Report for the Standardized Hospitalization Ratio

NQF #1463

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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).

Hospitalization rates are an important indicator of patient morbidity and quality of life. On average, dialysis patients are admitted to the hospital twice a year and spend an average of 11.2 days in the hospital per year [1]. Hospitalizations account for approximately 40 percent of total Medicare expenditures for ESRD patients [1]. Measures of the frequency of hospitalization have the potential to help efforts to control escalating medical costs, and to play an important role in identifying potential problems and helping facilities provide cost-effective health care.
At the end of 2013 there were 661,648 patients being dialyzed, of which 117,162 were new (incident) ESRD patients [1]. In 2013, total Medicare costs for the ESRD program were $30.9 billion, a 1.6% increase from 2012 [1]. Correspondingly, hospitalization costs for ESRD patients are very high with Medicare costs of over $10.3 billion in 2013.

Hospitalization measures have been in use in the Dialysis Facility Reports (formerly Unit-Specific Reports) since 1995. The Dialysis Facility Reports are used by the dialysis facilities and ESRD Networks for quality improvement, and by ESRD state surveyors for monitoring and surveillance. In particular, the SHR for Admissions is used by ESRD state surveyors in conjunction with other standard criteria for prioritizing and selecting facilities to survey and has been found to be predictive of citations in the past (ESRD State Outcomes List). The SHR is also a public reporting measure on the Centers for Medicare and Medicaid Services (CMS) Dialysis Facility Compare website.

The Standardized Hospitalization Ratio (SHR) for Admissions is designed to reflect the number of hospital admissions for the patients at a dialysis facility, relative to the number of hospital admissions that would be expected based on overall national rates and the characteristics of the patients at that facility. Numerically, the SHR is calculated as the ratio of two numbers: the numerator ("observed") is the actual number of hospital admissions for the patients in a facility over a specified time period, and the denominator ("expected") is the number of hospital admissions that would have been expected for the same patients if they were in a facility conforming to the national norm.

Methods

Overview

The denominator of SHR, the expected number of hospital admissions, is calculated from a Cox model for recurrent events, adjusting for age, sex, diabetes, duration of ESRD, nursing home status, a set of prevalent comorbidities, comorbidities at incidence, BMI at incidence, and calendar year. The SHR is not adjusted for race and ethnicity. Duration of ESRD is divided into six intervals with cut points at 6 months, 1 year, 2 years, 3 years and 5 years, and hospitalization rates are estimated separately within each interval. For each patient, the time at risk in each ESRD interval is multiplied by the (risk-adjusted) national admissions rate for that interval, and a sum over the intervals gives the expected number of admissions for each patient in a facility.

The SHR is an overall measure of hospital use and is composed of many different causes or reasons for hospitalization. In 2007, a Technical Expert Panel (TEP) was convened; the TEP provided advice on various aspects of the hospitalization measure, including adjustment factors. The TEP considered the possibility of devising cause specific SHRs, but recommended the use of overall SHR measures due to various reasons including the lack of clear research to indicate what causes should be selected as indicative of poor ESRD care and issues associated with inter-rater reliability in assessing cause of hospitalization. The TEP reached a strong consensus that the overall measures should give a reliable and valid measure that would typically be related to quality of care. In addition to the 2007 TEP, CMS contracted with UM-KECC to convene a Technical Expert Panel (TEP) in September 2015 to consider the addition of prevalent comorbidity risk adjustment. This resulted in the addition of a set of prevalent comorbidities to the SHR, described further in the risk adjustment section.

The SHR (NQF 1463) is currently endorsed by the National Quality Forum (NQF), with initial endorsement given in 2011, and the SHRs for most dialysis facilities in the United States are posted on the Centers for Medicare and Medicaid Services' (CMS) Dialysis Facility Compare (DFC) website.

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 Catheter Last 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.

Handling of Hospital Admissions from Medicare Inpatient Claims

In calculating the SHR, Medicare inpatient claims that are adjacent to or overlap with another claim are collapsed into one record. Specifically, if the admission date of an inpatient record is within one day of a previous admission's discharge date, these adjacent inpatient records are collapsed into one inpatient record that takes on the first hospitalization's admission date and the following hospitalization's discharge date. Similarly, if an inpatient record overlaps with another inpatient record, the two records are collapsed into one record where the earliest admission date between the two records becomes the new admission date and the latest discharge date between the two records becomes the new discharge date.

Outcome Definition

The outcome for this measure is admission to a hospital among Medicare eligible dialysis patients.

Cohort Definition and Inclusion Criteria

Assignment of Patients to Facilities

As patients can receive dialysis treatment at more than one facility in a given year, we assign each patient day to a facility (or no facility, in some cases) based on a set of conventions below, which largely align with those for the Standardized Mortality Ratio (SMR) and the Standardized Transfusion Ratio (STrR). We detail patient inclusion criteria, facility assignment and how to count days at risk, all of which are required for the risk adjustment model.

General Inclusion Criteria for Dialysis Patients

Since a patient's follow-up in the database can be incomplete during the first 90 days of ESRD therapy, we only include a patient's follow-up into the tabulations after that patient has received chronic renal replacement therapy for at least 90 days. Thus, hospitalizations, mortality and survival during the first 90 days of ESRD do not enter into the calculations. This minimum 90-day period also assures that most patients are eligible for Medicare, either as their primary or secondary insurer. It also excludes from analysis patients who die or recover during the first 90 days of ESRD.

In order to exclude patients who only received temporary dialysis therapy, we assigned patients to a facility only after they had been on dialysis there for at least 60 days. This 60 day period is used any time a patient begins therapy at a new facility whether the patient transferred from another facility, started ESRD for the first time, or returned to dialysis after a transplant. That is, hospitalizations during the first 60 days of dialysis at a facility do not affect the SHR of that facility.

Identifying Facility Treatment Histories for Each Patient

For each patient, we identify the dialysis provider at each point in time. Starting with day 91 after onset of ESRD, we attribute patients to facilities according to the following rules. A patient is attributed to a facility once the patient has been treated there for 60 days. When a patient transfers from one facility to another, the patient continues to be attributed to the original facility for 60 days and then is attributed to the destination facility. In particular, a patient is attributed to their current facility on day 91 of ESRD if that facility had treated him or her for at least 60 days. If on day 91, the facility had treated a patient for fewer than 60 days, we wait until the patient reaches day 60 of treatment at that facility before attributing the patient to that facility. When a patient is not treated in a single facility for a span of 60 days (for instance, if there were two switches within 60 days of each other), we do not attribute that patient to any facility. Patients are removed from facilities three days prior to transplant in order to exclude the transplant hospitalization. Patients who withdrew from dialysis or recovered renal function remain assigned to their treatment facility for 60 days after withdrawal or recovery.

If a period of one year passes with neither paid dialysis claims nor CROWNWeb/SIMS information to indicate that a patient was receiving dialysis treatment, we consider the patient lost to follow-up and do not include that patient in the analysis. If dialysis claims or other evidence of dialysis reappears, the patient is entered into analysis after 60 days of continuous therapy at a single facility.

Days at Risk for Medicare Dialysis Patients

After patient treatment histories are defined as described above, periods of follow-up in time since ESRD onset are created for each patient. In order to adjust for duration of ESRD appropriately, we define 6 time intervals with cut points at 6 months, 1 year, 2 years, 3 years and 5 years. A new time period

begins each time the patient is determined to be at a different facility, or at the start of each calendar year or when crossing any of the above cut points.

Since hospitalization data tend not to be as complete as mortality data, we include only patients whose Medicare billing records should include all hospitalizations. To achieve this goal, we require that patients reach a certain level of Medicare-paid dialysis bills to be included in the hospitalization statistics, or that patients have Medicare-paid inpatient claims during the period. Specifically, months within a given dialysis patient-period are used for SHR calculation when they meet the criterion of being within two months after a month with either: (a) $900+ of Medicare-paid dialysis claims OR (b) at least one Medicare-paid inpatient claim. The intention of this criterion is to assure completeness of information on hospitalizations for all patients included in the analysis.

The number of days at risk in each of these patient-ESRD-year-facility time periods is used to calculate the expected number of hospital admissions for the patient during that period. The SHR for a facility is the ratio of the total number of observed hospitalizations to the total number of expected hospitalizations during all time periods at the facility.

Risk Adjustment

Approach to Risk Adjustment

The risk adjustment is based on a Cox or relative risk model. The adjustment is made for patient age, sex, diabetes, duration of ESRD, nursing home status, BMI at incidence, comorbidities at incidence, a set of prevalent comorbidities, and calendar year. In this model, covariates are taken to act multiplicatively on the admission rate, and the adjustment model is fitted with facility defining strata so as to provide valid estimates even if the distribution of adjustment variables differs across facilities. Relevant references are Cox (1972), Kalbfleisch and Prentice (2002), Lawless and Nadeau (1995), Lin et al. (2000), Cook and Lawless (2007) and Liu, Schaubel and Kalbfleisch (2010). All analyses are done using SAS.

In general, adjustment factors for the SHR were selected based on several considerations. We began with a large set of patient characteristics, including demographics, comorbidities at ESRD incidence, a set of prevalent comorbidities, and other characteristics. Factors considered appropriate were then investigated with statistical models, including interactions between sets of adjusters, to determine if they were related to hospitalizations. Factors related to the SHR were also evaluated for face validity before being included. This evaluation included advice provided by two Technical Expert Panels, as described below. Finally, SDS/SES factors were evaluated based on appropriateness (whether related to disparities in care), empirical association with the outcome, and as supported in published literature.

In 2007, a Technical Expert Panel was convened; the TEP provided advice on various aspects of the SHR, including adjustment factors. The 2007 Hospitalization TEP felt that facility characteristics are generally not appropriate for use as adjusters, but should be evaluated for their potential as proxies for patient characteristics. The TEP also recommended that facility market characteristics, such as local hospital utilization rates, should not be considered as risk adjusters.

More recently, there has been great interest among dialysis care providers and other stakeholders in adjusting for more current (prevalent) comorbidities to reflect the current health status of dialysis patients, and specifically inclusion of conditions associated with hospitalization. In response, CMS contracted with UM-KECC to convene a Technical Expert Panel (TEP) in September 2015 to consider the addition of prevalent comorbidity risk adjustment. The summary report for the TEP can be found here: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-

Instruments/MMS/TechnicalExpertPanels.html. The TEP was charged with evaluating the potential of including prevalent comorbidities in the SMR and SHR risk adjustment models. Specific objectives included: (1) review of the comorbidity adjustment (determined at ESRD incidence) in the current NQF endorsed SMR and SHR measures; and (2) consideration of what, if any, prevalent comorbidities would be appropriate to include in each measure. In developing its recommendations, the TEP was asked to apply the criteria for risk-adjusters developed by the National Quality Forum (NQF): (1) Risk adjustment should be based on patient factors that influence the measured outcome and are present at the start of care; (2) Measures should not be adjusted for factors related to disparities in care or the quality of care; (3) Risk adjustment factors must be substantially related to the outcome being measured; (4) Risk adjustment factors should not reflect quality of care by the provider/facility being evaluated.

Reflecting these criteria, the TEP evaluated a list of prevalent comorbidities derived through the following process. First, the ESRD Hierarchical Condition Categories (ESRD-HCCs) were used as a starting point to identify ICD-9 diagnosis codes related to dialysis care. Those individual ICD-9 conditions that comprised the respective ESRD HCCs, with a prevalence of at least 0.1% in the patient population, were then selected for analysis to determine their statistical relationship to mortality and/or hospitalization. This step resulted in 555 diagnoses comorbidities (out of over 3000 ICD-9 diagnosis codes in the ESRD-HCCs). Next, an adaptive lasso variable selection method was applied to these 555 diagnoses to identify those with a statistically significant relationship to mortality and/or hospitalization ($p<0.05$). This process identified 242 diagnoses. The TEP members then scored each of these diagnoses as follows:

1. Very likely the result of dialysis facility care
2. Likely the result of dialysis facility care
3. May or may not be the result of dialysis facility care
4. Unlikely to be the result of dialysis facility care
5. Very likely not the result of dialysis facility care

This scoring exercise aimed at identifying a set of prevalent comorbidities not likely the result of facility care and therefore potentially appropriate as risk adjusters for SHR and SMR. The TEP established that comorbidities scored as “unlikely” or “very unlikely the result of facility care” by at least half of TEP members (simple majority) were judged as appropriate for inclusion as risk-adjusters. This process resulted in 210 conditions as risk adjustors. The TEP further recommended that: (1) comorbidities for inclusion as risk-adjusters in a particular year should be present in Medicare claims in the preceding calendar year; and (2) determination of a prevalent comorbidity required at least two outpatient claims or one inpatient claim. The set of prevalent comorbidities recommended by the TEP for inclusion as risk-adjusters is presented below.

Adjustment in the SHR

The regression model used to compute a facility’s “expected” number of hospitalizations for the SHR measure contains many factors thought to be associated with hospitalization rates. Specifically, the model adjusts for patient age, sex, diabetes as cause of ESRD, duration of ESRD, nursing home status, BMI at incidence, comorbidities at incidence, prevalent comorbidities, and calendar year. The stage 1 model allows the baseline hospitalization rates to vary between strata, which are defined by facilities, but assumes that the regression coefficients are the same across all strata; this approach is robust to possible differences between facilities in the patient mix being treated. In essence, it avoids a possible confounding between facility effects and patient covariates as can arise, for example, if patients with

favorable values of the covariate tend to be treated at facilities with better treatment policies and outcomes. Thus, for example, if patients with diabetes as a cause of ESRD tended to be treated at better facilities, one would underestimate the effect of diabetes unless the model is adjusted for facility. In this model, facility adjustment is done by stratification.

The patient characteristics included in the stage 1 model as covariates are:

- Age: We determine each patient's age from the birth date provided in the CROWNWeb and REMIS databases. Medicare claims and his/her Medical Evidence Form (CMS-2728) are used as check to verify birthdate (in the event of an error in the first three sources).
- Sex: We determine each patient's sex from CROWNWeb and REMIS databases, or SRTR.
- Diabetes as cause of ESRD: We determine each patient's primary cause of ESRD from his/her CMS-2728, and the CROWNWeb and REMIS databases. Duration of ESRD: We determine each patient's length of time since start of ESRD treatment using his/her CMS-2728, claims history (all claim types), the SIMS database and the SRTR database and categorize as 91 days-6 months, 6 months-1 year, 1-2 years, 2-3 years, 3-5 years, or 5+ years as of the period start date.
- Nursing home status: Using the Nursing Home Minimum Dataset, we determine if a patient was in a nursing home the previous year.
- BMI at incidence: We calculate each patient's BMI as the height and weight provided on his/her CMS 2728. BMI is included as a log-linear term.
- Comorbidities at incidence are determined using a selection of comorbidities reported on the CMS-2728 namely, alcohol dependence, atherosclerotic heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, congestive heart failure, diabetes (includes currently on insulin, on oral medications, without medications, and diabetic retinopathy), drug dependence, inability to ambulate, inability to transfer, malignant neoplasm, cancer, other cardiac disease, peripheral vascular disease, and tobacco use (current smoker). Each comorbidity is included as a separate covariate in the model.
- Prevalent comorbidities: We identify a patient's prevalent comorbidities based on claims from the previous calendar year. The comorbidities adjusted for in are listed later in this report.
- Calendar year

Categorical indicator variables are included as covariates in the stage I model to account for records with missing values for cause of ESRD, comorbidities at incidence (missing CMS-2728), and BMI. These variables have a value of 1 if the patient is missing the corresponding variable and a value of 0 otherwise. Another categorical indicator variable is included as a covariate in the stage 1 model to flag records where the patient has at least one of the incident comorbidities listed earlier. This variable has a value of 1 if the patient has at least one of the comorbidities and a value of 0 otherwise.
Beside main effects, two-way interaction terms between age, sex and duration and cause of ESRD are also included:

- Diabetes as cause of ESRD*Duration of ESRD
- Diabetes as cause of ESRD*Sex
- Diabetes as cause of ESRD*Age
- Age*Sex

Evaluation of Patient-level and Area-level Sociodemographic (SDS) and Socioeconomic (SES) factors and hospitalization

Age and sex are currently in the SHR. We also evaluated other patient and area-level SDS and SES factors (race, ethnicity; insurance status, employment status, and area-level deprivation indicators) not in SHR, to assess their respective impact on hospitalization.

Patient-level SDS: Compared with males, females were more likely to experience a hospital admission (OR=1.06; p<0.01). However the interaction of female sex and age demonstrated the highest odds were observed in the age 15 – 24, 25-44, and 45-59 age groups, with a decreasing gradient, and the 45-59 age group showing the most diminished impact. There was no significant difference in the oldest female-age-specific group. These results suggest the possibility of an unidentified biologic effect or, alternatively, confounding by an unmeasured association for younger females. Hispanics were less likely to be admitted to the hospital (OR=0.92; p<0.01) than non-Hispanics. Compared with white patients, Asian/PI (OR=0.81, p<0.01), Native American (OR=0.97, p<0.01) and black (OR=0.94, p<0.01) patients were less likely to be admitted to the hospital. The results for ethnicity and race are consistent with prior studies within the dialysis setting.

Patient-level SES: Compared with Medicare-only patients, patients with both Medicare and Medicaid (OR=1.08; p<0.01) and patients with Medicare as secondary/Medicare HMO (OR=2.66, p<0.01) were more likely to be hospitalized. The result for dually eligible patients having higher odds of hospitalization is consistent with the hypothesis that this insurance category, on average, represents an at-risk group. Further examination is needed for the higher odds of hospitalization for patients with Medicare as secondary payer or HMO. It is possible that these patients represent a larger portion of incident ESRD patients, which have a known higher risk of complications in the first year of ESRD.
Patients who were employed prior to ESRD incidence were more likely to be admitted to the hospital (OR=1.05; p<0.01) than unemployed patients. Note that for employment categories, the "Other/Unknown" category also had higher odds of hospital admission. We note this represents diverse patient groups with regard to SES, such as students, homemakers and those who are retired. The higher odds of hospitalization may be associated with unmeasured risk characteristics of this diverse group but that will require further empirical examination based on data availability.

Area-level SES: Overall, measures of area-level deprivation had very low impact on the odds of hospitalization. Among statistically significant impacts were measures of low median family income (OR=0.998, p=0.0188), the percentage of families below the poverty level (OR=1.001, p=0.002), the percentage of individuals without a high school diploma (OR=1.002, p<0.01), and the area-level unemployment rate (OR=1.002, p<0.01). In general the magnitude of the effects of the individual indicators was very small. In addition to the very small coefficients, a few were not in the expected direction suggesting potential collinearity with other SES or SDS factors in the model.

Conclusions: Race, ethnicity and patient level SES factors are not included in the final risk adjusted SHR model. While adjustment for these factors would account for different outcomes by race and ethnicity and SES factors, and guard against barriers in access to care, adjustment would also introduce the potential unintended consequence of allowing access to lower quality of care. Additionally, race and Hispanic ethnicity were observed to indicate lower risk of hospitalization. Including race and Hispanic ethnicity did not contribute substantially to the SHR, nor did patient-level measures of SES.

Given the very small impact of area-level SES factors we also decided not to include these as risk adjustments in the final model. While other studies have shown the association between these patient

and area-level SDS/SES factors and hospitalization, further work is needed to demonstrate that differences based on these factors are not related to facility care, in order to prevent disparities in care. Patients in lower SES strata are typically in poorer health as they face greater resource limitations as a result of their limited access to primary care. Adjusting for SES would effectively further comprise the quality of care received as it would lower standards of care based on an assumption these patients will just generally always be sicker.

Model for Calculating Expected Hospitalization

The denominator of the SHR stems from a proportional rates model (Lawless and Nadeau, 1995; Lin et al., 2000; Kalbfleisch and Prentice, 2002). This is the recurrent event analog of the well-known proportional hazards or Cox model (Cox, 1972; Kalbfleisch and Prentice, 2002). To accommodate large-scale data, we adopt a model with piecewise constant baseline rates (e.g. Cook and Lawless, 2007) and the computational methodology developed in Liu, Schaubel and Kalbfleisch (2012).

The modeling process has two stages. At stage I, a stratified model is fitted to the national data with piecewise-constant baseline rates and stratification by facility. Specifically, the model is of the following form

$$Pr(\text{hospital admission on day } t \text{ given covariates } X) = r_{0k}(t)\exp(\beta' X_{ik})$$

where X_{ik} is the vector of covariates for the i^{th} patient in the k^{th} facility and β is the vector of regression coefficients. Time t is measured from the start of ESRD. The baseline rate function $r_{0k}(t)$ is specific to the k^{th} facility, and is assumed to be a step function with break points at 6 months, 1 year, 2 years, 3 years and 5 years since the onset of dialysis. This model allows the baseline hospitalization rates to vary between strata (facilities), but assumes that the regression coefficients are the same across all strata; this approach is robust to possible differences between facilities in the patient mix being treated. The stratification on facilities is important in this phase to avoid bias due to possible confounding between covariates and facility effects.

At stage II, the relative risk estimates from the first stage are used to create offsets and an unstratified model is fitted to obtain estimates of an overall baseline rate function. That is, we estimate a common baseline rate of admissions, $r_0(t)$, across all facilities by considering the model

$$Pr(\text{hospital admission on day } t \text{ given covariates } X) = r_0(t)\, R_{ik},$$

where $R_{ik} = \exp(\beta' X_{ik})$ is the estimated relative risk for patient i in facility k obtained from the stage I. In our computation, we assume the baseline to be a step function with 6 unknown parameters, $\alpha_1, \ldots, \alpha_6$, to estimate. These estimates are used to compute the expected number of admissions given a patient's characteristics.

Specifically, let t_{iks} represent the number of days that patient i from facility k is under observation in the s^{th} time interval with estimated rate α_s. The corresponding expected number of hospital admissions in the s^{th} interval for this patient is calculated as

$$E_{iks} = \alpha_s\, t_{iks}\, R_{ik} \quad .$$

It should be noted that t_{iks} and hence E_{iks} can be 0 if patient i from facility k is never at risk during the s^{th} time interval. Summing the E_{iks} over all 6 intervals and all N_k patients in facility k gives

$$\text{Exp} = \sum_{i=1}^{N_k} \sum_{s=1}^{6} E_{iks} = \sum_{i=1}^{N_k} \sum_{s=1}^{6} \alpha_s t_{iks} R_{ik} \quad ,$$

which is the expected number of hospital admissions during follow-up at that facility.

Let Obs be the observed total number of hospital admissions at this facility. The SHR for hospital admissions is the ratio of the observed total admissions to this expected value, or

$$SHR = Obs/Exp$$

Missing Data

Patients with missing data are not excluded from the model. For the purposes of calculation, missing values for the comorbidity index and BMI are replaced with mean values for patients of similar age and identical race, sex, and cause of ESRD. Missing values for cause of ESRD are replaced with the other/unknown category. No patients were missing age, sex, or date of first ESRD treatment. Indicator variables identifying patients with missing values for cause of ESRD, comorbidity index, and BMI are also included as covariates in the model.

Calculation of SHR P-Values and Confidence Intervals

To adjust for over-dispersion of the data, we compute the p-value for our estimates using the empirical null distribution, a robust approach that takes account of the natural random variation among facilities that is not accounted for in the model (Efron, 2004; Kalbfleisch and Wolfe, 2013). Our algorithm consists of the following concrete steps. First, we fit an over-dispersed Poisson model (e.g., SAS PROC GENMOD with link=log, dist=poisson and scale=dscale) for the number of hospital admissions

$$\log(E[\mathbf{n}_{ik}]) = \log(\mathbf{E}_{ik}) + \boldsymbol{\theta}_k,$$

where $\mathbf{n}_{ik}$ is the observed number of events for patient *i* in facility *k*, $\mathbf{E}_{ik}$ is the expected number of events for patient *i* in facility *k* and $\boldsymbol{\theta}_k$ is the facility-specific intercept. Here, i ranges over the number of patients $\underline{N_k}$ who are treated in the *k*th facility. The natural log of the SHR for the *k*th facility is then given by the corresponding estimate of $\boldsymbol{\theta}_k$. The standard error of $\boldsymbol{\theta}_k$ is obtained from the robust estimate of variance arising from the overdispersed Poisson model.

Second, we obtain a z-score for each facility by dividing the natural log of its SHR by the standard error from the general linear model described above. These z-scores are then grouped into quartiles based on the number of patient years at risk for Medicare patients in each facility. Finally, using robust estimates of location and scale based on the normal curve fitted to the center of the z-scores for the SHR, we derive the mean and variance of a normal empirical null distribution for each quartile. This empirical null distribution is then used to calculate the p-value for a facility's SHR.

Example

The uncertainty or confidence intervals are obtained by applying the following steps:

- From the general linear model we obtain the natural log of the SHR (ln SHR) as well as its standard error, (SE). From the empirical null, we obtain a mean (μ) and a standard deviation (σ). The 95% uncertainty interval for the 'true' log standardized hospitalization ratio for this facility is

  $$\ln SHR - \mu * SE \pm 1.96 * \sigma * SE.$$

  Note that 1.96 is the critical point from the standard normal distribution for a 95% interval.

- Exponentiating the endpoints of this interval gives the uncertainty interval for the true SHR.

For example, consider a hypothetical facility whose SHR is 0.927 for which ln SHR = -0.076 with corresponding standard error, SE = 0.118. This facility falls in a quartile where the empirical null has μ = -0.143 and σ = 1.479. The corresponding uncertainty interval for the log SHR is

$$-0.076 - (-0.143)*0.118 \pm 1.96 *0.118*1.479 = (-0.401, 0.283).$$

The 95% interval for the true SHR is then 0.67 to 1.33.

Flagging rules for Dialysis Facility Compare (DFC)

As currently implemented for DFC, for reporting purposes we identify outlier facilities from amongst those with at least 5 patient-years at risk during the time period. If the 95% interval lies entirely above the value of 1.00 (i.e. both endpoints exceed 1.00), the facility is said to have outcomes that are "worse than expected". On the other hand, if the 95% interval lies entirely below the value 1.00, the facility is said to be better than expected. If the interval contains the value 1.00, the facility is said to have outcomes that are "as expected. For other purposes (e.g. QIP) other scoring methods may be used.

Results

Table 1. Model Coefficients, Data Years 2010–2013.

Covariate	Coefficient	P-value
Comorbidities at start of ESRD		
At least one of the comorbidities listed below	0.08624	<.0001
Atherosclerotic heart disease	0.04999	<.0001
Other cardiac disease	0.04395	<.0001
Diabetes*	-0.02026	<.0001
Congestive heart failure	0.04269	<.0001
Inability to ambulate	0.02042	<.0001
Chronic obstructive pulmonary disease	0.05646	<.0001
Inability to transfer	0.02401	<.0001
Malignant neoplasm, cancer	0.04102	<.0001
Peripheral vascular disease	0.04104	<.0001
Cerebrovascular disease, CVA, TIA	0.01904	<.0001
Tobacco use (current smoker)	0.08539	<.0001
Alcohol dependence	0.01285	0.036
Drug dependence	0.17361	<.0001
No Medical Evidence (CMS-2728) Form	0.15316	<.0001
Cause of ESRD		
Diabetes	0.03848	<.0001
Missing	-0.03547	<.0001
Sex: Female	0.07156	<.0001
Age		
0-14	0.48884	<.0001
15-24	0.13135	<.0001
25-44	-0.0678	<.0001
45-59	-0.065	<.0001
60-74	Reference	
75+	0.10178	<.0001
BMI		
Log BMI	-0.15032	<.0001

Covariate	Coefficient	P-value
BMI missing	0.01656	0.0002
Calendar year		
2010	Reference	
2011	-0.02546	<.0001
2012	-0.12676	<.0001
2013	-0.16265	<.0001
In nursing home the previous year	0.20788	<.0001
Diabetes as cause of ESRD X time on ESRD interaction term		
91 days-6 months	Reference	
6 months-1 year	0.03417	<.0001
1-2 years	0.01166	0.0737
2-3 years	0.00139	0.8356
3-5 years	-0.01549	0.0147
5+ years	-0.06398	<.0001
Cause of ESRD: diabetes X sex: female interaction term	-0.02622	<.0001
Age X diabetes as cause of ESRD interaction term		
0-14	-0.93749	<.0001
15-24	0.16727	<.0001
25-44	0.15502	<.0001
45-59	0.05013	<.0001
60-74	Reference	
75+	-0.03426	<.0001
Age X female sex interaction term		
0-14	-0.13038	0.0002
15-24	0.24562	<.0001
25-44	0.12877	<.0001
45-59	0.03139	<.0001
60-74	Reference	
75+	-0.00664	0.0685

*The diabetes indicator includes all diabetes comorbidities on CMS-2728 and diabetes as cause of ESRD

Table 2. Prevalent Comorbidity Coefficients, Data Years 2010–2013.

ICD-9 Description	ICD-9 Code	Coefficient	P-value
Sarcoidosis	135	0.0624	<.0001
Malign neopl prostate	185	-0.03133	<.0001
Malign neopl thyroid	193	-0.04837	0.0087
Oth severe malnutrition	262	0.0382	<.0001
Chr airway obstruct NEC	496	0.1908	<.0001
Postinflam pulm fibrosis	515	0.11769	<.0001
Malignant neopl rectum	1541	0.1335	<.0001
Mal neo liver, primary	1550	0.12225	<.0001
Mal neo upper lobe lung	1623	0.08088	<.0001
Mal neo bronch/lung NOS	1629	0.13617	<.0001
Malig neo bladder NOS	1889	0.10792	<.0001
Malig neopl kidney	1890	0.02548	0.0004
Secondary malig neo lung	1970	0.17282	<.0001
Second malig neo liver	1977	0.38071	<.0001
Secondary malig neo bone	1985	0.29043	<.0001
Malignant neoplasm NOS	1991	0.13518	<.0001
Protein-cal malnutr NOS	2639	0.10345	<.0001
Dis urea cycle metabol	2706	0.06036	0.0002
Senile dementia uncomp	2900	-0.02563	0.0001
Drug withdrawal	2920	0.26748	<.0001
Mental disor NEC oth dis	2948	0.04058	<.0001
Cereb degeneration NOS	3319	0.08582	<.0001
Aut neuropthy in oth dis	3371	0.02621	<.0001
Grand mal status	3453	0.01548	0.1722
Anoxic brain damage	3481	-0.03408	0.0008
Cerebral edema	3485	0.09181	<.0001
Idio periph neurpthy NOS	3569	0.09859	<.0001
Neuropathy in diabetes	3572	0.04133	<.0001
Intermed coronary synd	4111	0.2052	<.0001
Angina pectoris NEC/NOS	4139	0.12568	<.0001
Prim pulm hypertension	4160	-0.01251	0.0316
Chr pulmon heart dis NEC	4168	0.15189	<.0001
Prim cardiomyopathy NEC	4254	0.16394	<.0001
Cardiomyopath in oth dis	4258	0.16331	<.0001
Atriovent block complete	4260	0.02671	0.0001
Parox ventric tachycard	4271	0.09607	<.0001
Parox tachycardia NOS	4272	0.06145	<.0001
Subdural hemorrhage	4321	0.03408	0.0004
Aortic atherosclerosis	4400	0.09852	<.0001

ICD-9 Description	ICD-9 Code	Coefficient	P-value
Lower extremity aneurysm	4423	0.10898	<.0001
Periph vascular dis NOS	4439	0.09731	<.0001
Stricture of artery	4471	0.00238	0.6534
Oth inf vena cava thromb	4532	0.2153	<.0001
Emphysema NEC	4928	0.05787	<.0001
Bronchiectas w/o ac exac	4940	0.06175	<.0001
Food/vomit pneumonitis	5070	0.05726	<.0001
Lung involv in oth dis	5178	0.17403	<.0001
Regional enteritis NOS	5559	0.17154	<.0001
Ulceratve colitis unspcf	5569	0.06821	<.0001
Chr vasc insuff intest	5571	0.15765	<.0001
Paralytic ileus	5601	0.10245	<.0001
Intestinal obstruct NOS	5609	0.10671	<.0001
Alcohol cirrhosis liver	5712	0.05621	<.0001
Cirrhosis of liver NOS	5715	0.20344	<.0001
Hepatic encephalopathy	5722	0.17945	<.0001
Portal hypertension	5723	0.20086	<.0001
Oth sequela, chr liv dis	5728	0.14523	<.0001
Chronic pancreatitis	5771	0.38153	<.0001
Chronic skin ulcer NEC	7078	0.07843	<.0001
Syst lupus erythematosus	7100	0.24781	<.0001
Systemic sclerosis	7101	0.12899	<.0001
Rheumatoid arthritis	7140	0.10921	<.0001
Inflamm polyarthrop NOS	7149	0.02641	0.1369
Sacroiliitis NEC	7202	0.16649	<.0001
Gangrene	7854	0.05466	<.0001
Cachexia	7994	0.14375	<.0001
Fracture of pubis-closed	8082	0.06248	<.0001
Pelvic fracture NOS-clos	8088	-0.01048	0.4819
Fx neck of femur NOS-cl	8208	-0.02685	<.0001
Amput below knee, unilat	8970	-0.10393	<.0001
Amputat bk, unilat-compl	8971	-0.10582	<.0001
Amput above knee, unilat	8972	-0.08573	<.0001
Amputat leg, unilat NOS	8974	-0.077	<.0001
Candidal esophagitis	11284	0.1985	<.0001
Oth lymp unsp xtrndl org	20280	0.14363	<.0001
Mult mye w/o achv rmson	20300	0.19204	<.0001
Ch lym leuk wo achv rmsn	20410	0.25565	<.0001
Essntial thrombocythemia	23871	0.10421	<.0001
Low grde myelody syn les	23872	0.14376	<.0001

ICD-9 Description	ICD-9 Code	Coefficient	P-value
Myelodysplastic synd NOS	23875	0.17806	<.0001
DMII wo cmp nt st uncntr	25000	0.11986	<.0001
DMII wo cmp uncntrld	25002	0.02111	<.0001
DMII keto nt st uncntrld	25010	0.03729	<.0001
DMII ketoacd uncontrold	25012	0.13424	<.0001
DMI ketoacd uncontrold	25013	0.25355	<.0001
DMII hprosmlr uncontrold	25022	0.12376	<.0001
DMII renl nt st uncntrld	25040	0.0746	<.0001
DMI renl nt st uncntrld	25041	0.04644	<.0001
DMII ophth nt st uncntrl	25050	0.00743	0.0064
DMI ophth uncntrld	25053	0.05823	<.0001
DMII neuro nt st uncntrl	25060	0.05824	<.0001
DMI neuro nt st uncntrld	25061	0.04909	<.0001
DMII neuro uncntrld	25062	0.07612	<.0001
DMI neuro uncntrld	25063	0.13715	<.0001
DMII circ nt st uncntrld	25070	-0.04017	<.0001
DMI circ nt st uncntrld	25071	-0.05298	<.0001
DMII circ uncntrld	25072	-0.02251	<.0001
DMII oth nt st uncntrld	25080	0.08205	<.0001
DMI oth nt st uncntrld	25081	0.02286	0.0002
DMII oth uncntrld	25082	0.03781	<.0001
DMI oth uncntrld	25083	0.00729	0.3939
Glucocorticoid deficient	25541	0.17576	<.0001
Amyloidosis NEC	27739	0.15827	<.0001
Metabolism disorder NEC	27789	0.21983	<.0001
Morbid obesity	27801	0.07927	<.0001
Obesity hypovent synd	27803	-0.05432	<.0001
Sickle cell disease NOS	28260	0.71791	<.0001
Antin chemo indcd pancyt	28411	0.10449	0.0005
Other pancytopenia	28419	0.1945	<.0001
Neutropenia NOS	28800	0.16551	<.0001
Drug induced neutropenia	28803	0.14431	<.0001
Prim hypercoagulable st	28981	0.18562	<.0001
Senile delusion	29020	-0.11382	<.0001
Vascular dementia,uncomp	29040	-0.00174	0.8249
Dementia w/o behav dist	29410	0.01212	0.0613
Dementia w behavior dist	29411	-0.02334	0.0177
Demen NOS w/o behv dstrb	29420	0.04516	<.0001
Schizophrenia NOS-unspec	29590	0.15532	<.0001
Depress psychosis-unspec	29620	0.17524	<.0001

ICD-9 Description	ICD-9 Code	Coefficient	P-value
Recurr depr psychos-unsp	29630	0.08526	<.0001
Recur depr psych-severe	29633	0.07789	<.0001
Bipolar disorder NOS	29680	0.19198	<.0001
Bipolar disorder NEC	29689	0.08524	<.0001
Episodic mood disord NOS	29690	0.07786	<.0001
Alcoh dep NEC/NOS-unspec	30390	0.16788	<.0001
Alcoh dep NEC/NOS-remiss	30393	0.07322	<.0001
Opioid dependence-unspec	30400	0.25245	<.0001
Opioid dependence-contin	30401	0.18003	<.0001
Drug depend NOS-unspec	30490	0.27902	<.0001
Psymotr epil w/o int epi	34540	-0.08114	<.0001
Epilep NOS w/o intr epil	34590	0.19176	<.0001
Critical illness myopthy	35981	-0.09196	<.0001
Prolif diab retinopathy	36202	-0.08631	<.0001
Mod nonprolf db retinoph	36205	-0.07697	<.0001
Diabetic macular edema	36207	-0.0601	<.0001
Hyp ht dis NOS w ht fail	40291	0.03839	<.0001
Subendo infarct, initial	41071	0.18348	<.0001
AMI NEC, unspecified	41080	0.03986	0.0367
AMI NOS, unspecified	41090	-0.03149	<.0001
Ac ischemic hrt dis NEC	41189	0.11644	<.0001
Pulm embol/infarct NEC	41519	0.13237	<.0001
Atrial fibrillation	42731	0.13302	<.0001
Atrial flutter	42732	0.08346	<.0001
Sinoatrial node dysfunct	42781	-0.00923	0.0206
Crbl emblsm w infrct	43411	0.01754	0.0772
Crbl art ocl NOS w infrc	43491	0.07113	<.0001
Athscl extrm ntv art NOS	44020	0.00141	0.6632
Ath ext ntv at w claudct	44021	0.04379	<.0001
Ath ext ntv at w rst pn	44022	0.09607	<.0001
Ath ext ntv art ulcrtion	44023	0.02268	<.0001
Dsct of thoracic aorta	44101	0.23712	<.0001
Periph vascular dis NEC	44389	0.01881	0.0012
Deep phlebitis-leg NEC	45119	0.00269	0.7906
Ac DVT/emb prox low ext	45341	0.12676	<.0001
Ch DVT/embl low ext NOS	45350	0.12558	<.0001
Ch DVT/embl prox low ext	45351	0.09937	<.0001
Ch emblsm subclav veins	45375	0.17741	<.0001
Ac DVT/embl up ext	45382	0.08862	<.0001
Ac emblsm axillary veins	45384	0.10835	<.0001

ICD-9 Description	ICD-9 Code	Coefficient	P-value
Ac embl internl jug vein	45386	0.16307	<.0001
Ac embl thorac vein NEC	45387	0.13445	<.0001
Esoph varice oth dis NOS	45621	0.19764	<.0001
Obs chr bronc w(ac) exac	49121	0.16393	<.0001
Obs chr bronc w ac bronc	49122	0.11419	<.0001
Chronic obst asthma NOS	49320	0.10527	<.0001
Ch obst asth w (ac) exac	49322	0.10999	<.0001
Ac resp flr fol trma/srg	51851	-0.04255	0.0003
Ot pul insuf fol trm/srg	51852	-0.0827	0.0003
Other pulmonary insuff	51882	0.13098	<.0001
Chronic respiratory fail	51883	0.0293	<.0001
Acute & chronc resp fail	51884	0.02507	<.0001
Gastrostomy comp - mech	53642	0.10042	<.0001
Fecal impaction	56032	0.09744	<.0001
Pressure ulcer, low back	70703	0.0362	<.0001
Pressure ulcer, hip	70704	0.09173	<.0001
Pressure ulcer, buttock	70705	0.00396	0.4043
Ulcer of lower limb NOS	70710	0.01138	0.0098
Ulcer other part of foot	70715	0.04066	<.0001
Ulcer oth part low limb	70719	0.03358	<.0001
Pyogen arthritis-unspec	71100	0.03922	0.0151
Pyogen arthritis-l/leg	71106	0.11218	<.0001
Ac osteomyelitis-unspec	73000	-0.04005	0.0005
Ac osteomyelitis-ankle	73007	-0.03799	<.0001
Ac osteomyelitis NEC	73008	-0.01851	0.102
Osteomyelitis NOS-hand	73024	0.05835	0.0001
Osteomyelitis NOS-ankle	73027	-0.03107	<.0001
Path fx vertebrae	73313	0.1329	<.0001
Aseptic necrosis femur	73342	0.20291	<.0001
Asept necrosis bone NEC	73349	0.17431	<.0001
Coma	78001	0.02143	0.1083
Convulsions NEC	78039	0.10277	<.0001
Fx femur intrcaps NEC-cl	82009	0.03652	0.0079
Fx femur NOS-closed	82100	-0.05632	<.0001
React-indwell urin cath	99664	0.15093	<.0001
Compl heart transplant	99683	0.02305	0.3552
Asymp hiv infectn status	V08	0.37403	<.0001
Heart transplant status	V421	0.26702	<.0001
Liver transplant status	V427	0.16234	<.0001
Trnspl status-pancreas	V4283	0.14978	<.0001

ICD-9 Description	ICD-9 Code	Coefficient	P-value
Gastrostomy status	V441	0.02184	0.0173
Ileostomy status	V442	0.12312	<.0001
Colostomy status	V443	0.13378	<.0001
Urinostomy status NEC	V446	0.33981	<.0001
Respirator depend status	V4611	-0.02597	0.001
Status amput othr toe(s)	V4972	0.031	<.0001
Status amput below knee	V4975	0.02473	<.0001
Status amput above knee	V4976	0.01774	0.0036
Atten to gastrostomy	V551	-0.03053	0.0012
Long-term use of insulin	V5867	0.12534	<.0001
BMI 40.0-44.9, adult	V8541	0.03116	<.0001
Less than 6 months of Medicare eligible claims in the previous calendar year		0.73799	<.0001

Most of the coefficient estimates for the prevalent comorbidities are positive and statistically significant, but several do not obtain statistical significance. The very large number of clinical factors in the model expectedly generates substantial multicollinearity among the covariates, likely resulting in some unexpected results in the direction of the coefficient sign and levels of statistical significance. Inclusion of this set of prevalent comorbidities reflects the consensus of the TEP that adjustment for all of these prevalent comorbidities, in addition to incident comorbidities, is important to reflect the current health condition of the patient in risk adjustment.

Reliability Testing

The reliability of the SHR was assessed using data among Medicare ESRD dialysis patients during 2010-2013. 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. The inter-unit reliability (IUR) measures the proportion of the total variation of a measure that is attributable to the between-facility variation. The SHR, 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 that cannot be directly estimated by ANOVA. A small IUR (near 0) reveals that most of the variation of the measures between facilities is driven by random noise, indicating the measure would not be a good characterization of the differences among facilities, whereas a large IUR (near 1) indicates that most of the variation between facilities is due to the real difference between facilities.

Overall, we found that IURs for the one-year SHRs have a range of 0.70-0.72 across the years 2010, 2011, 2012 and 2013, which indicates that over two-thirds of the variation in the one-year SHR can be attributed to the between-facility differences and less than one-third to within-facility variation. The SHR calculation only included facilities with at least 5 patient years at risk.

Table 3: IUR for one-year SHR, Overall and by Facility Size, 2010-2013

	2010		2011		2012		2013	
Facility Size (Number of patients)	**IUR**	**N**	**IUR**	**N**	**IUR**	**N**	**IUR**	**N**
All	0.72	5407	0.71	5583	0.70	5709	0.70	5864
Small (<=50)	0.54	1864	0.51	1921	0.48	1977	0.46	2028
Medium (51–87)	0.65	1702	0.63	1785	0.58	1825	0.57	1930
Large (>=88)	0.81	1841	0.81	1877	0.81	1907	0.82	1906

Validity Testing

We have assessed the validity of the measure through various comparisons of this measure with other quality measures in use, using Spearman correlations.

The measure is also maintained on face validity. Hospitalization measures were reviewed by a TEP in 2007 and overall measures based on admissions and on days were recommended for inclusion in the Dialysis Facility Reports. In 2015, a TEP was held specifically to consider prevalent comorbidity adjustments for inclusion in the measure. The TEP's recommendations are reflected in the risk adjustment methodology. In addition, hospitalization is a major cost factor in the management of ESRD patients as noted earlier, further establishing a very strong case for face validity of the SHR admissions measure.

The SHR Admissions measure is correlated with the Standardized Mortality Ratio (SMR) for each individual year from 2010-2013, where Spearman's correlation coefficient ranged from 0.27 to 0.30, with all four correlations being highly significant ($p<0.0001$). Also for each year from 2011-2013, the SHR was correlated with the Standardized Readmission Ratio (SRR) (Spearman's rho=0.54, 0.50, 0.48; $p<0.0001$).

In addition, SHR Admissions is negatively correlated in each of the four years with percent of patients in the facility with AV Fistula (Spearman's rho= -0.12, -0.15, -0.12, -0.13). Thus higher values of SHR are associated with lower usage of AV Fistulas. Further, SHR admissions is positively correlated in each of the four years with percent of patients with catheter >= 90 days (Spearman's rho=0.21, 0.21, 0.18, 0.16), indicating that higher values of SHR are associated with increased use of catheters. These correlations are all highly significant ($p<0.001$). For each year of 2010 through 2013, the SHR Admissions is also found to be negatively correlated with the percent of hemodialysis patients with Kt/V>=1.2, again in the direction expected (Spearman's rho= -0.11, -0.13, -0.10,-0.11; $p<0.0001$). Lower SHRs are associated with a higher percentage of patients receiving adequate dialysis dose.

The SHR correlates with outcomes, processes of care, and causes of hospitalization that are commonly thought to be potentially related to poor quality of care. Higher hospitalization was associated with higher facility mortality rates; and similarly with higher readmissions. We found higher values of SHR are associated with lower usage of AV Fistulas, higher catheter use, and suboptimal dialysis adequacy.

References

Centers for Medicaid and Medicare Services (CMS). CMS Quality Strategy: 2013—Beyond. CMS website. http://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/QualityInitiativesGenInfo/Downloads/CMS-Quality-Strategy.pdf. Published November 2013. Accessed June 6, 2014.

Cook, R. and Lawless, J. (2007). *The Statistical Analysis of Recurrent Events*. Springer, New York. See page 65-67.

Cox, D. (1972). Regression models and life tables (with discussion). *J. Royal statistical Society, Series B*, 34:187–220.

de Jager DJ, Grootendorst DC, Jager KJ, et al. Cardiovasucular and noncardiovascular mortality among patients starting dialysis. 2009;302(16):1782–1789.

Efron, B. (2004). Large scale simultaneous hypothesis testing: the choice of null hypothesis. *J. Amer. Statist. Assoc.*, 99:96–104.

Kalbfleisch, J. and Prentice, R. (2002). *The Statistical Analysis of Failure Time Data*. Wiley, New York.

Kalbfleisch, J. and Wolfe, R. (2013). On monitoring outcomes of medical providers. *Statistics in the Biosciences*, 5:286–302.

Lawless, J. and Nadeau, C. (1995). Some simple and robust methods for the analysis of recurrent events. *Technometrics*, 37:355–364.

Lin, D., Wei, L., Yang, I., and Ying, Z. (2000). Semiparametric regression for the mean and rate functions of recurrent events. *Journal of the Royal Statistical Society Series B*, 62:771–730.

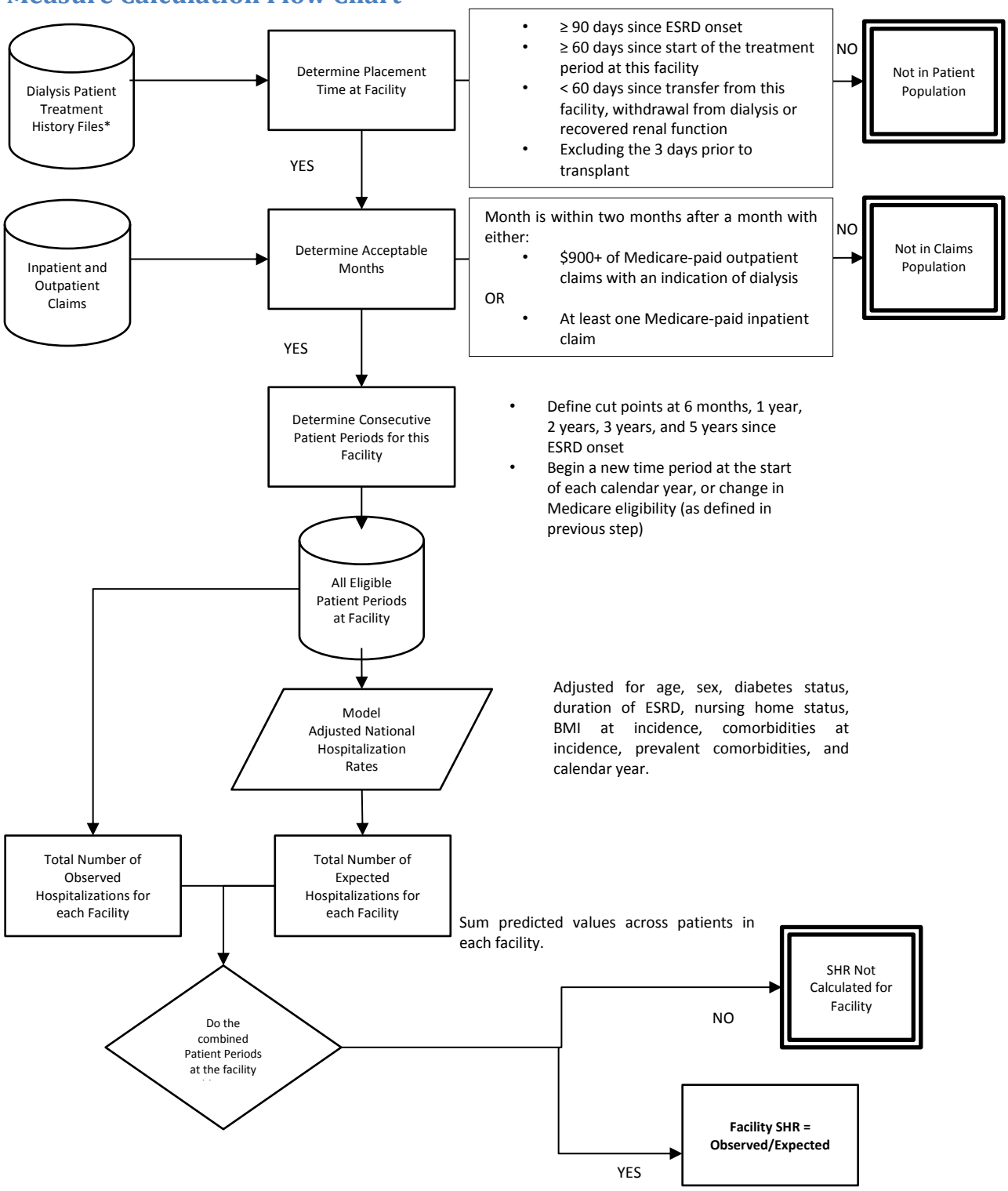
Liu, D., Schaubel, D., and Kalbfleisch, J. (2012). Computationally efficient marginal models for clustered recurrent event data, Biometrics 68, 637-647.

Medicare Payment Advisory Commission (MedPAC). “Chapter 5: Payment policy for inpatient readmissions.” From: Report to the Congress: Promoting Greater Efficiency in Medicare. MedPAC. Washington, DC. 2007:103–120.

United States Renal Data System. 2015 USRDS annual data report: Epidemiology of kidney disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, Bethesda, MD, 2015

Appendix

Measure Calculation Flow Chart



*Multiple data sources include CMS Consolidated Renal Operations in a Web-enabled Network (CROWNWeb), the CMS Annual Facility Survey (Form CMS-2744), Medicare dialysis and hospital payment records, the CMS Medical Evidence Form (Form CMS-2728), transplant data from the Organ Procurement and Transplant Network (OPTN), the Death Notification Form (Form CMS-2746), the Dialysis Facility Compare (DFC) and the Social Security Death Master File.

ICD-9 to ICD-10 Crosswalk

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
11284	Candidal esophagitis	B3781	B3781 Candidal esophagitis
135	Sarcoidosis	D869	D869 Sarcoidosis, unspecified
1541	Malignant neoplasm of rectum	C20	C20 Malignant neoplasm of rectum
1550	Malignant neoplasm of liver, primary	C220	C220 Liver cell carcinoma
1550	Malignant neoplasm of liver, primary	C222	C222 Hepatoblastoma
1550	Malignant neoplasm of liver, primary	C227	C227 Other specified carcinomas of liver
1550	Malignant neoplasm of liver, primary	C228	C228 Malignant neoplasm of liver, primary, unspecified as to type
1623	Malignant neoplasm of upper lobe, bronchus or lung	C3410	C3410 Malignant neoplasm of upper lobe, unspecified bronchus or lung
1629	Malignant neoplasm of bronchus and lung, unspecified	C3490	C3490 Malignant neoplasm of unspecified part of unspecified bronchus or lung
185	Malignant neoplasm of prostate	C61	C61 Malignant neoplasm of prostate
1889	Malignant neoplasm of bladder, part unspecified	C679	C679 Malignant neoplasm of bladder, unspecified
1890	Malignant neoplasm of kidney, except pelvis	C649	C649 Malignant neoplasm of unspecified kidney, except renal pelvis
193	Malignant neoplasm of thyroid gland	C73	C73 Malignant neoplasm of thyroid gland
1970	Secondary malignant neoplasm of lung	C7800	C7800 Secondary malignant neoplasm of unspecified lung
1977	Malignant neoplasm of liver, secondary	C787	C787 Secondary malignant neoplasm of liver and intrahepatic bile duct
1985	Secondary malignant neoplasm of bone and bone marrow	C7951	C7951 Secondary malignant neoplasm of bone
1985	Secondary malignant neoplasm of bone and bone marrow	C7952	C7952 Secondary malignant neoplasm of bone marrow
1991	Other malignant neoplasm without specification of site	C801	C801 Malignant (primary) neoplasm, unspecified
20280	Other malignant lymphomas, unspecified site, extranodal and solid organ sites	C8580	C8580 Other specified types of non-Hodgkin lymphoma, unspecified site
20280	Other malignant lymphomas, unspecified site, extranodal and solid organ sites	C8589	C8589 Other specified types of non-Hodgkin lymphoma, extranodal and solid organ sites
20300	Multiple myeloma, without mention of having achieved remission	C9000	C9000 Multiple myeloma not having achieved remission
20410	Chronic lymphoid leukemia, without mention of having achieved remission	C9110	C9110 Chronic lymphocytic leukemia of B-cell type not having achieved remission
23871	Essential thrombocythemia	D473	D473 Essential (hemorrhagic) thrombocythemia
23872	Low grade myelodysplastic syndrome lesions	D460	D460 Refractory anemia without ring sideroblasts, so stated
23872	Low grade myelodysplastic syndrome lesions	D461	D461 Refractory anemia with ring sideroblasts
23872	Low grade myelodysplastic syndrome lesions	D4620	D4620 Refractory anemia with excess of blasts, unspecified
23872	Low grade myelodysplastic syndrome lesions	D4621	D4621 Refractory anemia with excess of blasts 1
23872	Low grade myelodysplastic syndrome lesions	D46A	D46A Refractory cytopenia with multilineage dysplasia

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
23872	Low grade myelodysplastic syndrome lesions	D46B	D46B Refractory cytopenia with multilineage dysplasia and ring sideroblasts
23875	Myelodysplastic syndrome, unspecified	D469	D469 Myelodysplastic syndrome, unspecified
25000	Diabetes mellitus without mention of complication, type II or unspecified type, not stated as uncontrolled	E119	E119 Type 2 diabetes mellitus without complications
25002	Diabetes mellitus without mention of complication, type II or unspecified type, uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25010	Diabetes with ketoacidosis, type II or unspecified type, not stated as uncontrolled	E1169	E1169 Type 2 diabetes mellitus with other specified complication
25010	Diabetes with ketoacidosis, type II or unspecified type, not stated as uncontrolled	E1310	E1310 Other specified diabetes mellitus with ketoacidosis without coma
25012	Diabetes with ketoacidosis, type II or unspecified type, uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25012	Diabetes with ketoacidosis, type II or unspecified type, uncontrolled	E1169	E1169 Type 2 diabetes mellitus with other specified complication
25012	Diabetes with ketoacidosis, type II or unspecified type, uncontrolled	E1310	E1310 Other specified diabetes mellitus with ketoacidosis without coma
25013	Diabetes with ketoacidosis, type I [juvenile type], uncontrolled	E1010	E1010 Type 1 diabetes mellitus with ketoacidosis without coma
25013	Diabetes with ketoacidosis, type I [juvenile type], uncontrolled	E1065	E1065 Type 1 diabetes mellitus with hyperglycemia
25022	Diabetes with hyperosmolarity, type II or unspecified type, uncontrolled	E1100	E1100 Type 2 diabetes mellitus with hyperosmolarity without nonketotic hyperglycemic-hyperosmolar coma (NKHHC)
25022	Diabetes with hyperosmolarity, type II or unspecified type, uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25040	Diabetes with renal manifestations, type II or unspecified type, not stated as uncontrolled	E1129	E1129 Type 2 diabetes mellitus with other diabetic kidney complication
25041	Diabetes with renal manifestations, type I [juvenile type], not stated as uncontrolled	E1029	E1029 Type 1 diabetes mellitus with other diabetic kidney complication
25050	Diabetes with ophthalmic manifestations, type II or unspecified type, not stated as uncontrolled	E11311	E11311 Type 2 diabetes mellitus with unspecified diabetic retinopathy with macular edema
25050	Diabetes with ophthalmic manifestations, type II or unspecified type, not stated as uncontrolled	E11319	E11319 Type 2 diabetes mellitus with unspecified diabetic retinopathy without macular edema
25050	Diabetes with ophthalmic manifestations, type II or unspecified type, not stated as uncontrolled	E1136	E1136 Type 2 diabetes mellitus with diabetic cataract
25050	Diabetes with ophthalmic manifestations, type II or unspecified type, not stated as uncontrolled	E1139	E1139 Type 2 diabetes mellitus with other diabetic ophthalmic complication
25053	Diabetes with ophthalmic manifestations, type I [juvenile type], uncontrolled	E10311	E10311 Type 1 diabetes mellitus with unspecified diabetic retinopathy with macular edema
25053	Diabetes with ophthalmic manifestations, type I [juvenile type], uncontrolled	E10319	E10319 Type 1 diabetes mellitus with unspecified diabetic retinopathy without macular edema

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
25053	Diabetes with ophthalmic manifestations, type I [juvenile type], uncontrolled	E1036	E1036 Type 1 diabetes mellitus with diabetic cataract
25053	Diabetes with ophthalmic manifestations, type I [juvenile type], uncontrolled	E1039	E1039 Type 1 diabetes mellitus with other diabetic ophthalmic complication
25053	Diabetes with ophthalmic manifestations, type I [juvenile type], uncontrolled	E1065	E1065 Type 1 diabetes mellitus with hyperglycemia
25060	Diabetes with neurological manifestations, type II or unspecified type, not stated as uncontrolled	E1140	E1140 Type 2 diabetes mellitus with diabetic neuropathy, unspecified
25061	Diabetes with neurological manifestations, type I [juvenile type], not stated as uncontrolled	E1040	E1040 Type 1 diabetes mellitus with diabetic neuropathy, unspecified
25062	Diabetes with neurological manifestations, type II or unspecified type, uncontrolled	E1140	E1140 Type 2 diabetes mellitus with diabetic neuropathy, unspecified
25062	Diabetes with neurological manifestations, type II or unspecified type, uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25063	Diabetes with neurological manifestations, type I [juvenile type], uncontrolled	E1040	E1040 Type 1 diabetes mellitus with diabetic neuropathy, unspecified
25063	Diabetes with neurological manifestations, type I [juvenile type], uncontrolled	E1065	E1065 Type 1 diabetes mellitus with hyperglycemia
25070	Diabetes with peripheral circulatory disorders, type II or unspecified type, not stated as uncontrolled	E1151	E1151 Type 2 diabetes mellitus with diabetic peripheral angiopathy without gangrene
25071	Diabetes with peripheral circulatory disorders, type I [juvenile type], not stated as uncontrolled	E1051	E1051 Type 1 diabetes mellitus with diabetic peripheral angiopathy without gangrene
25072	Diabetes with peripheral circulatory disorders, type II or unspecified type, uncontrolled	E1151	E1151 Type 2 diabetes mellitus with diabetic peripheral angiopathy without gangrene
25072	Diabetes with peripheral circulatory disorders, type II or unspecified type, uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11618	E11618 Type 2 diabetes mellitus with other diabetic arthropathy
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11620	E11620 Type 2 diabetes mellitus with diabetic dermatitis
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11621	E11621 Type 2 diabetes mellitus with foot ulcer
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11622	E11622 Type 2 diabetes mellitus with other skin ulcer
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11628	E11628 Type 2 diabetes mellitus with other skin complications
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11630	E11630 Type 2 diabetes mellitus with periodontal disease
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11638	E11638 Type 2 diabetes mellitus with other oral complications

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E11649	E11649 Type 2 diabetes mellitus with hypoglycemia without coma
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25080	Diabetes with other specified manifestations, type II or unspecified type, not stated as uncontrolled	E1169	E1169 Type 2 diabetes mellitus with other specified complication
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10618	E10618 Type 1 diabetes mellitus with other diabetic arthropathy
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10620	E10620 Type 1 diabetes mellitus with diabetic dermatitis
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10621	E10621 Type 1 diabetes mellitus with foot ulcer
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10622	E10622 Type 1 diabetes mellitus with other skin ulcer
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10628	E10628 Type 1 diabetes mellitus with other skin complications
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10630	E10630 Type 1 diabetes mellitus with periodontal disease
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10638	E10638 Type 1 diabetes mellitus with other oral complications
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E10649	E10649 Type 1 diabetes mellitus with hypoglycemia without coma
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E1065	E1065 Type 1 diabetes mellitus with hyperglycemia
25081	Diabetes with other specified manifestations, type I [juvenile type], not stated as uncontrolled	E1069	E1069 Type 1 diabetes mellitus with other specified complication
25082	Diabetes with other specified manifestations, type II or unspecified type, uncontrolled	E1165	E1165 Type 2 diabetes mellitus with hyperglycemia
25082	Diabetes with other specified manifestations, type II or unspecified type, uncontrolled	E1169	E1169 Type 2 diabetes mellitus with other specified complication
25083	Diabetes with other specified manifestations, type I [juvenile type], uncontrolled	E1065	E1065 Type 1 diabetes mellitus with hyperglycemia
25083	Diabetes with other specified manifestations, type I [juvenile type], uncontrolled	E1069	E1069 Type 1 diabetes mellitus with other specified complication
25541	Glucocorticoid deficiency	E271	E271 Primary adrenocortical insufficiency
25541	Glucocorticoid deficiency	E272	E272 Addisonian crisis
25541	Glucocorticoid deficiency	E2740	E2740 Unspecified adrenocortical insufficiency
262	Other severe protein-calorie malnutrition	E43	E43 Unspecified severe protein-calorie malnutrition
2639	Unspecified protein-calorie malnutrition	E46	E46 Unspecified protein-calorie malnutrition

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
2706	Disorders of urea cycle metabolism	E7220	E7220 Disorder of urea cycle metabolism, unspecified
2706	Disorders of urea cycle metabolism	E7222	E7222 Arginosuccinic aciduria
2706	Disorders of urea cycle metabolism	E7223	E7223 Citrullinemia
2706	Disorders of urea cycle metabolism	E7229	E7229 Other disorders of urea cycle metabolism
27739	Other amyloidosis	E851	E851 Neuropathic heredofamilial amyloidosis
27739	Other amyloidosis	E853	E853 Secondary systemic amyloidosis
27739	Other amyloidosis	E858	E858 Other amyloidosis
27789	Other specified disorders of metabolism	C965	C965 Multifocal and unisystemic Langerhans-cell histiocytosis
27789	Other specified disorders of metabolism	C966	C966 Unifocal Langerhans-cell histiocytosis
27789	Other specified disorders of metabolism	E7139	E7139 Other disorders of fatty-acid metabolism
27789	Other specified disorders of metabolism	E803	E803 Defects of catalase and peroxidase
27789	Other specified disorders of metabolism	E8889	E8889 Other specified metabolic disorders
27789	Other specified disorders of metabolism	E889	E889 Metabolic disorder, unspecified
27801	Morbid obesity	E6601	E6601 Morbid (severe) obesity due to excess calories
27803	Obesity hypoventilation syndrome	E662	E662 Morbid (severe) obesity with alveolar hypoventilation
28260	Sickle-cell disease, unspecified	D571	D571 Sickle-cell disease without crisis
28411	Antineoplastic chemotherapy induced pancytopenia	D61810	D61810 Antineoplastic chemotherapy induced pancytopenia
28419	Other pancytopenia	D61818	D61818 Other pancytopenia
28800	Neutropenia, unspecified	D709	D709 Neutropenia, unspecified
28803	Drug induced neutropenia	D701	D701 Agranulocytosis secondary to cancer chemotherapy
28803	Drug induced neutropenia	D702	D702 Other drug-induced agranulocytosis
28981	Primary hypercoagulable state	D6851	D6851 Activated protein C resistance
28981	Primary hypercoagulable state	D6852	D6852 Prothrombin gene mutation
28981	Primary hypercoagulable state	D6859	D6859 Other primary thrombophilia
28981	Primary hypercoagulable state	D6861	D6861 Antiphospholipid syndrome
28981	Primary hypercoagulable state	D6862	D6862 Lupus anticoagulant syndrome
2900	Senile dementia, uncomplicated	F0390	F0390 Unspecified dementia without behavioral disturbance
29020	Senile dementia with delusional features	F0390	F0390 Unspecified dementia without behavioral disturbance
29020	Senile dementia with delusional features	F05	F05 Delirium due to known physiological condition
29040	Vascular dementia, uncomplicated	F0150	F0150 Vascular dementia without behavioral disturbance
2920	Drug withdrawal	F19939	F19939 Other psychoactive substance use, unspecified with withdrawal, unspecified
29410	Dementia in conditions classified elsewhere without behavioral disturbance	F0280	F0280 Dementia in other diseases classified elsewhere without behavioral disturbance

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
29411	Dementia in conditions classified elsewhere with behavioral disturbance	F0281	F0281 Dementia in other diseases classified elsewhere with behavioral disturbance
29420	Dementia, unspecified, without behavioral disturbance	F0390	F0390 Unspecified dementia without behavioral disturbance
2948	Other persistent mental disorders due to conditions classified elsewhere	F060	F060 Psychotic disorder with hallucinations due to known physiological condition
2948	Other persistent mental disorders due to conditions classified elsewhere	F068	F068 Other specified mental disorders due to known physiological condition
29590	Unspecified schizophrenia, unspecified	F209	F209 Schizophrenia, unspecified
29620	Major depressive affective disorder, single episode, unspecified	F329	F329 Major depressive disorder, single episode, unspecified
29630	Major depressive affective disorder, recurrent episode, unspecified	F339	F339 Major depressive disorder, recurrent, unspecified
29633	Major depressive affective disorder, recurrent episode, severe, without mention of psychotic behavior	F332	F332 Major depressive disorder, recurrent severe without psychotic features
29680	Bipolar disorder, unspecified	F319	F319 Bipolar disorder, unspecified
29689	Other bipolar disorders	F3181	F3181 Bipolar II disorder
29690	Unspecified episodic mood disorder	F39	F39 Unspecified mood [affective] disorder
30390	Other and unspecified alcohol dependence, unspecified	F1020	F1020 Alcohol dependence, uncomplicated
30393	Other and unspecified alcohol dependence, in remission	F1021	F1021 Alcohol dependence, in remission
30400	Opioid type dependence, unspecified	F1120	F1120 Opioid dependence, uncomplicated
30401	Opioid type dependence, continuous	F1120	F1120 Opioid dependence, uncomplicated
30490	Unspecified drug dependence, unspecified	F1920	F1920 Other psychoactive substance dependence, uncomplicated
3319	Cerebral degeneration, unspecified	G319	G319 Degenerative disease of nervous system, unspecified
3371	Peripheral autonomic neuropathy in disorders classified elsewhere	G990	G990 Autonomic neuropathy in diseases classified elsewhere
3453	Grand mal status	G40301	G40301 Generalized idiopathic epilepsy and epileptic syndromes, not intractable, with status epilepticus
34540	Localization-related (focal) (partial) epilepsy and epileptic syndromes with complex partial seizures, without mention of intractable epilepsy	G40201	G40201 Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, not intractable, with status epilepticus
34540	Localization-related (focal) (partial) epilepsy and epileptic syndromes with complex partial seizures, without mention of intractable epilepsy	G40209	G40209 Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, not intractable, without status epilepticus
34590	Epilepsy, unspecified, without mention of intractable epilepsy	G40901	G40901 Epilepsy, unspecified, not intractable, with status epilepticus
34590	Epilepsy, unspecified, without mention of intractable epilepsy	G40909	G40909 Epilepsy, unspecified, not intractable, without status epilepticus
3481	Anoxic brain damage	G931	G931 Anoxic brain damage, not elsewhere classified

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
3485	Cerebral edema	G936	G936 Cerebral edema
3569	Unspecified hereditary and idiopathic peripheral neuropathy	G609	G609 Hereditary and idiopathic neuropathy, unspecified
3572	Polyneuropathy in diabetes	E0842	E0842 Diabetes mellitus due to underlying condition with diabetic polyneuropathy
3572	Polyneuropathy in diabetes	E0942	E0942 Drug or chemical induced diabetes mellitus with neurological complications with diabetic polyneuropathy
3572	Polyneuropathy in diabetes	E1042	E1042 Type 1 diabetes mellitus with diabetic polyneuropathy
3572	Polyneuropathy in diabetes	E1142	E1142 Type 2 diabetes mellitus with diabetic polyneuropathy
3572	Polyneuropathy in diabetes	E1342	E1342 Other specified diabetes mellitus with diabetic polyneuropathy
35981	Critical illness myopathy	G7281	G7281 Critical illness myopathy
36202	Proliferative diabetic retinopathy	E11359	E11359 Type 2 diabetes mellitus with proliferative diabetic retinopathy without macular edema
36205	Moderate nonproliferative diabetic retinopathy	E11339	E11339 Type 2 diabetes mellitus with moderate nonproliferative diabetic retinopathy without macular edema
36207	Diabetic macular edema	E11311	E11311 Type 2 diabetes mellitus with unspecified diabetic retinopathy with macular edema
40291	Unspecified hypertensive heart disease with heart failure	I110	I110 Hypertensive heart disease with heart failure
41071	Subendocardial infarction, initial episode of care	I214	I214 Non-ST elevation (NSTEMI) myocardial infarction
41080	Acute myocardial infarction of other specified sites, episode of care unspecified	I2129	I2129 ST elevation (STEMI) myocardial infarction involving other sites
41090	Acute myocardial infarction of unspecified site, episode of care unspecified	I213	I213 ST elevation (STEMI) myocardial infarction of unspecified site
4111	Intermediate coronary syndrome	I200	I200 Unstable angina
41189	Other acute and subacute forms of ischemic heart disease, other	I248	I248 Other forms of acute ischemic heart disease
4139	Other and unspecified angina pectoris	I208	I208 Other forms of angina pectoris
4139	Other and unspecified angina pectoris	I209	I209 Angina pectoris, unspecified
41519	Other pulmonary embolism and infarction	I2699	I2699 Other pulmonary embolism without acute cor pulmonale
4160	Primary pulmonary hypertension	I270	I270 Primary pulmonary hypertension
4168	Other chronic pulmonary heart diseases	I272	I272 Other secondary pulmonary hypertension
4168	Other chronic pulmonary heart diseases	I2789	I2789 Other specified pulmonary heart diseases
4254	Other primary cardiomyopathies	I425	I425 Other restrictive cardiomyopathy
4254	Other primary cardiomyopathies	I428	I428 Other cardiomyopathies
4258	Cardiomyopathy in other diseases classified elsewhere	I43	I43 Cardiomyopathy in diseases classified elsewhere
4260	Atrioventricular block, complete	I442	I442 Atrioventricular block, complete
4271	Paroxysmal ventricular tachycardia	I472	I472 Ventricular tachycardia

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
4272	Paroxysmal tachycardia, unspecified	I479	I479 Paroxysmal tachycardia, unspecified
42731	Atrial fibrillation	I4891	I4891 Unspecified atrial fibrillation
42732	Atrial flutter	I4892	I4892 Unspecified atrial flutter
42781	Sinoatrial node dysfunction	I495	I495 Sick sinus syndrome
42781	Sinoatrial node dysfunction	R001	R001 Bradycardia, unspecified
4321	Subdural hemorrhage	I6200	I6200 Nontraumatic subdural hemorrhage, unspecified
43411	Cerebral embolism with cerebral infarction	I6340	I6340 Cerebral infarction due to embolism of unspecified cerebral artery
43491	Cerebral artery occlusion, unspecified with cerebral infarction	I6350	I6350 Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery
4400	Atherosclerosis of aorta	I700	I700 Atherosclerosis of aorta
44020	Atherosclerosis of native arteries of the extremities, unspecified	I70209	I70209 Unspecified atherosclerosis of native arteries of extremities, unspecified extremity
44021	Atherosclerosis of native arteries of the extremities with intermittent claudication	I70219	I70219 Atherosclerosis of native arteries of extremities with intermittent claudication, unspecified extremity
44022	Atherosclerosis of native arteries of the extremities with rest pain	I70229	I70229 Atherosclerosis of native arteries of extremities with rest pain, unspecified extremity
44023	Atherosclerosis of native arteries of the extremities with ulceration	I7025	I7025 Atherosclerosis of native arteries of other extremities with ulceration
44101	Dissection of aorta, thoracic	I7101	I7101 Dissection of thoracic aorta
4423	Aneurysm of artery of lower extremity	I724	I724 Aneurysm of artery of lower extremity
44389	Other specified peripheral vascular diseases	I7389	I7389 Other specified peripheral vascular diseases
4439	Peripheral vascular disease, unspecified	I739	I739 Peripheral vascular disease, unspecified
4471	Stricture of artery	I771	I771 Stricture of artery
45119	Phlebitis and thrombophlebitis of deep veins of lower extremities, other	I80209	I80209 Phlebitis and thrombophlebitis of unspecified deep vessels of unspecified lower extremity
4532	Other venous embolism and thrombosis of inferior vena cava	I82220	I82220 Acute embolism and thrombosis of inferior vena cava
4532	Other venous embolism and thrombosis of inferior vena cava	I82221	I82221 Chronic embolism and thrombosis of inferior vena cava
45341	Acute venous embolism and thrombosis of deep vessels of proximal lower extremity	I82419	I82419 Acute embolism and thrombosis of unspecified femoral vein
45341	Acute venous embolism and thrombosis of deep vessels of proximal lower extremity	I82429	I82429 Acute embolism and thrombosis of unspecified iliac vein
45341	Acute venous embolism and thrombosis of deep vessels of proximal lower extremity	I82439	I82439 Acute embolism and thrombosis of unspecified popliteal vein
45341	Acute venous embolism and thrombosis of deep vessels of proximal lower extremity	I824Y9	I824Y9 Acute embolism and thrombosis of unspecified deep veins of unspecified proximal lower extremity
45350	Chronic venous embolism and thrombosis of unspecified deep	I82509	I82509 Chronic embolism and thrombosis of unspecified deep veins of

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
	vessels of lower extremity		unspecified lower extremity
45350	Chronic venous embolism and thrombosis of unspecified deep vessels of lower extremity	I82599	I82599 Chronic embolism and thrombosis of other specified deep vein of unspecified lower extremity
45351	Chronic venous embolism and thrombosis of deep vessels of proximal lower extremity	I82519	I82519 Chronic embolism and thrombosis of unspecified femoral vein
45351	Chronic venous embolism and thrombosis of deep vessels of proximal lower extremity	I82529	I82529 Chronic embolism and thrombosis of unspecified iliac vein
45351	Chronic venous embolism and thrombosis of deep vessels of proximal lower extremity	I82539	I82539 Chronic embolism and thrombosis of unspecified popliteal vein
45351	Chronic venous embolism and thrombosis of deep vessels of proximal lower extremity	I825Y9	I825Y9 Chronic embolism and thrombosis of unspecified deep veins of unspecified proximal lower extremity
45375	Chronic venous embolism and thrombosis of subclavian veins	I82B29	I82B29 Chronic embolism and thrombosis of unspecified subclavian vein
45382	Acute venous embolism and thrombosis of deep veins of upper extremity	I82629	I82629 Acute embolism and thrombosis of deep veins of unspecified upper extremity
45384	Acute venous embolism and thrombosis of axillary veins	I82A19	I82A19 Acute embolism and thrombosis of unspecified axillary vein
45386	Acute venous embolism and thrombosis of internal jugular veins	I82C19	I82C19 Acute embolism and thrombosis of unspecified internal jugular vein
45387	Acute venous embolism and thrombosis of other thoracic veins	I82290	I82290 Acute embolism and thrombosis of other thoracic veins
45621	Esophageal varices in diseases classified elsewhere, without mention of bleeding	I8510	I8510 Secondary esophageal varices without bleeding
49121	Obstructive chronic bronchitis with (acute) exacerbation	J441	J441 Chronic obstructive pulmonary disease with (acute) exacerbation
49122	Obstructive chronic bronchitis with acute bronchitis	J440	J440 Chronic obstructive pulmonary disease with acute lower respiratory infection
4928	Other emphysema	J439	J439 Emphysema, unspecified
49320	Chronic obstructive asthma, unspecified	J449	J449 Chronic obstructive pulmonary disease, unspecified
49322	Chronic obstructive asthma with (acute) exacerbation	J441	J441 Chronic obstructive pulmonary disease with (acute) exacerbation
4940	Bronchiectasis without acute exacerbation	J479	J479 Bronchiectasis, uncomplicated
496	Chronic airway obstruction, not elsewhere classified	J449	J449 Chronic obstructive pulmonary disease, unspecified
5070	Pneumonitis due to inhalation of food or vomitus	J690	J690 Pneumonitis due to inhalation of food and vomit
515	Postinflammatory pulmonary fibrosis	J8410	J8410 Pulmonary fibrosis, unspecified
515	Postinflammatory pulmonary fibrosis	J8489	J8489 Other specified interstitial pulmonary diseases
5178	Lung involvement in other diseases classified elsewhere	J99	J99 Respiratory disorders in diseases classified elsewhere
51851	Acute respiratory failure following trauma and surgery	J95821	J95821 Acute postprocedural respiratory failure
51851	Acute respiratory failure following trauma and surgery	J9600	J9600 Acute respiratory failure, unspecified whether with hypoxia or hypercapnia
51852	Other pulmonary insufficiency, not elsewhere classified,	J951	J951 Acute pulmonary insufficiency following thoracic surgery

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
	following trauma and surgery		
51852	Other pulmonary insufficiency, not elsewhere classified, following trauma and surgery	J952	J952 Acute pulmonary insufficiency following nonthoracic surgery
51852	Other pulmonary insufficiency, not elsewhere classified, following trauma and surgery	J953	J953 Chronic pulmonary insufficiency following surgery
51882	Other pulmonary insufficiency, not elsewhere classified	J80	J80 Acute respiratory distress syndrome
51883	Chronic respiratory failure	J9610	J9610 Chronic respiratory failure, unspecified whether with hypoxia or hypercapnia
51884	Acute and chronic respiratory failure	J9620	J9620 Acute and chronic respiratory failure, unspecified whether with hypoxia or hypercapnia
53642	Mechanical complication of gastrostomy	K9423	K9423 Gastrostomy malfunction
5559	Regional enteritis of unspecified site	K5090	K5090 Crohn's disease, unspecified, without complications
5569	Ulcerative colitis, unspecified	K5190	K5190 Ulcerative colitis, unspecified, without complications
5571	Chronic vascular insufficiency of intestine	K551	K551 Chronic vascular disorders of intestine
5601	Paralytic ileus	K560	K560 Paralytic ileus
5601	Paralytic ileus	K567	K567 Ileus, unspecified
56032	Fecal impaction	K5641	K5641 Fecal impaction
5609	Unspecified intestinal obstruction	K5660	K5660 Unspecified intestinal obstruction
5712	Alcoholic cirrhosis of liver	K7030	K7030 Alcoholic cirrhosis of liver without ascites
5715	Cirrhosis of liver without mention of alcohol	K740	K740 Hepatic fibrosis
5715	Cirrhosis of liver without mention of alcohol	K7460	K7460 Unspecified cirrhosis of liver
5715	Cirrhosis of liver without mention of alcohol	K7469	K7469 Other cirrhosis of liver
5722	Hepatic encephalopathy	K7290	K7290 Hepatic failure, unspecified without coma
5722	Hepatic encephalopathy	K7291	K7291 Hepatic failure, unspecified with coma
5723	Portal hypertension	K766	K766 Portal hypertension
5728	Other sequelae of chronic liver disease	K7210	K7210 Chronic hepatic failure without coma
5728	Other sequelae of chronic liver disease	K7290	K7290 Hepatic failure, unspecified without coma
5771	Chronic pancreatitis	K861	K861 Other chronic pancreatitis
70703	Pressure ulcer, lower back	L89139	L89139 Pressure ulcer of right lower back, unspecified stage
70703	Pressure ulcer, lower back	L89149	L89149 Pressure ulcer of left lower back, unspecified stage
70703	Pressure ulcer, lower back	L89159	L89159 Pressure ulcer of sacral region, unspecified stage
70704	Pressure ulcer, hip	L89209	L89209 Pressure ulcer of unspecified hip, unspecified stage
70705	Pressure ulcer, buttock	L89309	L89309 Pressure ulcer of unspecified buttock, unspecified stage
70710	Ulcer of lower limb, unspecified	L97909	L97909 Non-pressure chronic ulcer of unspecified part of unspecified lower leg with unspecified severity

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
70715	Ulcer of other part of foot	L97509	L97509 Non-pressure chronic ulcer of other part of unspecified foot with unspecified severity
70719	Ulcer of other part of lower limb	L97809	L97809 Non-pressure chronic ulcer of other part of unspecified lower leg with unspecified severity
7078	Chronic ulcer of other specified sites	L98419	L98419 Non-pressure chronic ulcer of buttock with unspecified severity
7078	Chronic ulcer of other specified sites	L98429	L98429 Non-pressure chronic ulcer of back with unspecified severity
7100	Systemic lupus erythematosus	M3210	M3210 Systemic lupus erythematosus, organ or system involvement unspecified
7101	Systemic sclerosis	M340	M340 Progressive systemic sclerosis
7101	Systemic sclerosis	M341	M341 CR(E)ST syndrome
7101	Systemic sclerosis	M349	M349 Systemic sclerosis, unspecified
71100	Pyogenic arthritis, site unspecified	M0000	M0000 Staphylococcal arthritis, unspecified joint
71100	Pyogenic arthritis, site unspecified	M0010	M0010 Pneumococcal arthritis, unspecified joint
71100	Pyogenic arthritis, site unspecified	M0020	M0020 Other streptococcal arthritis, unspecified joint
71100	Pyogenic arthritis, site unspecified	M0080	M0080 Arthritis due to other bacteria, unspecified joint
71100	Pyogenic arthritis, site unspecified	M009	M009 Pyogenic arthritis, unspecified
71106	Pyogenic arthritis, lower leg	M00069	M00069 Staphylococcal arthritis, unspecified knee
71106	Pyogenic arthritis, lower leg	M00169	M00169 Pneumococcal arthritis, unspecified knee
71106	Pyogenic arthritis, lower leg	M00269	M00269 Other streptococcal arthritis, unspecified knee
71106	Pyogenic arthritis, lower leg	M00869	M00869 Arthritis due to other bacteria, unspecified knee
7140	Rheumatoid arthritis	M069	M069 Rheumatoid arthritis, unspecified
7149	Unspecified inflammatory polyarthropathy	M064	M064 Inflammatory polyarthropathy
7202	Sacroiliitis, not elsewhere classified	M461	M461 Sacroiliitis, not elsewhere classified
73000	Acute osteomyelitis, site unspecified	M8610	M8610 Other acute osteomyelitis, unspecified site
73000	Acute osteomyelitis, site unspecified	M8620	M8620 Subacute osteomyelitis, unspecified site
73007	Acute osteomyelitis, ankle and foot	M86179	M86179 Other acute osteomyelitis, unspecified ankle and foot
73007	Acute osteomyelitis, ankle and foot	M86279	M86279 Subacute osteomyelitis, unspecified ankle and foot
73008	Acute osteomyelitis, other specified sites	M8618	M8618 Other acute osteomyelitis, other site
73008	Acute osteomyelitis, other specified sites	M8628	M8628 Subacute osteomyelitis, other site
73024	Unspecified osteomyelitis, hand	M869	M869 Osteomyelitis, unspecified
73027	Unspecified osteomyelitis, ankle and foot	M869	M869 Osteomyelitis, unspecified
73313	Pathologic fracture of vertebrae	M4850XA	M4850XA Collapsed vertebra, not elsewhere classified, site unspecified, initial encounter for fracture
73313	Pathologic fracture of vertebrae	M8008XA	M8008XA Age-related osteoporosis with current pathological fracture, vertebra(e), initial encounter for fracture

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
73313	Pathologic fracture of vertebrae	M8448XA	M8448XA Pathological fracture, other site, initial encounter for fracture
73313	Pathologic fracture of vertebrae	M8468XA	M8468XA Pathological fracture in other disease, other site, initial encounter for fracture
73342	Aseptic necrosis of head and neck of femur	M87059	M87059 Idiopathic aseptic necrosis of unspecified femur
73349	Aseptic necrosis of bone, other	M8708	M8708 Idiopathic aseptic necrosis of bone, other site
78001	Coma	R4020	R4020 Unspecified coma
78039	Other convulsions	R569	R569 Unspecified convulsions
7854	Gangrene	I96	I96 Gangrene, not elsewhere classified
7994	Cachexia	R64	R64 Cachexia
8082	Closed fracture of pubis	S32501A	S32501A Unspecified fracture of right pubis, initial encounter for closed fracture
8082	Closed fracture of pubis	S32502A	S32502A Unspecified fracture of left pubis, initial encounter for closed fracture
8082	Closed fracture of pubis	S32509A	S32509A Unspecified fracture of unspecified pubis, initial encounter for closed fracture
8088	Closed unspecified fracture of pelvis	S329XXA	S329XXA Fracture of unspecified parts of lumbosacral spine and pelvis, initial encounter for closed fracture
82009	Other closed transcervical fracture of neck of femur	S72099A	S72099A Other fracture of head and neck of unspecified femur, initial encounter for closed fracture
8208	Closed fracture of unspecified part of neck of femur	S72009A	S72009A Fracture of unspecified part of neck of unspecified femur, initial encounter for closed fracture
82100	Closed fracture of unspecified part of femur	S7290XA	S7290XA Unspecified fracture of unspecified femur, initial encounter for closed fracture
8970	Traumatic amputation of leg(s) (complete) (partial), unilateral, below knee, without mention of complication	S88119A	S88119A Complete traumatic amputation at level between knee and ankle, unspecified lower leg, initial encounter
8970	Traumatic amputation of leg(s) (complete) (partial), unilateral, below knee, without mention of complication	S88129A	S88129A Partial traumatic amputation at level between knee and ankle, unspecified lower leg, initial encounter
8971	Traumatic amputation of leg(s) (complete) (partial), unilateral, below knee, complicated	S88119A	S88119A Complete traumatic amputation at level between knee and ankle, unspecified lower leg, initial encounter
8971	Traumatic amputation of leg(s) (complete) (partial), unilateral, below knee, complicated	S88129A	S88129A Partial traumatic amputation at level between knee and ankle, unspecified lower leg, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S78019A	S78019A Complete traumatic amputation at unspecified hip joint, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S78029A	S78029A Partial traumatic amputation at unspecified hip joint, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S78119A	S78119A Complete traumatic amputation at level between unspecified hip and knee, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S78129A	S78129A Partial traumatic amputation at level between unspecified hip and knee, initial encounter

ICD9DX	ICD9::ICD9DX_desc	ICD10CM	ICD10::ICD10CM_desc
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S78919A	S78919A Complete traumatic amputation of unspecified hip and thigh, level unspecified, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S78929A	S78929A Partial traumatic amputation of unspecified hip and thigh, level unspecified, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S88019A	S88019A Complete traumatic amputation at knee level, unspecified lower leg, initial encounter
8972	Traumatic amputation of leg(s) (complete) (partial), unilateral, at or above knee, without mention of complication	S88029A	S88029A Partial traumatic amputation at knee level, unspecified lower leg, initial encounter
8974	Traumatic amputation of leg(s) (complete) (partial), unilateral, level not specified, without mention of complication	S78919A	S78919A Complete traumatic amputation of unspecified hip and thigh, level unspecified, initial encounter
8974	Traumatic amputation of leg(s) (complete) (partial), unilateral, level not specified, without mention of complication	S78929A	S78929A Partial traumatic amputation of unspecified hip and thigh, level unspecified, initial encounter
8974	Traumatic amputation of leg(s) (complete) (partial), unilateral, level not specified, without mention of complication	S88919A	S88919A Complete traumatic amputation of unspecified lower leg, level unspecified, initial encounter
8974	Traumatic amputation of leg(s) (complete) (partial), unilateral, level not specified, without mention of complication	S88929A	S88929A Partial traumatic amputation of unspecified lower leg, level unspecified, initial encounter
99664	Infection and inflammatory reaction due to indwelling urinary catheter	T8351XA	T8351XA Infection and inflammatory reaction due to indwelling urinary catheter, initial encounter
99683	Complications of transplanted heart	T8620	T8620 Unspecified complication of heart transplant
99683	Complications of transplanted heart	T8621	T8621 Heart transplant rejection
99683	Complications of transplanted heart	T8622	T8622 Heart transplant failure
V08	Asymptomatic human immunodeficiency virus [HIV] infection status	Z21	Z21 Asymptomatic human immunodeficiency virus [HIV] infection status
V421	Heart replaced by transplant	Z941	Z941 Heart transplant status
V427	Liver replaced by transplant	Z944	Z944 Liver transplant status
V4283	Pancreas replaced by transplant	Z9483	Z9483 Pancreas transplant status
V441	Gastrostomy status	Z931	Z931 Gastrostomy status
V442	Ileostomy status	Z932	Z932 Ileostomy status
V443	Colostomy status	Z933	Z933 Colostomy status
V446	Other artificial opening of urinary tract status	Z936	Z936 Other artificial openings of urinary tract status
V4611	Dependence on respirator, status	Z9911	Z9911 Dependence on respirator [ventilator] status
V4972	Other toe(s) amputation status	Z89429	Z89429 Acquired absence of other toe(s), unspecified side
V4975	Below knee amputation status	Z89519	Z89519 Acquired absence of unspecified leg below knee
V4976	Above knee amputation status	Z89619	Z89619 Acquired absence of unspecified leg above knee
V551	Attention to gastrostomy	Z431	Z431 Encounter for attention to gastrostomy
V5867	Long-term (current) use of insulin	Z794	Z794 Long term (current) use of insulin
V8541	Body Mass Index 40.0-44.9, adult	Z6841	Z6841 Body mass index (BMI) 40.0-44.9, adult

Additional ICD-10 codes (added 10/1/2016)

E113591	Type 2 diabetes mellitus with proliferative diabetic retinopathy without macular edema, right eye
E113592	Type 2 diabetes mellitus with proliferative diabetic retinopathy without macular edema, left eye
E113593	Type 2 diabetes mellitus with proliferative diabetic retinopathy without macular edema, bilateral
E113599	Type 2 diabetes mellitus with proliferative diabetic retinopathy without macular edema, unspecified eye
E113391	Type 2 diabetes mellitus with moderate nonproliferative diabetic retinopathy without macular edema, right eye
E113392	Type 2 diabetes mellitus with moderate nonproliferative diabetic retinopathy without macular edema, left eye
E113393	Type 2 diabetes mellitus with moderate nonproliferative diabetic retinopathy without macular edema, bilateral
E113399	Type 2 diabetes mellitus with moderate nonproliferative diabetic retinopathy without macular edema, unspecified eye
T83518A	Infection and inflammatory reaction due to other urinary catheter, initial encounter