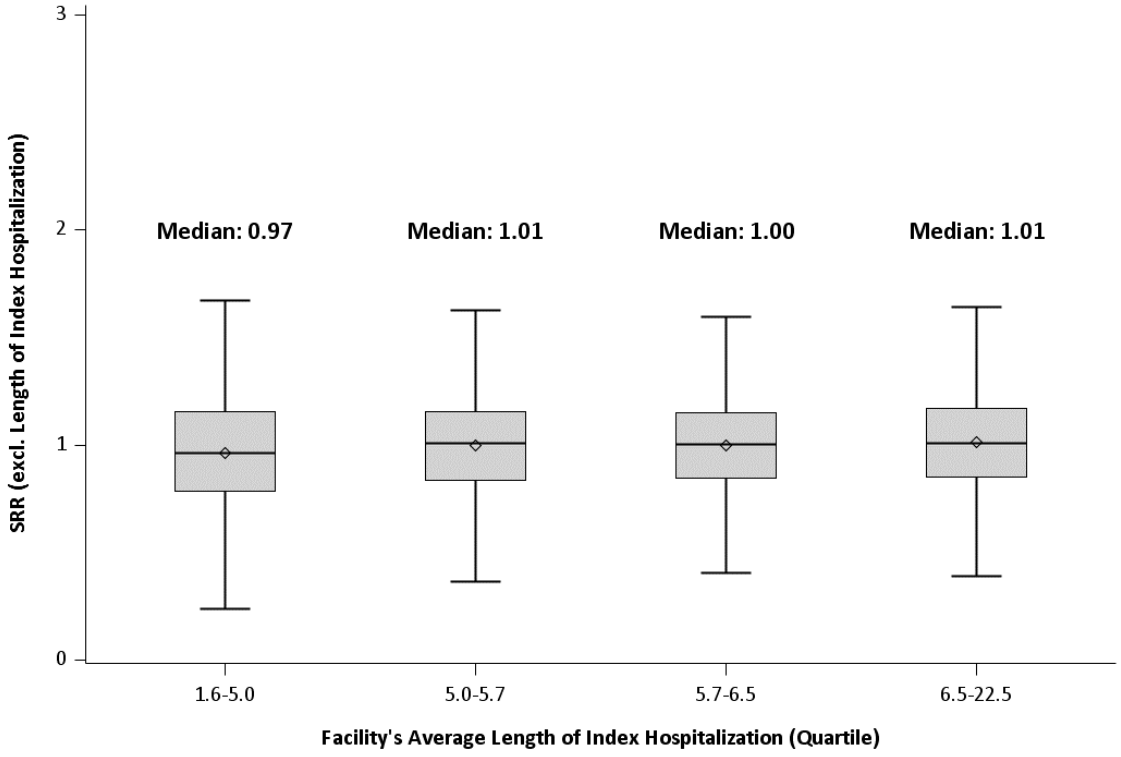


Table 4. Flagging Rates for U.S. Dialysis Facilities Based on 2012 SRRs, by Model with and without Index Hospitalization Length of Stay (LOS)

	Without LOS			
With LOS *(current model)*	**Better than Expected**	**As Expected**	**Worse than Expected**	**Total**
Better than Expected	93	14	0	**107 (1.9%)**
As Expected	11	5431	35	**5477 (94.8%)**
Worse than Expected	0	14	179	**193 (3.3%)**
Total	**104 (1.8%)**	**5459 (94.5%)**	**214 (3.7%)**	—

Nephrologist/Physician

The SRR does not include an adjustment for a patient's physician, although during the Technical Expert Panel meeting and the public comment period, there was interest voiced in such an adjustment. The rationale motivating this request is the view that the decision to admit a patient is a physician decision, and not directly under the control of the dialysis facility.

It is CMS' view that dialysis facilities should be encouraged to coordinate with the nephrologists and other physicians with whom they work to reduce readmissions. It should also be noted that adjustment for physician would mean that this measure would not harmonize in an important way with other ESRD (and general health care) measures approved by NQF and in use. It was therefore decided not to attempt any adjustment of this sort in the proposed measure.

There are also a number of technical issues associated with the assignment of physicians to patients. Physician adjustment would require consensus criteria for identifying what physician is included in the model. Issues such as extent of responsibility—complicated by the existence of physician groups, treatment by multiple physicians, transitions between physicians, and the time of treatment necessary to render a physician responsible for patient outcomes—are non-trivial and afford no obvious standard by which to make the decisions.

These issues are not, however, the primary reason for not adjusting for physician effects. Measuring readmissions at the dialysis facility level encourages facility management to seek opportunities for coordination of care among hospitals, patients, nephrologists and other dialysis facility staff. The measure provides a direct indication of how the dialysis facility's outcomes fare in comparison to the national norm, taking account of important patient characteristics and the discharging hospital. Dialysis facilities have an explicit responsibility defined in current regulations to oversee the provision of care by an interdisciplinary team (IDT), which includes the nephrologist treating the patient. Oversight of individual staff nephrologist care, ensuring adherence to dialysis facility policies and Medicare regulations is primarily the responsibility of the site Medical Director, a paid employee of the dialysis facility, and, additionally, the responsibility of the dialysis facility governing body (Conditions for Coverage [CfCs] 494.150 and 494.180; CMS 2008). The IDT is responsible for assessing dialysis patients in

a timely manner and developing a plan of care specific to that patient, per Medicare regulation. (CfCs 494.80 and 494.90; CMS 2008) The assessment and plan of care developed by this team includes aspects of dialysis care that are frequently the cause of hospital admission and, plausibly, readmission, including fluid management, dialysis vascular access management, anemia management, dialysis prescription.

The overall effectiveness of patient care provided by the IDT(s) at any given facility is monitored by the Quality Assurance and Performance Improvement Committee, specified by the current CMS regulations at 494.110 (CMS 2008). The scope of this oversight includes the performance of all professional members of the facility's IDT(s), and Interpretive Guidance for this regulation specifies that the QAPI Committee be chaired by the facility's medical director. Failure of the dialysis facility's IDT to evaluate the medical results of hospitalization and to revise the patient's plan of care in a timely manner is entirely the responsibility of the facility. If the ability if the IDT is hampered by poorly trained staff, systemic problems with the facility operations or lack of nephrologist engagement, the failure remains the responsibility of the facility, through the authority of the facility's governing body and medical director. Whether facilities choose to act on this responsibility is a matter of policy, and therefore properly belongs within the purview of quality assessment for the facility. Risk adjusting for physician would place CMS in the position of suggesting that a dialysis facility is not responsible for health consequences experienced by patients as the result of business or policy decisions by the facility administration.

SES and Race

To explore the effect of socioeconomic status (SES) on a facility's readmission rate, we took as a proxy patients' estimated income, measured as the median income for each discharged patient's ZIP code of residence on the discharge date. As shown below, the model without this adjustment—that is, the model in current use—does not demonstrate observable differences between facilities comprising patients with differing SES levels. Furthermore, the magnitude of the coefficient of SES in the model is very small (relative risk = 0.99 for a $10,000 increase in average income for the patient's ZIP code).

Figure 5. Distribution of 2012 SRRs for U.S. dialysis facilities, by average income.

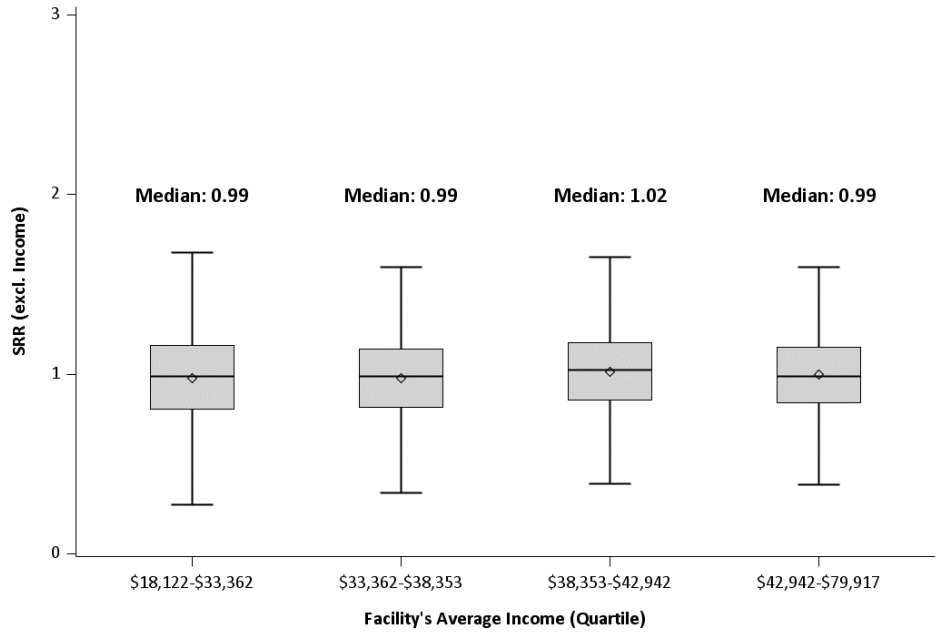


Table 5. Flagging Rates for U.S. Dialysis Facilities Based on 2012 SRRs, by Model with and without SES

	With SES			
Without SES *(current model)*	**Better than Expected**	**As Expected**	**Worse than Expected**	**Total**
Better than Expected	94	13	0	**107 (1.9%)**
As Expected	13	5428	36	**5477 (94.8%)**
Worse than Expected	0	8	185	**193 (3.3%)**
Total	**107 (1.9%)**	**5449 (94.3%)**	**221 (3.8%)**	—

In assessing the effect of race, we fitted a model in which racial groups were included and found only very small differences in readmission rates among the racial groups. This model is comparing outcomes of racial groups between patients within facilities, and not across facilities. Therefore, this approach, which conditions on facility outcomes, removes any potential confounding in facility outcomes if one racial group tended to be associated with facilities with better or poorer quality of care. If facilities are not accounted for in this way in estimating covariate effects, then differences between the quality of facility care can be confounded with differences between racial groups. Because there is no observed within facility differences in the readmission rates by race, essentially the same results are obtained whether one adjusts for race or not.

To explore potential disparities related to race, we examined facilities' relationships between SRR and the proportions of African American patients in each facility in the 2009 testing model. Specifically, we classified facilities into three groups based on their proportion of African American patients: 0%–10%, 10%–30% and 30%+. Results shown in Table 6 indicate that the median SRR increases with the increasing proportion of African American patients. The reasons for these differences are not clear, but they do not account for the apparent differences in outcomes among racial groups as assessed by comparisons within facilities. The SRR is not adjusted for race as is consistent with CMS policy and current NQF guidelines.

Table 6. Distribution of the Standardized Readmission Ratio (SRR), by Facility Percentage of African American Patients, 2009

		SRR						
% African American Patients at Facility		**Mean**	**SD**	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**
0 – 10	1628	0.92	0.27	0	0.76	0.93	1.10	2.29
10 – 30	1165	1.01	0.25	0	0.86	1.02	1.16	2.21
30+	2389	1.03	0.25	0	0.86	1.03	1.19	2.46

Readmission Model and SRR Calculation

Overview

The expected number of readmissions in the denominator of the SRR is calculated based on a statistical model for the probability that a given hospital discharge will give rise to an unplanned readmission within the next 30 days. This model is technically termed a hierarchical logistic model and takes into account the patient characteristics or covariates discussed above. In addition, our model includes a random effect term for hospital of discharge and so makes an adjustment in patient outcomes for the potential effect of the care received at the hospital. This adjustment acknowledges the fact that there is a shared responsibility between the dialysis facility and the discharging hospital for patient care. At the same time, the model retains an incentive for facilities and hospitals to coordinate care in order improve outcomes with respect to readmissions. Facility effects are also estimated in the model, and the number of readmissions in each facility is compared to the number that would be expected at an 'average' facility (actually the median facility) given the patient characteristics. There are a number of technical details associated with this computation that are not dealt with in this summary. The interested reader is referred to He et al. (2013).

In general, we aim to adjust for patient characteristics that affect the endpoint of interest. These include such factors as age, BMI and comorbidities as measured at the time origin or baseline. For SRR, the relevant time origin is the index discharge, and so we adjust for most of the patient's characteristics around the time of that discharge.

In assessing the effects of patient covariates or characteristics, we estimate the within facility differences in outcomes that can be attributed to that covariate. To do this, we estimate the regression coefficients for the covariate while adjusting for potential facility effects through inclusion of facilities in the model as fixed effects. It is important in estimating covariate effects to take this approach since otherwise there is a potential confounding between the effects of facilities and patient characteristics. For example, suppose that older patients are associated with poorer outcomes and that older patients tended to attend facilities that provided better care and that, as a result, tended to have better outcomes. If the effect of the covariates were estimated without adjusting for facilities, either by ignoring possible facility effects of including facilities as random effects, the age effect would be incorrectly estimated. In effect, we would underestimate the negative effect of older age on the outcome.

From a technical perspective, fixed effects provide more precise estimation of the true effects for those facilities with extreme outcomes, as opposed to random effects, which result in shrinkage estimators (where the estimate for each facility is shifted toward the overall mean). The shrinkage becomes substantial for smaller facilities, making identification of poor performance in smaller facilities even more difficult. Issues associated with this choice are described in some detail in Kalbfleisch and Wolfe (2013) and He et al. (2013).

In what follows we give a brief overview of the approach taken in a more technical framework for any reader who would like to have a more specific summary of the approach. The section can, however, be omitted by the reader who is not interested in such detail.

Calculation of SRR

The equations used in the measure calculation are as follows:

1. The main model, which produces the estimates used to calculate SRR, takes the form:

$$\log \frac{p_{ijk}}{1 - p_{ijk}} = \gamma_i + \alpha_j + \beta^T Z_{ijk} \,, \tag{1}$$

   Where p_{ijk} represents the probability of an unplanned readmission for the k[th] discharge among patients from the i[th] facility who are discharged from j[th] hospital, and Z_{ijk} represents the set of patient-level characteristics. Here, γ_i is the fixed effect for facility and α_j is the random effect for hospital j. It is assumed that the α_js arise as independent normal variables (i.e., $\alpha_j \sim N(0, \sigma^2)$)

2. We use the estimates from this model to calculate the i[th] facility's SRR:

$$SRR_i = \frac{O_i}{E_i} = \frac{O_i}{\Sigma_{j \in \mathcal{H}(i)} \Sigma_{k=1}^{n_{ij}} \hat{p}_{ijk}} \,,$$

(2)

where, for the i^{th} facility, O_i is the number of observed unplanned readmissions, E_i is the expected number of unplanned readmissions, *H(i)* is the collection of indices of hospitals from which patients are discharged to the *i*th facility, and $\boldsymbol{p_{ijk}}$ is the estimated probability of an unplanned readmission under the national norm for each discharge. More specifically,

$$\hat{p}_{ijk} = \frac{\exp(\hat{\gamma}_M + \hat{\alpha}_j + \hat{\beta}^T Z_{ijk})}{1 + \exp(\hat{\gamma}_M + \hat{\alpha}_j + \hat{\beta}^T Z_{ijk})},$$

(3)

estimates the probability that a discharge from hospital *j* to facility *i* of a patient with characteristics Z_{ijk} would result in an unplanned readmission; this probability is being estimated assuming that the facility's effect corresponds to the median of national facility effects, denoted by $\widehat{\gamma_M}$. Here, $\hat{\alpha}_j$ and $\hat{\beta}$ are estimates from model (1). The sum of these probabilities is the expected number of unplanned readmissions E_i at facility *i*, adjusting for patient mix and under the national norm.

Properties of the Hierarchical Logistic Model

In the model, we aim to formulate shared responsibilities among hospitals and facilities, while encouraging cooperation and communication between them.

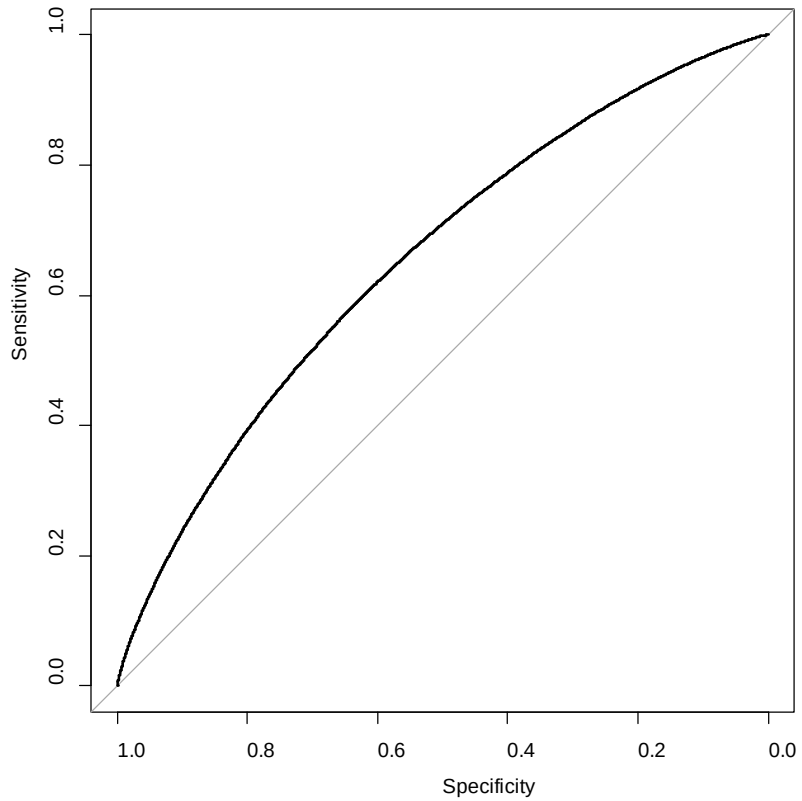
The inclusion of hospitals as random effects avoids the non-identifiability issue that apparently arises when a single hospital is associated with a single facility. Also, the random effects tend to smooth the effect of the hospital by "shrinking" the estimates toward a national average for hospitals serving dialysis patients. Thus, for example, if a given facility-hospital combination has a much higher readmission rate than the national median rate, the explanation for this outcome would be shared between the facility and the hospital. The hospital effect is estimated to be somewhat higher than the national average to reflect the high rates, but the estimated hospital effect will be 'shrunk' toward the overall national rate for hospitals. In this sense, facilities as well as hospitals will benefit from coordination of care.

We also use fixed effects to make inferences about dialysis facilities. Fixed effects models treat individual facilities separately and provide more precise estimation of the true effects for facilities with outcomes that are substantially worse (or better) than expected. We utilize an "exact" method to calculate the *p*-values associated for each facility. This method assesses the probability that the facility would experience a number of readmissions more extreme than that observed if readmission rates at that facility were identical to those of the national average. This method also works even if there are no readmissions observed or if all or nearly all discharges result in a readmission.

We find that the model is fairly accurate (see Figure 6), with a C statistic of 0.65, which is comparable to CMS's existing measure of readmission for hospitals (YNHHSC/CORE, 2013; C statistic range: 0.62–0.67). The C statistic is the area under the Receiver Operating Curve (ROC) that is pictured in Figure 6, and is a

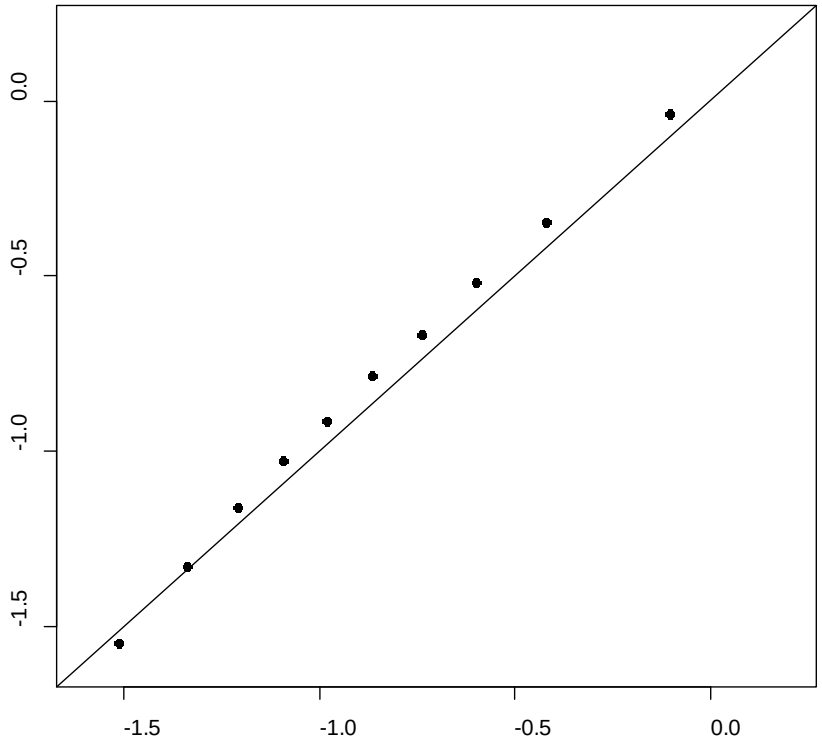
measure of the predictive power of the regression model. An alternative interpretation of the C statistic is obtained by considering the set of all pairs of index discharges where one discharge in the pair leads to a readmission and the other leads to no readmission. The C statistic is then the proportion of the pairs where the model would correctly suggest which discharge was more likely to give rise to the readmission. A purely random assignment would give a C statistic of 0.5, whereas a perfect measure would yield a C statistic of 1.0.

Figure 6. The receiver operating characteristic (ROC) curve for SRR model, 2012.



The model's fit is demonstrated in Figure 7, which compares the observed rates with the model-based predictions. We bin all observations into 20 groups based on their model-based predicted values and compute the observed readmission proportion for each group. We then apply the logit transformation to each group's observed readmission proportion and plot it against the same group's average linear prediction; see the dots for all 20 groups in the plot. The 45-degree line would represent a perfect match between the observed values and the model-based predictions. In general, the closer the observed values are to this line the better the model fit. As Figure 7 shows, the observed values are spaced fairly equally and lie very close to the 45-degree line, indicating an overall good fit.

Figure 7. Dialysis facility observed proportion of readmissions vs. estimated probability of readmission, 2012. This plot is on a logit scale.



Creating Interval Estimates

Measuring or assessing significance of a large SRR (i.e., an SRR greater than 1) is based on the *p*-value. To calculate the *p*-value, we use an exact method that assesses the probability that the facility would experience a number of readmissions as extreme as that observed if the null hypothesis were true; this calculation accounts for each facility's patient mix. For instance, to test the hypothesis that a facility's true SRR is 1.0, we calculate the positive one-tailed *p*-value or significance level (SL^+) for each facility as the probability that the number of readmissions in that facility would be at least as large as that observed under the assumption that this facility has readmission rates corresponding to the median facility and given the patient characteristics or covariates. The negative one-tailed *p*-value (SL^-) is defined correspondingly (e.g., as small as). The two-tailed *p*-value is then defined as $p = 2*\min(SL^+, SL^-)$. We use a "mid-p" value to avoid two-tailed *p*-values greater than 1. Approaches for flagging are based on converting the *p*-values to z-statistics and using methods based on the empirical null hypothesis, which accounts for overdispersion in the data (Efron, 2004; Kalbfleisch and Wolfe, 2013). In effect, this method takes into account the natural variation observed between facilities and that cannot be accounted for by the model. To implement the empirical null methods, we stratify facilities into three groups based on the number of eligible discharges within each facility. We then plot the histograms of Z-scores for each strata along with normal curves fitted to the center of the histograms using a robust M-estimation method. We use these empirical null distributions to assess outlier facilities. This empirical null method

makes appropriate adjustment in each of the strata and yields fairly consistent flagging rates across all strata.

To calculate the 95% interval estimate for SRR, we use an exact method that assesses the range of facility effects, such that the probability the facility would experience a number of readmissions more extreme than that observed under the assumed facility effect is non-significant (e.g., $p > 0.05$). To account for natural facility variation not explained by the model, evaluation of significance is based on the empirical null distribution, instead of the standard normal density.

Results

Population Characteristics, Data Years 2009–2012

Characteristic	2009	2010	2011	2012
Patients	234,833	240,546	243,636	242,521
Facilities	6,112	6,348	6,589	6,898
Index discharges	544,172	558,387	564,596	552,236
Readmissions	173,056	177,818	179,305	171,578
Unadjusted readmission rate	31.8%	31.8%	31.8%	31.1%

Risk Factor Frequency (%) in Data Samples, Data Years 2009–2012

Risk Factor	2009	2010	2011	2012
Age (y)				
<25	1.2	1.2	1.1	1.1
25–45	11.2	10.8	10.7	10.6
45–60	25.3	25.2	25.0	25.1
60–75	37.1	37.7	38.2	38.5
>75	25.2	25.1	25.0	24.6
BMI				
Underweight	4.3	4.1	4.1	4.4
Normal weight	29.6	28.6	28.1	27.2
Overweight	29.3	28.9	28.6	28.5
Obese	36.8	38.3	39.3	40.0
Cause of ESRD: Diabetes	48.1	48.7	48.6	48.7
Comorbidity (past year)				
Amputation status	8.7	9.0	11.9	12.8
COPD	27.4	28.2	32.8	34.3
Cardiorespiratory failure/shock	24.5	26.5	30.3	31.6
Coagulation defects & other specified hematological disorders	15.8	17.6	22.6	24.3
Drug and alcohol disorders	4.5	4.5	5.7	6.4
End-Stage Liver Disease	4.2	4.6	5.7	6.1
Fibrosis of lung or other chronic lung disorders	3.8	3.8	4.6	4.3

Risk Factor	2009	2010	2011	2012
Hemiplegia, paraplegia, paralysis	8.2	8.2	8.5	8.5
Hip fracture/dislocation	3.7	3.7	3.7	3.7
Major organ transplants (excl. kidney)	1.6	1.6	1.7	1.7
Metastatic cancer/acute leukemia	1.5	1.5	1.6	1.6
Other hematological disorders	5.2	5.6	6.3	3.6
Other infectious disease & pneumonias	52.2	52.8	57.7	57.8
Other major cancers	9.4	9.6	11.6	12.8
Pancreatic disease	6.3	6.4	6.9	7.2
Psychiatric comorbidity	26.0	27.6	37.7	41.5
Respirator dependence/tracheostomy status	1.1	1.1	1.5	1.6
Rheumatoid arthritis & inflammatory connective tissue disease	5.9	6.0	7.0	7.3
Seizure disorders & convulsions	10.1	10.1	11.7	12.1
Septicemia/shock	27.7	27.4	27.5	27.4
Severe cancer	3.6	3.7	4.0	4.0
Severe infection	5.4	5.5	5.8	5.8
Ulcers	20.8	21.2	23.5	24.3
Length of Index Hospitalization (days)				
<5 days	27.2	27.9	27.8	27.3
5 days	25.6	25.7	26.1	26.7
6 days	21.6	21.5	21.6	21.9
>6days	25.6	24.9	24.5	24.1
High-Risk Index Hospitalization	1.2	1.1	1.2	1.2
Sex: Female	48.9	48.7	48.7	48.8
Time on ESRD (y)				
<1	28.8	28.1	26.9	26.1
1–2	15.0	14.9	14.7	14.3
2–3	12.2	12.1	12.2	12.3
3–6	23.7	24.1	24.4	24.8
>6	20.3	20.7	21.6	22.6

Trend in Adjusted Odds Ratio for Model Risk Factors, Data Years 2009–2012

	2009		2010		2011		2012	
Variable	OR	95% Interval	OR	95% Interval	OR	95% Interval	OR	95% Interval
Age (y)								
<25	**1.46**	(1.38–1.53)	**1.46**	(1.36–1.56)	**1.59**	(1.52–1.65)	**1.50**	(1.40–1.58)
25–45	**1.22**	(1.19–1.23)	**1.22**	(1.18–1.25)	**1.24**	(1.21–1.27)	**1.25**	(1.22–1.28)
45–60 (ref)	—	—	—	—	—	—	—	—
60–75	**0.98**	(0.96–0.99)	**0.99**	(0.97–1.00)	**1.00**	(0.97–1.01)	**0.99**	(0.97–1.00)
>75	**1.09**	(1.06–1.10)	**1.09**	(1.06–1.11)	**1.08**	(1.05–1.10)	**1.06**	(1.04–1.08)
BMI								
Underweight	**1.05**	(1.02–1.08)	**1.00**	(0.97–1.03)	**1.03**	(0.99–1.06)	**1.03**	(0.99–1.06)
Normal Weight (ref)	—	—	—	—	—	—	—	—
Overweight	**0.96**	(0.94–0.97)	**0.96**	(0.95–0.97)	**0.96**	(0.94–0.97)	**0.96**	(0.94–0.97)
Obese	**0.91**	(0.89–0.91)	**0.90**	(0.88–0.91)	**0.89**	(0.87–0.90)	**0.90**	(0.88–0.91)
Cause of ESRD: Diabetes	**1.06**	(1.04–1.06)	**1.06**	(1.04–1.06)	**1.06**	(1.04–1.07)	**1.04**	(1.02–1.05)
Comorbidity (past year)								
Amputation status	**1.11**	(1.08–1.13)	**1.07**	(1.04–1.08)	**1.04**	(1.01–1.05)	**1.02**	(0.99–1.04)
COPD	**1.28**	(1.25–1.29)	**1.26**	(1.24–1.28)	**1.25**	(1.24–1.26)	**1.25**	(1.23–1.27)
Cardiorespiratory failure/shock	**1.27**	(1.24–1.28)	**1.25**	(1.23–1.27)	**1.24**	(1.22–1.25)	**1.26**	(1.24–1.27)
Coagulation defects & other specified hematological disorders	**1.15**	(1.13–1.17)	**1.17**	(1.14–1.18)	**1.15**	(1.13–1.17)	**1.15**	(1.13–1.16)
Drug and alcohol disorders	**1.37**	(1.32–1.40)	**1.38**	(1.34–1.42)	**1.38**	(1.34–1.41)	**1.42**	(1.38–1.45)
End–Stage Liver Disease	**1.42**	(1.37–1.46)	**1.37**	(1.31–1.41)	**1.35**	(1.31–1.38)	**1.30**	(1.26–1.33)
Fibrosis of lung or other chronic lung disorders	**1.07**	(1.04–1.10)	**1.08**	(1.04–1.12)	**1.11**	(1.07–1.14)	**1.09**	(1.06–1.11)
Hemiplegia, paraplegia, paralysis	**1.11**	(1.08–1.14)	**1.11**	(1.08–1.13)	**1.04**	(1.01–1.07)	**1.04**	(1.01–1.06)
Hip fracture/dislocation	**1.03**	(1.00–1.06)	**1.01**	(0.97–1.04)	**1.04**	(1.02–1.06)	**1.00**	(0.97–1.03)
Major organ transplants (excl. kidney)	**1.07**	(1.01–1.11)	**1.12**	(1.07–1.16)	**1.05**	(0.99–1.10)	**1.06**	(1.00–1.10)
Metastatic cancer/acute leukemia	**1.31**	(1.24–1.37)	**1.31**	(1.24–1.37)	**1.29**	(1.23–1.34)	**1.36**	(1.29–1.41)
Other hematological disorders	**1.21**	(1.18–1.24)	**1.2**	(1.16–1.23)	**1.18**	(1.14–1.21)	**1.23**	(1.19–1.26)
Other infectious disease & pneumonias	**1.18**	(1.16–1.19)	**1.20**	(1.18–1.21)	**1.20**	(1.18–1.22)	**1.19**	(1.17–1.20)
Other major cancers	**1.05**	(1.02–1.06)	**1.04**	(1.01–1.05)	**1.06**	(1.03–1.08)	**1.08**	(1.05–1.09)
Pancreatic disease	**1.27**	(1.24–1.30)	**1.28**	(1.24–1.30)	**1.28**	(1.25–1.31)	**1.28**	(1.25–1.31)
Psychiatric comorbidity	**1.26**	(1.24–1.28)	**1.26**	(1.24–1.27)	**1.26**	(1.25–1.27)	**1.26**	(1.24–1.28)
Respirator dependence / tracheostomy status	**0.99**	(0.92–1.05)	**1.04**	(0.98–1.08)	**1.02**	(0.96–1.07)	**0.99**	(0.94–1.04)
Rheumatoid arthritis & inflammatory connective tissue disease	**1.08**	(1.04–1.10)	**1.08**	(1.05–1.10)	**1.05**	(1.02–1.07)	**1.06**	(1.04–1.08)
Seizure disorders & convulsions	**1.18**	(1.15–1.19)	**1.18**	(1.14–1.20)	**1.17**	(1.14–1.19)	**1.17**	(1.14–1.18)
Septicemia/shock	**1.17**	(1.14–1.18)	**1.15**	(1.13–1.16)	**1.12**	(1.10–1.14)	**1.11**	(1.09–1.13)
Severe cancer	**1.19**	(1.15–1.22)	**1.2**	(1.15–1.23)	**1.20**	(1.16–1.24)	**1.19**	(1.15–1.22)
Severe infection	**1.1**	(1.07–1.13)	**1.09**	(1.06–1.11)	**1.13**	(1.09–1.15)	**1.10**	(1.07–1.12)
Ulcers	**1.14**	(1.11–1.15)	**1.15**	(1.13–1.17)	**1.17**	(1.15–1.18)	**1.17**	(1.15–1.18)
Length of Index Hospitalization (days)								
Quartile 1 (ref)	—	—	—	—	—	—	—	—
Quartile 2	**1.10**	(1.08–1.11)	**1.08**	(1.06–1.10)	**1.06**	(1.04–1.08)	**1.08**	(1.06–1.09)

	2009		2010		2011		2012	
Variable	OR	95% Interval	OR	95% Interval	OR	95% Interval	OR	95% Interval
Quartile 3	**1.19**	(1.17–1.21)	**1.17**	(1.14–1.19)	**1.16**	(1.14–1.18)	**1.16**	(1.13–1.17)
Quartile 4	**1.39**	(1.36–1.41)	**1.36**	(1.34–1.38)	**1.32**	(1.30–1.34)	**1.31**	(1.28–1.33)
High-Risk Index Hospitalization	**1.42**	(1.32–1.50)	**1.49**	(1.39–1.58)	**1.45**	(1.36–1.52)	**1.50**	(1.40–1.60)
Sex: **Female**	**1.06**	(1.04–1.07)	**1.07**	(1.05–1.07)	**1.06**	(1.04–1.07)	**1.05**	(1.03–1.06)
Time on ESRD (y)								
<1 (ref)	—	—	—	—	—	—	—	—
1–2	**1.03**	(1.01–1.04)	**1.04**	(1.01–1.05)	**1.06**	(1.03–1.07)	**1.05**	(1.02–1.06)
2–3	**1.03**	(1.01–1.05)	**1.06**	(1.04–1.08)	**1.07**	(1.05–1.08)	**1.10**	(1.07–1.12)
3–6	**1.03**	(1.01–1.04)	**1.02**	(1.00–1.03)	**1.05**	(1.03–1.06)	**1.08**	(1.05–1.09)
>6	**1.00**	(0.98–1.02)	**1.00**	(0.98–1.01)	**1.01**	(0.99–1.03)	**1.03**	(1.01–1.05)

Reliability Testing

To assess the SRR's reliability, we evaluated the SRR derived from data on dialysis patient hospital discharges in 2012. If the measure were a simple average across individuals in the facility, the usual approach for determining measure reliability would be a one-way analysis of variance (ANOVA), in which the between- and within-facility variation in the measure is determined (HSAG, 2012). The inter-unit reliability (IUR) measures the proportion of the measure variability that is attributable to the between-facility variance. The SRR, however, is not a simple average, and we instead estimate the IUR using a bootstrap approach, which uses a resampling scheme to estimate the within-facility variation.

Here we describe our approach to calculating IUR. Suppose that there are *N* facilities with at least 11 discharges in the year. Let $T_1,\ldots,T_N$ be the SRR for these facilities. Within each facility, select at random and with replacement $B = 100$ bootstrap samples. That is, if the *i*th facility has n_i subjects, randomly draw with replacement n_i subjects from those in the same facility, find their corresponding SRR_i and repeat the process 100 times. Thus, for the *i*th facility, we have bootstrapped SRRs of T^*_{i1}..., T^*_{i100}. Let S^*_i be the sample variance of this bootstrap sample. From this it can be seen that

$$s^2_{t,w} = \frac{\sum_{i=1}^{N}[(n_i - 1)S_i^{*2}]}{\sum_{i=1}^{N}(n_i - 1)}$$

is a bootstrap estimate of the within-facility variance in the SRR, namely $\sigma^2_{t,w'}$.Calling on formulas from the one way analysis of variance, an estimate of the overall variance of T_i is

$$s_t^2 = \frac{1}{n'(N-1)} \sum_{i=1}^{N} n_i (T_i - \bar{T})^2$$

where

$$\bar{T} = \sum n_i T_i / \sum n_i$$

is the weighted mean of the observed SRR and

$$n' = \frac{1}{N-1} \left(\sum n_i - \sum n_i^2 / \sum n_i \right)$$

is approximately the average facility size (number of patients per facility). Note that s_t^2 is an estimate of $\sigma_b^2 + \sigma_{t,w}^2$ where σ_b^2 is the between-facility variance, the true signal reflecting the differences across facilities. Thus, the IUR, which is defined by

$$IUR = \frac{\sigma_b^2}{\sigma_b^2 + \sigma_{t,w}^2}$$

can be estimated with $(s_t^2 - s_{t,w}^2)/s_t^2$

Overall, IURs for the SRR ranged from 0.49–0.54 (F-statistic: 1.96–2.17; $p < 0.0001$) across the years 2009, 2010, 2011 and 2012, which indicates that about half of the variation in the SRR can be attributed to the between-facility differences and half to within-facility variation. This value of IUR indicates a moderate degree of reliability. When stratified by facility size, we find that, as expected, larger facilities have larger IURs (see Table 7).

Table 7. SRR Inter-Unit Reliability Measures, by Facility Size: 2009–2012

	2009			2010			2011			2012		
Facility Size (N patients)	**IUR**	**N**	**F**	**IUR**	**N**	**F**	**IUR**	**N**	**F**	**IUR**	**N**	**F**
All	**0.53**	5268	2.11	**0.54**	5469	2.17	**0.50**	5646	2.01	**0.49**	5777	1.96
Small (<=46)	**0.44**	1797	1.77	**0.45**	1859	1.81	**0.44**	1940	1.80	**0.43**	1919	1.77
Medium (47–83)	**0.51**	1749	2.05	**0.54**	1796	2.17	**0.47**	1804	1.87	**0.45**	1919	1.83
Large (>=84)	**0.58**	1722	2.39	**0.59**	1814	2.42	**0.56**	1902	2.27	**0.54**	1939	2.18

Validity Testing

We assessed the validity of the measure through various comparisons of this measure with other quality measures in use, and in May 2012 presented a preliminary version of the SRR to a CMS Technical Expert Panel (TEP) for assessment of clinical validity.

The SRR is a measure of hospital use, comprising many causes of hospitalization. The TEP considered devising cause-specific SRRs but recommended the use of overall SRR measures due to various reasons, including the lack of clear consensus on which causes are modifiable by the dialysis facility and concerns about gaming the system if certain conditions are identified. This decision was consistent with the HWR measure.

As hospitalization is a major cost factor in the management of ESRD patients, there is a strong case for face validity of the SRR measure. This face validity of the SRR measure is also supported by its association with other known quality measures, which include both dialysis facility outcomes and practices. Using 2012 data, the measure is positively correlated with the one-year SHR for hospital admissions ($r = .46$, $p < .0001$), the one-year SMR ($r = .19$, $p < .0001$) and the vascular access quality measure for percentage of patients with a catheter ($r = .05$, $p = .0003$). These relationships indicate that higher values of SRR are associated with increased use of catheters and higher rates of hospitalization and mortality. The SRR is negatively correlated with a quality measure of dialysis adequacy, the percentage of patients having a Urea Reduction Ratio (URR) of at least 65% ($r = -.03$, $p = .03$), and with a vascular access measure, percentage of patients using a fistula ($r = -.06$, $p < .0001$). That is, higher values of SRR are associated with lower rates of URR and fistula use, which indicate poorer performance for these quality measures. These are in the expected direction, although these correlations are very small.

Another way of assessing the relationship of the readmission rates and outcomes to other quality measures is by carrying out analyses at the patient level. When presence of a catheter in the two months prior to an index hospitalization is included in the regression model for readmission, it is found to increase the risk of readmission by about 12%. Similarly, URR of at least 65% is found to decrease the odds of readmission by about 23%. These are substantial odds ratios that are significant with $p < 0.0001$, and suggest that these process measures are important in reducing readmissions.

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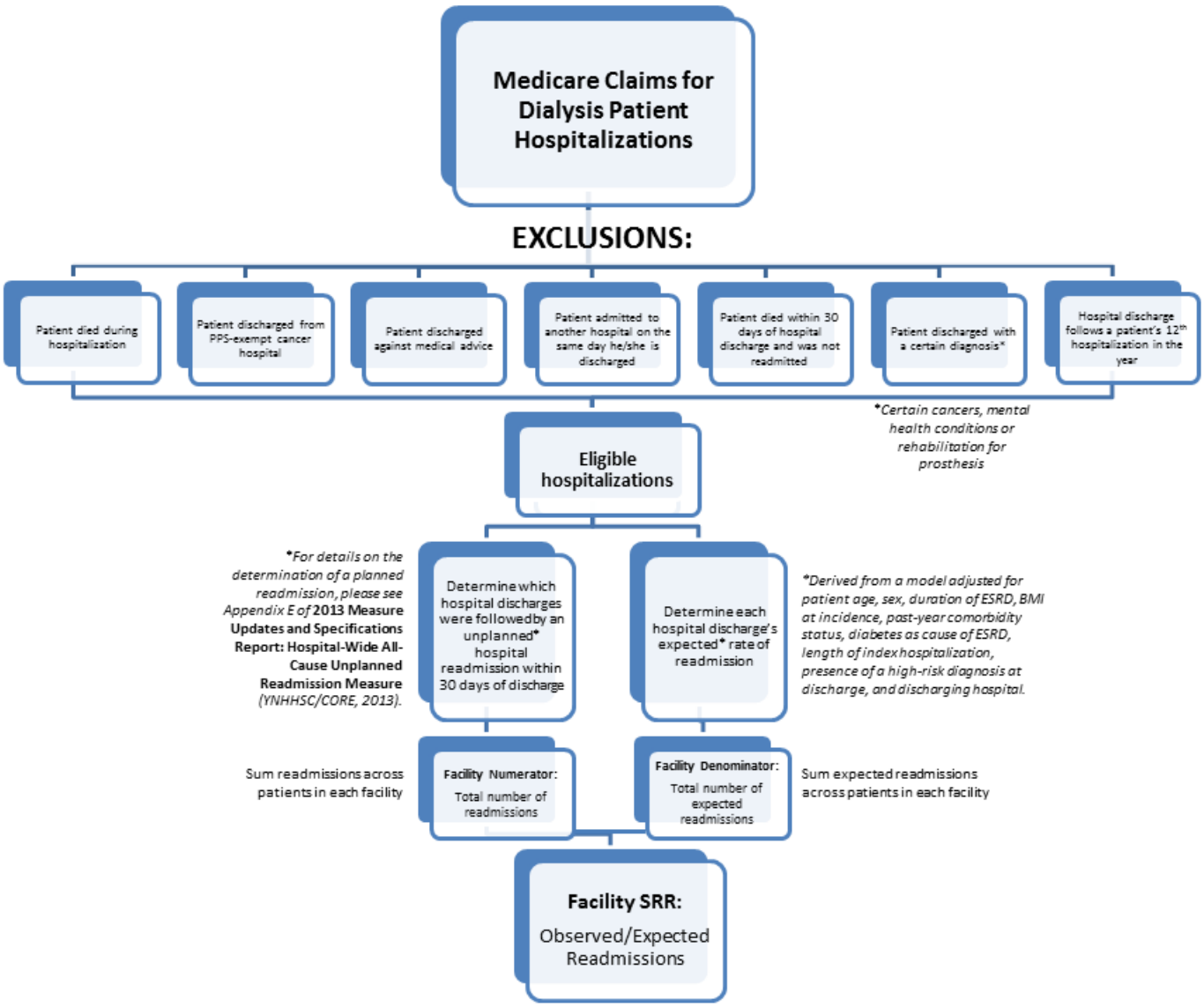
Appendix

Appendix I. Measure Calculation Flow Chart



Appendix II. Past-Year Comorbidities, Grouped by HHS' Hierarchical Condition Categories (CCs)

Description	CC	Detailed Description *(if applicable)*
Severe infection	**1, 3–5**	
	1	HIV/AIDS
	3	Central nervous system infection
	4	Tuberculosis
	5	Opportunistic infections
Other infectious disease & pneumonias	**6, 111–113**	
	6	Other infectious disease
	111	Aspiration and specified bacterial pneumonias
	112	Pneumococcal pneumonia, emphysema, lung abscess
	113	Viral and unspecified pneumonia, pleurisy
Metastatic cancer/acute leukemia	**7**	
Severe cancer	**8–9**	
	8	Lung, upper digestive tract, and other severe cancers
	9	Other major cancers
Other major cancers	**10–12**	
	10	Breast, prostate, colorectal and other cancers and tumors
	11	Other respiratory and heart neoplasms
	12	Other digestive and urinary neoplasms
End-stage liver disease	**25–26**	
	25	End-Stage Liver Disease
	26	Cirrhosis of Liver
Other hematologoical disorders	**44**	
Drug and alcohol disorders	**51–52**	
	51	Drug/alcohol psychosis
	52	Drug/alcohol dependence
Psychiatric comorbidity	**54–56, 58, 60**	
	54	Schizophrenia
	55	Major depressive, bipolar, and paranoid disorders
	56	Reactive and unspecified psychosis
	58	Depression
	60	Other psychiatric disorders
Hemiplegia, paraplegia, paralysis	**67–69, 100–101**	
	67	Quadriplegia, other extensive paralysis
	68	Paraplegia
	69	Spinal cord disorders/injuries
	100	Hemiplegia/hemiparesis
	101	Diplegia (upper), monoplegia, and

Description	CC	Detailed Description *(if applicable)*
		other paralytic syndromes
Fibrosis of lung or other chronic lung disorders	**109**	
Ulcers	**148–149**	
	148	Decubitus ulcer
	149	Decubitus ulcer or chronic skin ulcer
Septicemia/shock	**2**	
Cardio-respiratory failure or cardio-respiratory shock	**79**	
Pancreatic disease	**32**	
Rheumatoid arthritis and inflammatory connective tissue disease	**38**	
Respirator dependence/tracheostomy status	**77**	
Major organ transplant status	**128**	
Coagulation defects and other specified hematological disorders	**46**	
Hip fracture/dislocation	**158**	

Note. Based on the HWR measure. We removed or modified the following risk variable areas:

- Removed
  - Diabetes: Already adjust for in model
  - Protein calorie malnutrition: Present in many ESRD patients, potentially modifiable
  - CHF: Present in many ESRD patients, potentially modifiable
  - CAD/CVD: Present in many ESRD patients
  - Arrhythmia: Present in many ESRD patients
  - Dialysis status: Inappropriate to adjust for in dialysis population
  - Fluid/electrolyte disorders: Inappropriate to adjust for in dialysis population; most patients have it and thus essentially an indicator of ESRD
  - Iron deficiency: Inappropriate to adjust for in dialysis population; most patients have it and thus essentially an indicator of ESRD
  - Acute renal failure: Inappropriate to adjust for in dialysis population
- Modified
  - Removed CC 102 (Speech, language,cognitive, perceptual) from HWR's original functional status adjustment: This comorbidity was found to have a much smaller effect than CCs 177 and 178, and was deemed clinically unrelated.
  - Removed CCS 128 (Kidney transplant status) from HWR's original "Major organ transplant" adjustment: All patients in our population are currently on dialysis.

Appendix III. ICD-9 to ICD-10 Mapping

Table A. Clinician-Reviewed Readmission Codes: One-to-One Mapping Using CMS 2011 GEMs

ICD-9	Description	ICD-10	Description	Clinician Notes
3282	Diphtheritic myocarditis	**A3681**	Diphtheritic cardiomyopathy	
3640	Meningococcal carditis, unspecified	**A3950**	Meningococcal carditis, unspecified	
3641	Meningococcal pericarditis	**A3953**	Meningococcal pericarditis	
3642	Meningococcal endocarditis	**A3951**	Meningococcal endocarditis	
3643	Meningococcal myocarditis	**A3952**	Meningococcal myocarditis	
7420	Coxsackie carditis, unspecified	**B3320**	Viral carditis, unspecified	ICD-9 is more specific than ICD-10
7421	Coxsackie pericarditis	**B3323**	Viral pericarditis	ICD-9 is more specific than ICD-10
7422	Coxsackie endocarditis	**B3321**	Viral endocarditis	ICD-9 is more specific than ICD-10
7423	Coxsackie myocarditis	**B3322**	Viral myocarditis	ICD-9 is more specific than ICD-10
11281	Candidal endocarditis	**B376**	Candidal endocarditis	
1303	Myocarditis due to toxoplasmosis	**B5881**	Toxoplasma myocarditis	
3029	Unspecified psychosexual disorder	**F659**	Paraphilia, unspecified	ICD-9 is more specific than ICD-10
3910	Acute rheumatic pericarditis	**I010**	Acute rheumatic pericarditis	
3911	Acute rheumatic endocarditis	**I011**	Acute rheumatic endocarditis	
3912	Acute rheumatic myocarditis	**I012**	Acute rheumatic myocarditis	
3918	Other acute rheumatic heart disease	**I018**	Other acute rheumatic heart disease	
3919	Acute rheumatic heart disease, unspecified	**I019**	Acute rheumatic heart disease, unspecified	
3920	Rheumatic chorea with heart involvement	**I020**	Rheumatic chorea with heart involvement	
3980	Rheumatic myocarditis	**I090**	Rheumatic myocarditis	
39890	Rheumatic heart disease, unspecified	**I099**	Rheumatic heart disease, unspecified	
39899	Other rheumatic heart diseases	**I0989**	Other specified rheumatic heart diseases	
4200	Acute pericarditis in diseases classified elsewhere	**I32**	Pericarditis in diseases classified elsewhere	
42090	Acute pericarditis, unspecified	**I309**	Acute pericarditis, unspecified	
42091	Acute idiopathic pericarditis	**I300**	Acute nonspecific idiopathic pericarditis	
42099	Other acute pericarditis	**I308**	Other forms of acute pericarditis	
4210	Acute and subacute bacterial endocarditis	**I330**	Acute and subacute infective endocarditis	

ICD-9	Description	ICD-10	Description	Clinician Notes
4211	Acute and subacute infective endocarditis in diseases classified elsewhere	**I39**	Endocarditis and heart valve disorders in diseases classified elsewhere	
4219	Acute endocarditis, unspecified	**I339**	Acute and subacute endocarditis, unspecified	
4220	Acute myocarditis in diseases classified elsewhere	**I41**	Myocarditis in diseases classified elsewhere	
42290	Acute myocarditis, unspecified	**I409**	Acute myocarditis, unspecified	
42291	Idiopathic myocarditis	**I401**	Isolated myocarditis	
42292	Septic myocarditis	**I400**	Infective myocarditis	
42293	Toxic myocarditis	**I408**	Other acute myocarditis	
42299	Other acute myocarditis	**I408**	Other acute myocarditis	
4230	Hemopericardium	**I312**	Hemopericardium, not elsewhere classified	
4231	Adhesive pericarditis	**I310**	Chronic adhesive pericarditis	
4232	Constrictive pericarditis	**I311**	Chronic constrictive pericarditis	
4233	Cardiac tamponade	**I314**	Cardiac tamponade	
4260	Atrioventricular block, complete	**I442**	Atrioventricular block, complete	
42610	Atrioventricular block, unspecified	**I4430**	Unspecified atrioventricular block	
42611	First degree atrioventricular block	**I440**	Atrioventricular block, first degree	
42612	Mobitz (type) II atrioventricular block	**I441**	Atrioventricular block, second degree	
42613	Other second degree atrioventricular block	**I441**	Atrioventricular block, second degree	
4264	Right bundle branch block	**I4510**	Unspecified right bundle-branch block	
42650	Bundle branch block, unspecified	**I454**	Nonspecific intraventricular block	
42651	Right bundle branch block and left posterior fascicular block	**I452**	Bifascicular block	
42652	Right bundle branch block and left anterior fascicular block	**I452**	Bifascicular block	
42653	Other bilateral bundle branch block	**I452**	Bifascicular block	
42654	Trifascicular block	**I453**	Trifascicular block	
4266	Other heart block	**I455**	Other specified heart block	
4267	Anomalous atrioventricular excitation	**I456**	Pre-excitation syndrome	
42681	Lown-Ganong-Levine syndrome	**I456**	Pre-excitation syndrome	
42682	Long QT syndrome	**I4581**	Long QT syndrome	
4269	Conduction disorder, unspecified	**I459**	Conduction disorder, unspecified	
4272	Paroxysmal tachycardia, unspecified	**I479**	Paroxysmal tachycardia, unspecified	
42769	Other premature beats	**I4949**	Other premature depolarization	

ICD-9	Description	ICD-10	Description	Clinician Notes
4279	Cardiac dysrhythmia, unspecified	**I499**	Cardiac arrhythmia, unspecified	
42821	Acute systolic heart failure	**I5021**	Acute systolic (congestive) heart failure	
42823	Acute on chronic systolic heart failure	**I5023**	Acute on chronic systolic (congestive) heart failure	
42831	Acute diastolic heart failure	**I5031**	Acute diastolic (congestive) heart failure	
42833	Acute on chronic diastolic heart failure	**I5033**	Acute on chronic diastolic (congestive) heart failure	
42841	Acute combined systolic and diastolic heart failure	**I5041**	Acute combined systolic (congestive) and diastolic (congestive) heart failure	
42843	Acute on chronic combined systolic and diastolic heart failure	**I5043**	Acute on chronic combined systolic (congestive) and diastolic (congestive) heart failure	
4290	Myocarditis, unspecified	**I514**	Myocarditis, unspecified	
7850	Tachycardia, unspecified	**R000**	Tachycardia, unspecified	

Table B. Clinician-Reviewed Readmission Codes: Many-to-One Mapping Using CMS 2011 GEMs

ICD-9	Description	ICD-10	Description	Which ICD-10?
11503	Infection by Histoplasma capsulatum, pericarditis	**B394**	Histoplasmosis capsulati, unspecified	**both**
		I32	Pericarditis in diseases classified elsewhere	
11504	Infection by Histoplasma capsulatum, endocarditis	**B394**	Histoplasmosis capsulati, unspecified	**both**
		I39	Endocarditis and heart valve disorders in diseases classified elsewhere	
11513	Infection by Histoplasma duboisii, pericarditis	**B395**	Histoplasmosis duboisii	**both**
		I32	Pericarditis in diseases classified elsewhere	
11514	Infection by Histoplasma duboisii, endocarditis	**B395**	Histoplasmosis duboisii	**both**
		I39	Endocarditis and heart valve disorders in diseases classified elsewhere	
11593	Histoplasmosis, unspecified, pericarditis	**B399**	Histoplasmosis, unspecified	**both**
		I32	Pericarditis in diseases classified elsewhere	
11594	Histoplasmosis, unspecified, endocarditis	**B399**	Histoplasmosis, unspecified	**both**
		I39	Endocarditis and heart valve disorders in diseases classified elsewhere	
4262	Left bundle branch hemiblock	**I444**	Left anterior fascicular block	**either**
		I445	Left posterior fascicular block	
4263	Other left bundle branch block	**I4469**	Other fascicular block	**either**
		I447	Left bundle-branch block, unspecified	
42789	Other specified cardiac dysrhythmias	**I498**	Other specified cardiac arrhythmias	**either**