DRAFT

Standardized Readmission Ratio (SRR) for dialysis facilities

3a Measure Information Form (MIF)

Data Source

◆ Administrative claims

Data Source or Collection Instrument:

Data are derived from an extensive national ESRD patient database, which is currently based on the Standard Information Management System (SIMS) database maintained by the 18 ESRD Networks, 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 Nursing Home Minimum Dataset, and the Social Security Death Master File. The database is comprehensive for Medicare-covered ESRD patients. Information on hospitalizations is obtained from Medicare Inpatient Claims Standard Analysis Files (SAFs) and past-year comorbidity is obtained from multiple types (inpatient, outpatient institutional, physician/supplier, home health, hospice, skilled nursing facility claims) of Medicare Claims Standard Analysis Files (SAFs).

Data Source or Collection Instrument Reference:

http://www.cms.gov/Manuals/IOM/itemdetail.asp?filterType=none&filterByDID=-99&sortByDID=1&sortOrder=ascending&itemID=CMS018912

Data Dictionary or Code Table:

Main hospital claims:
http://www.resdac.org/sites/resdac.org/files/RIF%20Inpatient%20SNF%20SAF%20Version%20J%20CMS.pdf

Other claims sources (e.g., home health): http://www.resdac.org/cms-data/file-family/RIF-Medicare-Claims

Measure Set ID

◆ Not applicable

Version Number and Effective Date

◆ V. 1.4, 6/21/2013

CMS Approval Date

◆ Pending

NQF ID

- Not applicable

Date Endorsed

- Not applicable

Care Setting

- Dialysis facilities

Unit of Measurement

- Facility-level measure

Measurement Duration

- At least one year

Measurement Period

- Year

Measure Type

- This measure is an outcome measure.

Measure Scoring

- Ratio

Payer Source

- Medicare only

Improvement Notation

- Better quality = lower score

Measure Steward

- CMS

Copyright / Disclaimer

- Not applicable

Measure Description

- The Standardized Readmission Ratio (SRR) is defined to be the ratio of the number of index discharges from acute care hospitals that resulted in an unplanned readmission to an acute care hospital within 30 days of discharge for Medicare-covered dialysis patients treated at a particular dialysis facility to the number of readmissions that would be expected given the discharging hospitals and the characteristics of the patients as well as the national norm for dialysis facilities. Note that in this document, "hospital" always refers to acute care hospital.

Rationale

Unplanned readmission rates are an important indicator of patient morbidity and quality of life. On average, dialysis patients are admitted to the hospital nearly twice a year and hospitalizations account for approximately 38

percent of total Medicare expenditures for dialysis patients (U.S. Renal Data System, 2012). In 2010, more than 30% of dialysis patient discharges from an all-cause hospitalization were followed by an unplanned readmission within 30 days (U.S. Renal Data System, 2012). Measures of the frequency of unplanned readmissions, such as SRR, help efforts to control escalating medical costs, play an important role in providing cost-effective health care**,** and support coordination of care across inpatient and outpatient settings: discharge planning, transition, and follow-up care.

Studies have shown that pre- and post-discharge interventions may reduce admission and unplanned readmission rates. A variety of studies on non-ESRD populations that evaluated post-discharge interventions (Dunn 1994; Bostrom 1996; Dudas 2001; Azevedo 2002; Coleman 2004; Coleman 2006; Balaban 2008; Braun 2009) or a combination of pre- and post-discharge interventions (Naylor 1994; McDonald 2001; Creason 2001; Ahmed 2004; Anderson 2005; Jack 2009; Koehler 2009; Parry 2009) have indicated a reduction in the risk of unplanned readmissions to various degrees. In addition, a recent study in the ESRD population found that certain post-discharge assessments and changes in treatment at the dialysis facility may be associated with a reduced risk of readmission (Chan 2009). Altogether, these studies support the potential for modifying unplanned readmission rates with interventions performed prior to and immediately following patient discharge.

Clinical Recommendation Statement

◆ There are no known guidelines that specifically reference this measure.

References

◆ Please see Appendix A for references.

Release Notes / Summary of Changes

◆ Not applicable

Technical Specifications

◆ Target Population: Medicare-covered dialysis patients

Denominator

◆ **Denominator Statement**: The expected number of unplanned readmissions in each facility, which is derived from a model that accounts for patient characteristics and discharging acute care hospitals.

◆ **Denominator Details**
All Medicare live discharges of dialysis patients from a hospital in a calendar year are considered eligible for this measure.

We calculate the expected number of unplanned readmissions by fitting a model with random effects for discharging hospitals, fixed effects for facilities and regression adjustments for a set of patient-level characteristics, including measures of patient comorbidities. The expectation for the given facility is computed assuming readmission rates corresponding to an "average" facility with the same patient characteristics and same discharging hospitals as this facility. Model details are provided in the Risk Standardization section below.

◆ **Denominator Exceptions and Exclusions**

Hospital discharges that…
- End in death
- Result in a patient dying within 30 days with no readmission
- Are against medical advice

- Include a primary diagnosis for cancer, mental health or rehabilitation
- Occur after a patient's 12th readmission in the calendar year
- Are from a PPS-exempt cancer hospital
- Result in a transfer to another hospital on the same day

◆ **Denominator Exceptions and Exclusions Details**
- Death in hospital/within 30 days of discharge: We determine a patient's death date from his/her Death Notification Form (CMS Form 2746) and the Social Security Death Master File.
- Discharged against medical advice: We determine discharge status from the inpatient claim.
- Certain diagnoses: The primary diagnosis at discharge is available on the inpatient claim; we group these diagnoses into more general categories using AHRQ's Clinical Classification Software (CCS; see http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp for descriptions of each CCS). The excluded CCSs are shown below.
  - **Cancer:** 42, 19, 45, 44, 17, 38, 39, 14, 40, 35, 16, 13, 29, 15, 18, 12, 11, 27, 33, 32, 24, 43, 25, 36, 21, 41, 20, 23, 26, 28, 34, 37, 22, 31, 30
  - **Psychiatric**: 657, 659, 651, 670, 654, 650, 658, 652, 656, 655, 662
  - **Rehab for prosthesis**: 254
- Number of unplanned readmissions: We remove any records for a patient after his/her 12th unplanned readmission in the calendar year.
- PPS-exempt cancer hospitals: The following hospitals are listed as PPS-exempt cancer hospitals in the Federal Register (http://www.gpo.gov/fdsys/pkg/FR-2011-07-18/html/2011-16949.htm): 050146, 050660, 100079, 100271, 220162, 330154, 330354, 360242, 390196, 450076, 500138
- Same-day transfers: We determine same-day transfers using the hospital ID and date of discharge and date of next admission available in the inpatient claims data.

Numerator

◆ **Numerator Statement:** Each facility's observed number of hospital discharges that are followed by an unplanned hospital readmission within 30 days of discharge

◆ **Numerator Details**

Hospitalizations are counted as events in the numerator if they met the definition of unplanned readmission that (a) occurred within 30 days of a hospital discharge and (b) was not preceded by a "planned" readmission that also occurred within 30 days of discharge. In summary, a readmission is considered "planned" under two scenarios:
1. The patient undergoes a procedure that is always considered planned (e.g., bone marrow transplant) or has a primary diagnosis that always indicates the hospitalization is planned (e.g., maintenance chemotherapy).
2. The patient undergoes a procedure that MAY be considered planned if it is not accompanied by an acute diagnosis. For example, a hospitalization involving a heart valve procedure accompanied by a primary diagnosis of diabetes would be considered **planned**, whereas a hospitalization involving a heart valve procedure accompanied by a primary diagnosis of acute myocardial infarction (AMI) would be considered **unplanned**.

See Appendix B for details of determining "planned" readmissions.

Stratification or Risk Adjustment

◆ To estimate the probability of 30-day unplanned readmission, we use a two-stage model, the first of which is a double random-effects logistic regression model. In this model, both dialysis facilities and hospitals are represented as random effects, and regression adjustments are made for a set of patient-level characteristics. From this model, we obtain the estimated standard deviation of the random effects of hospitals.

The second model is a mixed-effects logistic regression model, in which facilities are fixed effects and hospitals are modeled as random effects, with the standard deviation specified as equal to its estimates from the first model. The expected number of readmissions for each facility is estimated as the summation of the probabilities of readmission of all patients in this facility and assuming the national norm for facility effect. This model accounts for a given facility's case mix using the same set of patient-level characteristics as those in the first model.

The equations used in the measure calculation are as follows:

o To estimate the probability of 30-day unplanned readmission, we use a two-stage approach. The main model, which produces the estimates used to calculate SRR, takes the form:

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

(1)

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

o We then use the estimates from this model to calculate each facility's SRR:

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

(2)

where, for the ith facility, O_i is the number of observed unplanned readmissions, E_i is the expected number of unplanned readmissions for discharges, $H(i)$ is the collection of indices of hospitals from which patients are discharged, and $\tilde{p}_{ijk}$ is the predicted probability of unplanned readmission under the national norm for each discharge. Specifically, $\tilde{p}_{ijk}$ takes the form

$$\tilde{p}_{ijk} = \frac{\exp(\widehat{\gamma_M} + \widehat{\alpha_j} + \widehat{\beta}^T Z_{ijk})}{1 + \exp(\widehat{\gamma_M} + \widehat{\alpha_j} + \widehat{\beta}^T Z_{ijk})} ,$$

(3)

which estimates the probability that a discharge from hospital j of an individual in facility i with characteristics Z_{ijk} would result in an unplanned readmission if the facility effect corresponded to the median of national facility effects, denoted by $\widehat{\gamma_M}$ Here, $\widehat{\alpha_j}$ and $\widehat{\beta}$ are estimates from model (1). The sum of these probabilities is the expected number of unplanned readmissions E_i at facility i, adjusting for patient mix and under the national norm.

◆ The coefficients for the patient characteristics resulting from the logistic model are shown below.

Table 1. Effects of Patient Characteristics on Readmission Rates for Medicare-Covered Dialysis Patients, 2009

Patient Characteristic	Beta	SE	p
Age (y)			
<25	0.31	0.03	<.0001
25–45	0.14	0.01	<.0001
45–60 (ref)	—	—	—
60–75	-0.04	0.01	<.0001
>75	0.04	0.01	<.0001
BMI			
Underweight	0.09	0.01	<.0001
Normal Weight (ref)	—	—	—
Overweight	-0.04	0.01	<.0001
Obese	-0.12	0.01	<.0001
Cause of ESRD: Diabetes	0.06	0.01	<.0001
Comorbidity (past year)			
Amputation status	0.09	0.01	<.0001
COPD	0.24	0.01	<.0001
Cardiorespiratory failure/shock	0.24	0.01	<.0001
Coagulation defects & other specified hematological disorders	0.14	0.01	<.0001
Drug and alcohol disorders	0.30	0.01	<.0001
End-Stage Liver Disease	0.34	0.02	<.0001
Fibrosis of lung or other chronic lung disorders	0.06	0.02	<.0001
Hemiplegia, paraplegia, paralysis	0.12	0.01	<.0001
Hip fracture/dislocation	0.04	0.02	0.01
Major organ transplants (excl. kidney)	0.04	0.02	0.02
Metastatic cancer/acute leukemia	0.29	0.03	<.0001
Other hematological disorders	0.18	0.01	<.0001
Other infectious disease & pneumonias	0.16	0.01	<.0001
Other major cancers	0.05	0.01	<.0001
Pancreatic disease	0.23	0.01	<.0001
Psychiatric comorbidity	0.22	0.01	<.0001
Respirator dependence/tracheostomy status	0.01	0.03	0.19
Rheumatoid arthritis & inflammatory connective tissue disease	0.07	0.01	<.0001
Seizure disorders & convulsions	0.15	0.01	<.0001
Septicemia/shock	0.15	0.01	<.0001
Severe cancer	0.17	0.02	<.0001
Severe infection	0.10	0.01	<.0001
Ulcers	0.14	0.01	<.0001
Length of Index Hospitalization (days)			
Quartile 1 (ref)	—	—	—
Quartile 2	0.11	0.01	<.0001
Quartile 3	0.22	0.01	<.0001
Quartile 4	0.42	0.01	<.0001
Presence of high-risk diagnosis at index discharge	0.35	0.04	<.0001
Sex: Female	0.06	0.01	<.0001
Time on ESRD (y)			
<1 (ref)	—	—	—
1–2	-0.04	0.01	0.001
2–3	-0.03	0.01	0.01
3–6	-0.02	0.01	0.03
>6	-0.07	0.01	<.0001

Note. Model results presented here are based on 2009 hospital discharges. The list of past-year comorbidities is based on the risk variables adjusted for in the Hospital-Wide Risk-Standardized Readmission Rate (RSRR; see Appendix C for details).

- ◆ Below are details on the risk adjustors used. Any variable dependent on data elements from the SIMS or REMIS databases will eventually be constructed using CROWNWeb data (when available):
    - o **Sex**: We determine each patient's sex from the SIMS and REMIS databases.
    - o **Age**: We determine each patient's age from the birth date provided the SIMS and REMIS databases.
    - o **Years on ESRD**: We determine each patient's length of time on dialysis using the first service date from his/her CMS 2728, claims history (all claim types), the SIMS database and the SRTR database.
    - o **Diabetes as cause of ESRD**: We determine each patient's primary cause of ESRD from his/her CMS 2728.
    - o **BMI at incidence**: We calculate each patient's BMI as the height and weight provided on his/her CMS 2728.
    - o **Days hospitalized during index admission**: Each admission's length is determined by taking the difference between the date of admission and the date of discharge available on the inpatient claim.
    - o **Past-year comorbidities (risk variables):** We identify all unique ICD-9 diagnosis codes from each patient's prior year of Medicare claims, using six available claim types: inpatient, outpatient, skilled nursing facility [SNF], hospice, home health and physician/supplier claims. We group these diagnosis codes by diagnosis area using HHS' Hierarchical Condition Categories (CCs; see https://www.cms.gov/Research-Statistics-Data-and-Systems/Research/HealthCareFinancingReview/downloads/04summerpg119.pdf). The HWR measure has determined that a subset of these diagnosis areas is appropriate to use in accounting for case mix; Appendix C provides a detailed list of the CCs included in these areas.
    - o **Discharged with high-risk condition**: We define a *high-risk* diagnosis as any diagnosis area (grouped by AHRQ CCS) that was extremely rare in our population but had a 30-day readmission rate of at least 40%. We did not include high-risk diagnosis groups related to cancer or mental health. The CCS areas identified as high-risk are:
        - ▪ CCS 5: HIV infection
        - ▪ CCS 6: Hepatitis
        - ▪ CCS 56: Cystic fibrosis
        - ▪ CCS 57: Immunity disorders
        - ▪ CCS 61: Sickle cell anemia
        - ▪ CCS 190: Fetal distress and abnormal forces of labor
        - ▪ CCS 151: Other liver diseases
        - ▪ CCS 182: Hemorrhage during pregnancy; abruptio placenta; placenta previa
        - ▪ CCS 186: Diabetes or abnormal glucose tolerance complicating pregnancy; childbirth; or the puerperium
        - ▪ CCS 210: Systemic lupus erythematosus and connective tissue disorders
        - ▪ CCS 243: Poisoning by nonmedicinal substances
- ◆ The code used for measure calculation is provided in Appendix D.

Sampling

Not applicable

Calculation Algorithm

Please see Appendix E for a flowchart describing how the measure is calculated.

Appendix A
References Supporting Readmission Measure

Articles & Technical Reports

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US Renal Data System

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Appendix B
Algorithm for Determining Planned Readmissions

Methodology from CMS' Hospital-Wide Readmission Measure
May 2012 Report

DRAFT

Centers for Medicare & Medicaid Services:

Measure Instrument Development and Support

Planned Readmissions Report

Section 1, Subtask 1.5b, Deliverable #74

Submitted May 3, 2012 to:

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Modification No. 000007, Option Year 2

YALE NEW HAVEN HEALTH

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Methodology

Unplanned readmissions are acute clinical events experienced by a patient that require urgent hospital admission. Higher than expected unplanned readmission rates suggest lower quality of hospital and post-discharge care and are the focus of hospital quality measurement as part of quality improvement efforts. Planned readmissions are not a signal of quality of care and should not be counted when assessing hospital quality. Furthermore, including planned readmissions in a readmissions measure could create a disincentive to provide appropriate care to patients who are scheduled for elective or necessary procedures. We have, therefore, developed an algorithm for using claims data to identify "planned readmissions" that will not count as outcomes in readmission measures.

Our algorithm is founded on three principles:

1. A few specific, limited types of care are always considered planned regardless of discharge diagnosis (rehabilitation, obstetrical delivery, transplant surgery, maintenance chemotherapy);

2. A planned readmission is defined as a non-acute readmission for a scheduled procedure; and

3. Admissions for acute illness or for complications of care are never planned.

Therefore, we classify as planned all readmissions for a *non-acute* diagnosis in which a typically planned procedure takes place and all readmissions for a limited set of conditions. See Figure 1 for a schematic of the planned readmissions algorithm.

We identify planned readmissions using the 231 mutually-exclusive procedure categories and 285 clinically-coherent, mutually-exclusive condition categories (diagnosis groups) defined by the Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS).

Although we developed the planned readmissions algorithm for use with CMS' hospital-wide all-cause unplanned readmission (HWR) measure (National Quality Forum [NQF] #1789), the algorithm could be used with condition-specific readmission measures since it identifies planned readmissions without consideration of the index admission condition.

Figure 1. Schematic of the planned readmission algorithm
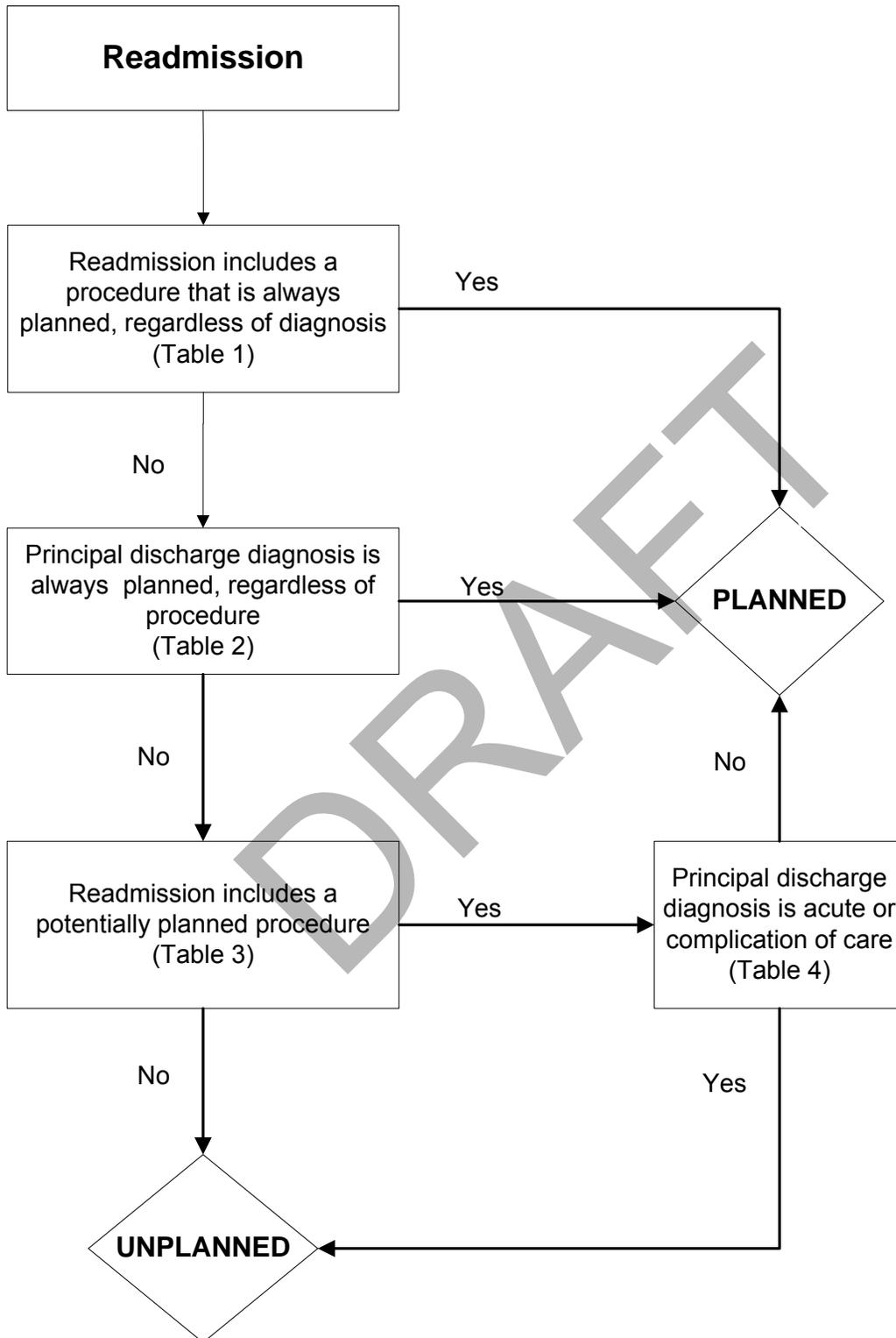
We developed our planned readmissions algorithm in three steps:

Step 1. Internal working group discussions

Clinicians in our internal working group reviewed the full list of AHRQ procedure CCS and identified procedure categories that are commonly planned. We considered procedures planned if they were typically: (1) elective and/or scheduled in advance; (2) the main reason for admission; and (3) not commonly done to treat a complication of care. This process identified as planned 31 procedure categories, one diagnosis group, and one group of ICD-9 codes within heterogeneous procedure categories.

Clinicians also reviewed the top 10 AHRQ condition CCS associated with the preliminary list of planned readmissions using data both from the Medicare fee-for-service (FFS) population aged 65 years and older in 2008 and from the California adult population (aged 18 years and older) in 2006. We identified 33 discharge diagnosis groups considered acute or complications of care. If a diagnosis group contained a mix of acute and chronic diagnoses, we tended to categorize it as acute.

Step 2. Public comment

The full preliminary list of planned readmissions and acute diagnoses was posted as part of the HWR measure for public comment by CMS from August 15-29, 2011, and again as part of the National Quality Forum public and member comment process from January 9-20, 2012. We received 27 comments about planned procedures in these two public comment periods. In response, we added two procedure categories and one group of ICD-9 codes to the list of potentially planned procedures. We also added one discharge diagnosis group to the list of acute diagnoses and complications of care list.

The planned readmissions algorithm submitted to the NQF as part of the HWR measure (NQF #1789) contained two "always planned" diagnosis groups, 33 procedure categories and two sets of ICD-9 codes on the potentially planned procedures list, and 34 diagnosis groups in the acute diagnosis and complications of care list. The algorithm counted 77,371 readmissions (5.5% of total readmissions) as planned.

Step 3. Consultations with expert surgeons

To further verify and refine the preliminary list of planned procedures and acute conditions, we contacted 15 surgical specialty societies to identify experts available for further consultation. Eleven societies recommended a total of 30 experts. Seventeen experts from nine societies reviewed relevant portions of the algorithm (e.g., cardiologists reviewed cardiac procedures). We also consulted with 10 additional surgeons recommended by internal team members or expert surgeons. We sought input on the appropriateness of our existing algorithm, and reviewed both the procedures that had been

categorized as unplanned and the diagnosis groups that had either been unclassified (i.e. not in the top 10 diagnoses for any procedure) or categorized as chronic, for potential addition to the algorithm.

The following specialty societies recommended experts who provided feedback for the algorithm:

- American Academy of Otolaryngology — Head and Neck Surgery, Inc.
- American Association of Neurological Surgeons
- American Society of Colon and Rectal Surgeons
- American Society of Metabolic & Bariatric Surgeons
- American Society of Plastic Surgeons
- Heart Rhythm Society
- Society for Vascular Surgery
- Society of Interventional Radiology
- Society of Thoracic Surgeons

We received input from experts in the following specialties:

Specialty	Number of experts
Colon and rectal surgery	2
Electrophysiology	4
Interventional radiology	1
Metabolic and bariatric surgery	1
Neurological surgery	2
Orthopedic surgery	2
Otolaryngology	3
Plastic surgery	2
Surgical oncology	1
Thoracic surgery	2
Trauma surgery	1
Urology	1
Vascular surgery	5

Consultation with specialists added 27 procedure categories, two groups of ICD-9 codes, and three individual ICD-9 codes within an existing group of ICD-9 codes to the list of potentially planned procedures and removed two procedure categories. In addition, two procedure groups and two diagnosis groups, intended for use in all-payer data but not applicable in readmission measures using CMS data, and which define maternity patients, were added to the list of always planned procedures and diagnoses. Finally, 73 diagnosis groups were added to the list of acute diagnoses and complications

of care, and 8 diagnosis groups were removed, four of which are now instead split at the ICD-9 level into acute and chronic diagnoses.

In total, the final planned readmissions algorithm contains:

- List of "always planned" procedures and diagnoses (Table 1 and Table 2)
    - o 5 procedure categories that are always planned (Table 1)
    - o 4 diagnosis groups that are always planned (Table 2)
- List of potentially planned procedures
    - o 60 procedure categories that are planned if not accompanied by an acute diagnosis (Table 3)
    - o 4 procedures identified by ICD-9 code(s) that are planned if not accompanied by an acute diagnosis (bottom of Table 3)
- List of acute diagnoses
    - o 99 diagnosis groups that disqualify a readmission as planned (Table 4)
    - o 4 additional subsets of diagnoses identified by ICD-9 codes within diagnosis groups (bottom of Table 4)

Under the final algorithm, 112,557 readmissions in the HWR measure in 2008 Medicare FFS data (8.0% of total readmissions) are categorized as planned. This represents an increase of 35,186 readmissions categorized as planned compared to the algorithm that was submitted to NQF. The median hospital will have 6.8% of all its readmissions characterized as planned, with an interquartile range (IQR) of 4.3 to 9.1%.

Final Algorithm

Table 1. Procedures that are always planned regardless of diagnosis

Proc CCS	Description	Total readmissions
64	Bone marrow transplant	490
105	Kidney transplant	517
134	Cesarean section*	
135	Forceps; vacuum; and breech delivery*	
176	Other organ transplantation	646

*CCS only to be included in all-payer settings, not intended for inclusion in CMS claims-based readmission measures

Table 2. Diagnoses that are always planned regardless of procedure

Dx CCS	Description	Total readmissions
45	Maintenance Chemotherapy (condition CCS 45)	17,232
194	**Forceps delivery***	
196	**Normal pregnancy and/or delivery***	
254	Rehabilitation (condition CCS 254)	259

Bolded conditions were added to the algorithm after NQF submission of the algorithm as part of the HWR measure
*CCS only to be included in all-payer settings, not intended for inclusion in CMS claims-based readmission measures

Table 3. Potentially planned procedures, if accompanied by non-acute diagnosis (Proc CCS)

Proc CCS	Description	Total readmissions
1	~~Incision and excision of CNS~~	-
3	Laminectomy; excision intervertebral disc	3,951
5	**Insertion of catheter or spinal stimulator and injection into spinal**	**4,781**
9	**Other OR therapeutic nervous system procedures**	**3,230**
10	Thyroidectomy; partial or complete	503
12	**Other therapeutic endocrine procedures**	**825**
33	**Other OR therapeutic procedures on nose; mouth and pharynx**	**927**
36	Lobectomy or pneumonectomy	1,519
38	Other diagnostic procedures on lung and bronchus	610
40	**Other diagnostic procedures of respiratory tract and mediastinum**	**3,221**
43	Heart valve procedures	1,791
44	Coronary artery bypass graft (CABG)	6,829
45	Percutaneous transluminal coronary angioplasty (PTCA)	6,708
47	**Diagnostic cardiac catheterization; coronary arteriography**	**57,514**
48	Insertion; revision; replacement; removal of cardiac pacemaker or cardioverter/defibrillator	22,922
49	**Other OR heart procedures**	**5,032**
51	Endarterectomy; vessel of head and neck	5,581
52	Aortic resection; replacement or anastomosis	1,828
53	**Varicose vein stripping; lower limb**	**26**
55	Peripheral vascular bypass	3,624
56	**Other vascular bypass and shunt; not heart**	**514**
59	**Other OR procedures on vessels of head and neck**	**1,764**
60	~~Embolectomy and endarterectomy of lower limbs~~	-
62	**Other diagnostic cardiovascular procedures**	**6,216**
64	Bone marrow transplant	490
66	**Procedures on spleen**	**726**
67	**Other therapeutic procedures; hemic and lymphatic system**	**4,771**
74	Gastrectomy; partial and total	802
78	Colorectal resection	11,547
79	**Local excision of large intestine lesion (not endoscopic)**	**91**
84	Cholecystectomy and common duct exploration	11,793
85	Inguinal and femoral hernia repair	1,318
86	**Other hernia repair**	**4,991**
99	Other OR gastrointestinal therapeutic procedures	10,637
104	Nephrectomy; partial or complete	1,564
105	Kidney transplant	517
106	**Genitourinary incontinence procedures**	**160**
107	**Extracorporeal lithotripsy; urinary**	**524**
109	**Procedures on the urethra**	**1,981**

Proc CCS	Description	Total readmissions
112	**Other OR therapeutic procedures of urinary tract**	**2,735**
113	Transurethral resection of prostate (TURP)	4,759
114	Open prostatectomy	303
119	Oophorectomy; unilateral and bilateral	1,180
120	**Other operations on ovary**	**128**
124	Hysterectomy; abdominal and vaginal	131
129	**Repair of cystocele and rectocele; obliteration of vaginal vault**	**143**
132	**Other OR therapeutic procedures; female organs**	**738**
134	**Cesarean section***	
135	**Forceps; vacuum; and breech delivery***	
142	**Partial excision bone**	**5,740**
152	Arthroplasty knee	4,323
153	Hip replacement; total and partial	11,164
154	Arthroplasty other than hip or knee	1,187
157	Amputation of lower extremity	12,930
158	Spinal fusion	3,978
159	**Other diagnostic procedures on musculoskeletal system**	**4,880**
166	Lumpectomy; quadrantectomy of breast	298
167	Mastectomy	649
169	**Debridement of wound; infection or burn**	**27,665**
172	**Skin graft**	**3,646**
176	Other organ transplantation	646
211	Therapeutic radiology for cancer treatment	7,784

ICD-9 Codes	Description	Total readmissions
30.1, 30.29, 30.3, 30.4, 31.74, 34.6	Laryngectomy, revision of tracheostomy, scarification of pleura (from Proc CCS 42- Other OR Rx procedures on respiratory system and mediastinum)	1,329
38.18	**Endarterectomy leg vessel (from Proc CCS 60- Embolectomy and endarterectomy of lower limbs)**	**2,340**
55.03, 55.04	**Percutaneous nephrostomy with and without fragmentation (from Proc CCS 103- Nephrotomy and nephrostomy)**	**2,625**
94.26, 94.27	Electroshock therapy (from Proc CCS 218- Psychological and psychiatric evaluation and therapy)	243

Bolded procedures were added to the algorithm after NQF submission of the algorithm as part of the HWR measure

~~Strikethrough~~ procedures were removed from the algorithm after NQF submission of the algorithm as part of the HWR measure

*procedure only to be included in all-payer settings, not intended for inclusion in CMS claims-based readmission measures

Table 4. Diagnoses that disqualify a readmission from being considered planned

Dx CCS	Description
1	**Tuberculosis**
2	Septicemia (except in labor)
3	**Bacterial infection; unspecified site**
4	**Mycoses**
5	**HIV infection**
7	**Viral infection**
8	**Other infections; including parasitic**
9	**Sexually transmitted infections (not HIV or hepatitis)**
54	**Gout and other crystal arthropathies**
55	Fluid and electrolyte disorders
60	**Acute posthemorrhagic anemia**
61	**Sickle cell anemia**
63	**Diseases of white blood cells**
76	**Meningitis (except that caused by tuberculosis or sexually transmitted disease)**
77	**Encephalitis (except that caused by tuberculosis or sexually transmitted disease)**
78	**Other CNS infection and poliomyelitis**
82	**Paralysis**
83	**Epilepsy; convulsions**
84	**Headache; including migraine**
85	**Coma; stupor; and brain damage**
87	**Retinal detachments; defects; vascular occlusion; and retinopathy**
89	**Blindness and vision defects**
90	**Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitteddisease)**
91	**Other eye disorders**
92	**Otitis media and related conditions**
93	**Conditions associated with dizziness or vertigo**
~~97~~	~~Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted disease)~~ *split by ICD-9 codes- see below*
100	Acute myocardial infarction
102	**Nonspecific chest pain**
104	**Other and ill-defined heart disease**
~~105~~	~~Conduction disorders~~ *split by ICD-9 codes- see below*
~~106~~	~~Cardiac dysrhythmias~~ *split by ICD-9 codes- see below*
107	**Cardiac arrest and ventricular fibrillation**
~~108~~	~~Congestive heart failure; nonhypertensive~~ *split by ICD-9 codes- see below*
109	Acute cerebrovascular disease
112	Transient cerebral ischemia
116	Aortic and peripheral arterial embolism or thrombosis

Dx CCS	Description
118	**Phlebitis; thrombophlebitis and thromboembolism**
120	**Hemorrhoids**
122	Pneumonia (except that caused by TB or sexually transmitted disease)
123	**Influenza**
124	**Acute and chronic tonsillitis**
125	**Acute bronchitis**
126	**Other upper respiratory infections**
127	Chronic obstructive pulmonary disease and bronchiectasis
128	**Asthma**
130	Pleurisy; pneumothorax; pulmonary collapse
131	Respiratory failure; insufficiency; arrest (adult)
135	**Intestinal infection**
137	**Diseases of mouth; excluding dental**
139	Gastroduodenal ulcer (except hemorrhage)
140	**Gastritis and duodenitis**
142	**Appendicitis and other appendiceal conditions**
145	Intestinal obstruction without hernia
146	Diverticulosis and diverticulitis
148	**Peritonitis and intestinal abscess**
153	Gastrointestinal hemorrhage
154	**Noninfectious gastroenteritis**
157	Acute and unspecified renal failure
159	Urinary tract infections
~~160~~	~~Calculus of urinary tract~~
165	**Inflammatory conditions of male genital organs**
168	**Inflammatory diseases of female pelvic organs**
172	**Ovarian cyst**
197	**Skin and subcutaneous tissue infections**
198	**Other inflammatory condition of skin**
~~201~~	~~Infective arthritis and osteomyelitis (except that caused by TB or sexually transmitted disease)~~
~~207~~	~~Pathological fracture~~
225	Joint disorders and dislocations; trauma-related
226	Fracture of neck of femur (hip)
227	Spinal cord injury
228	**Skull and face fractures**
229	Fracture of upper limb
230	Fracture of lower limb
~~231~~	~~Other fractures~~
232	Sprains and strains
233	Intracranial injury
234	**Crushing injury or internal injury**

Dx CCS	Description
235	**Open wounds of head; neck; and trunk**
237	Complication of device; implant or graft
238	Complications of surgical procedures or medical care
239	**Superficial injury; contusion**
240	**Burns**
241	**Poisoning by psychotropic agents**
242	**Poisoning by other medications and drugs**
243	**Poisoning by nonmedicinal substances**
244	**Other injuries and conditions due to external causes**
245	Syncope
246	**Fever of unknown origin**
247	**Lymphadenitis**
249	**Shock**
250	**Nausea and vomiting**
251	**Abdominal pain**
252	**Malaise and fatigue**
253	**Allergic reactions**
259	**Residual codes; unclassified**
650	**Adjustment disorders**
651	**Anxiety disorders**
652	**Attention-deficit, conduct, and disruptive behavior disorders**
653	**Delirium, dementia, and amnestic and other cognitive disorders**
656	**Impluse control disorders, NEC**
658	**Personality disorders**
660	**Alcohol-related disorders**
661	**Substance-related disorders**
662	**Suicide and intentional self-inflicted injury**
663	**Screening and history of mental health and substance abuse codes**
670	**Miscellaneous disorders**

ICD-9 codes	Description

Acute ICD-9 codes within Dx CCS 97: Per-; endo-; and myocarditis; cardiomyopathy

03282	Diphtheritic myocarditis
03640	Meningococcal carditis nos
03641	Meningococcal pericarditis
03642	Meningococcal endocarditis
03643	Meningococcal myocarditis
07420	Coxsackie carditis nos
07421	Coxsackie pericarditis
07422	Coxsackie endocarditis
07423	Coxsackie myocarditis
11281	Candidal endocarditis
11503	Histoplasma capsulatum pericarditis

Dx CCS	Description
11504	Histoplasma capssulatum endocarditis
11513	Histoplasma duboisii pericarditis
11514	Histoplasma duboisii endocarditis
11593	Histoplasmosis pericarditis
11594	Histoplasmosis endocarditis
1303	Toxoplasma myocarditis
3910	Acute rheumatic pericarditis
3911	Acute rheumatic endocarditis
3912	Acute rheumatic myocarditis
3918	Acute rheumatic heart disease nec
3919	Acute rheumatic heart disease nos
3920	Rheumatic chorea w heart involvement
3980	Rheumatic myocarditis
39890	Rheumatic heart disease nos
39899	Rheumatic heart disease nec
4200	Acute pericarditis in other disease
42090	Acute pericarditis nos
42091	Acute idiopath pericarditis
42099	Acute pericarditis nec
4210	Acute/subacute bacterial endocarditis
4211	Acute endocarditis in other diseases
4219	Acute/subacute endocarditis nos
4220	Acute myocarditis in other diseases
42290	Acute myocarditis nos
42291	Idiopathic myocarditis
42292	Septic myocarditis
42293	Toxic myocarditis
42299	Acute myocarditis nec
4230	Hemopericardium
4231	Adhesive pericarditis
4232	Constrictive pericarditis
4233	Cardiac tamponade
4290	Myocarditis nos

Acute ICD-9 codes within Dx CCS 105: Conduction disorders

4260	Atrioventricular block complete
42610	Atrioventricular block nos
42611	Atrioventricular block-1st degree
42612	Atrioventricular block-mobitz ii
42613	Atrioventricular block-2nd degree nec
4262	Left bundle branch hemiblock
4263	Left bundle branch block nec
4264	Right bundle branch block
42650	Bundle branch block nos

Dx CCS	Description
42651	Right bundle branch block/left posterior fascicular block
42652	Right bundle branch block/left ant fascicular block
42653	Bilateral bundle branch block nec
42654	Trifascicular block
4266	Other heart block
4267	Anomalous atrioventricular excitation
42681	Lown-ganong-levine syndrome
42682	Long qt syndrome
4269	Conduction disorder nos

Acute ICD-9 codes within Dx CCS 106: Dysrhythmia

Dx CCS	Description
4272	Paroxysmal tachycardia nos
7850	Tachycardia nos
42789	Cardiac dysrhythmias nec
4279	Cardiac dysrhythmia nos
42769	Premature beats nec

Acute ICD-9 codes within Dx CCS 108: Congestive heart failure; nonhypertensive

Dx CCS	Description
42821	Acute systolic heart failure
42823	Acute on chronic systolic heart failure
42831	Acute diastolic heart failure
42833	Acute on chronic diastolic heart failure
42841	Acute combined systolic & diastolic heart failure
42843	Acute on chronic combined systolic & diastolic heart failure

Bolded diagnosis groups were added to the algorithm after NQF submission of the algorithm as part of the HWR measure

~~Strikethrough~~ diagnosis groups were removed from the algorithm after NQF submission of the algorithm as part of the HWR measure

Additional updates to planned readmission algorithm based on feedback from dry run question and answer period

Updates to Planned Readmission Algorithm

1. **AHRQ Procedure CCS 170 – Excision of skin lesion**
   - *Update*: Add list of potentially planned procedures (Table A3 in report).
   - *Rationale*: Typically performed as planned procedure for cutaneous malignancy; this omission was noted by a hospital during dry run period.
2. **AHRQ Procedures CCS 224 – Cancer chemotherapy**
   - *Update:* Add to list of potentially planned procedures (Table A3 in report).
   - *Rationale:* Currently, patients readmitted with Diagnosis CCD 45 – Maintenance chemotherapy are considered planned readmissions. However, some patients who receive scheduled chemotherapy during hospitalization have a principal diagnosis of malignancy and only a procedure code of chemotherapy (procedure CCS 45); consequently they were previously missed by the planned readmission algorithm. This omission was noted by a hospital during the dry run period.
3. **AHRQ Diagnosis CCS 129 – Aspiration pneumonitis; food/vomitus**
   - *Update:* Add to list of acute diagnosis list (Table A4 in report); this will prevent an accompanying potentially planned procedure from being considered planned.
   - *Rationale:* Aspiration pneumonitis is an acute event; readmissions for aspiration pneumonitis are not typically planned.
4. **ICD-9 Diagnosis Codes 410.x2 – Acute myocardial infarction, subsequent episode of care**
   - *Update:* Remove from acute diagnosis list (Table A4 in report).
   - *Rationale:* ICD-9 410.x2 specifically refers to a subsequent episode of care for a previous acute MI, and does not refer to an acute MI. It was previously included in the overall diagnosis CCS 100, Acute Myocardial Infarction, and was thus incorrectly considered an acute event. This error was noted by a hospital during the dry run period.

Effect of update for each measure:

Measure	Planned readmission rate		
	Original specification	With new planned readmission algorithm	**After addition of these updates to algorithm**
Acute myocardial infarction	1.6%	2.2%	**2.3%**
Heart failure	N/A	1.3%	**1.3%**
Total hip and total knee arthroplasty	0.2%	0.5%	**0.5%**

Update to how subsequent readmissions after a planned readmission are handled

Previously, the AMI and hip and knee measures included some planned readmissions. For these measures, unplanned readmissions (C in diagram below) following planned readmissions (B) were counted as readmissions for the index admission (A) if they occurred within 30 days of discharge from the index admission. All measures are being updated to include a more comprehensive planned readmission algorithm and also to **end the measurement period for a readmission when a patient has been rehospitalized for any reason**, including a planned readmission. In other words, unplanned readmissions that fall within the 30-day post discharge timeframe will no longer be counted as outcomes for the index admission if they are preceded by a planned readmission

Current Approach for AMI, and for total hip and total knee arthroplasty

Index Admission (A) → Planned Readmission (B) → Unplanned Readmission (C)

30-day timeframe after discharge

Updated Approach for all Measures

Index Admission (A) → Planned Readmission (B) ✖ Unplanned Readmission (C)

30-day timeframe after discharge
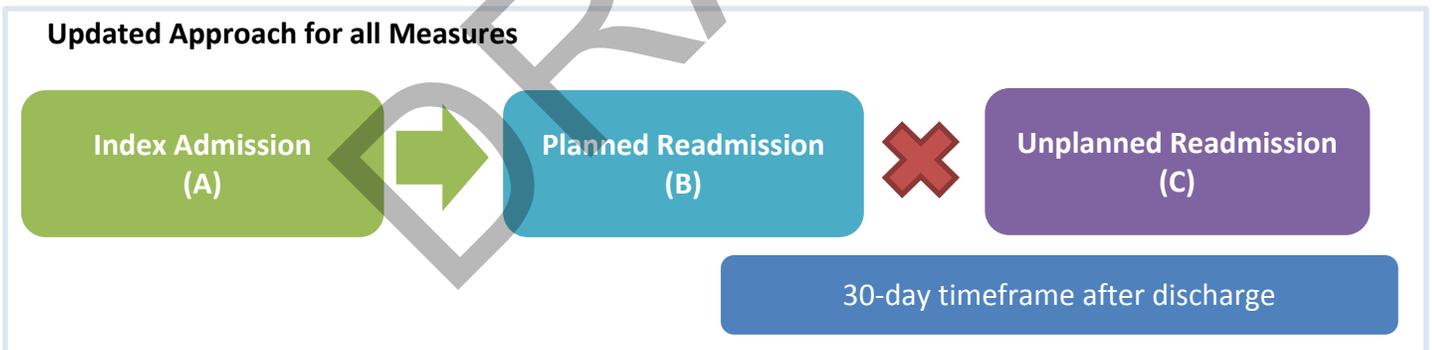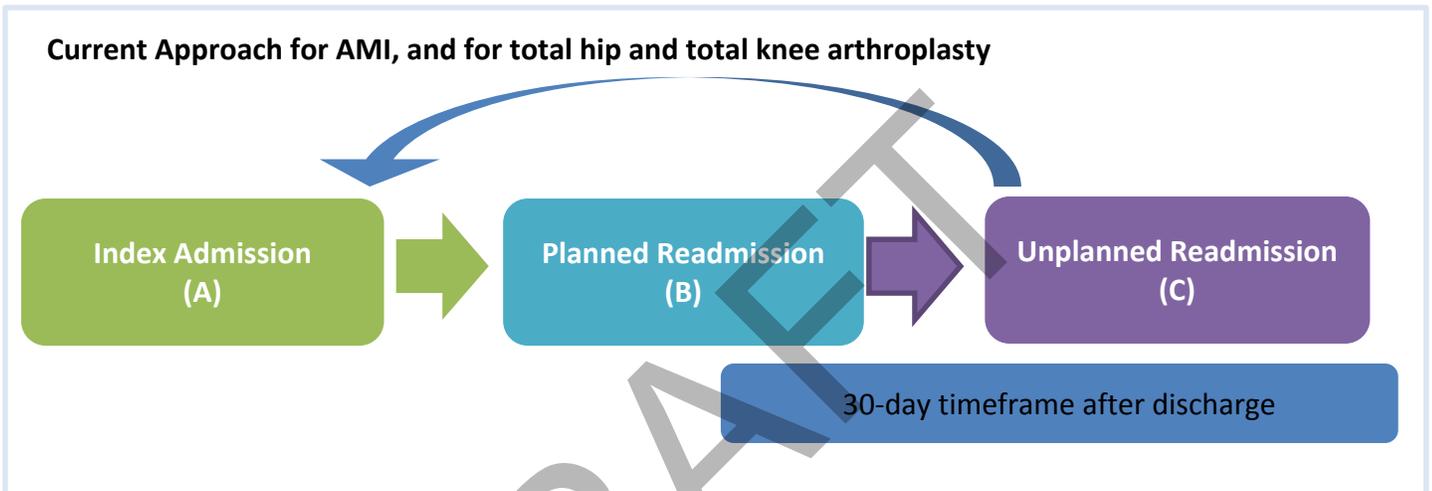
Effect of update for each measure:

Measure	Unplanned readmission rate	
	Revised measure, including updated planned readmission algorithm	After applying subsequent readmission update
Acute myocardial infarction	18.9%	18.7%
Heart failure	23.5%	23.3%
Total hip and total knee arthroplasty	5.5%	5.5%

Appendix C
Description of Past-Year Comorbidity Risk Variables

Risk Variable (rv)	CMS CCs	Description
rv1	**1, 3-5**	**Severe infection**
	1	HIV/AIDS
	3	Central nervous system infection
	4	Tuberculosis
	5	Opportunistic infections
rv2	**6, 111-113**	**Other infectious disease & pneumonias**
	6	Other infectious disease
	111	Aspiration and specified bacterial pneumonias
	112	Pneumococcal pneumonia, emphysema, lung abscess
	113	Viral and unspecified pneumonia, pleurisy
rv3	**7**	**Metastatic cancer/acute leukemia**
rv4	**8, 9**	**Severe cancer**
	8	Lung, upper digestive tract, and other severe cancers
	9	Other major cancers
rv6	**10, 11, 12**	**Other major cancers**
	10	Breast, prostate, colorectal and other cancers and tumors
	11	Other respiratory and heart neoplasms
	12	Other digestive and urinary neoplasms
rv11	**25, 26**	**End-Stage liver disease**
	25	End-Stage Liver Disease
	26	Cirrhosis of Liver
rv12	**44**	**Other hematologoical disorders**
rv14	**51-52**	**Drug and Alcohol disorders**
	51	Drug/alcohol psychosis
	52	Drug/alcohol dependence
rv15	**54-56, 58, 60**	**Psychiatric comorbidity**
	54	Schizophrenia
	55	Major depressive, bipolar, and paranoid disorders
	56	Reactive and unspecified psychosis
	58	Depression
	60	Other psychiatric disorders
rv18a	**67-69, 100, 101**	**Hemiplegia, paraplegia, paralysis**
	67	Quadriplegia, other extensive paralysis
	68	Paraplegia
	69	Spinal cord disorders/injuries
	100	Hemiplegia/hemiparesis
	101	Diplegia (upper), monoplegia, and other paralytic syndromes
rv18b	**177, 178**	**Amputation**
	177	Amputation status, lower limb/amputation
	178	Amputation status, upper limb
rv19	**74**	**Seizure disorders and convulsions**
rv26	**108**	**Chronic obstructive pulmonary disease**
rv27	**109**	**Fibrosis of lung or other chronic lung disorders**
rv30	**148, 149**	**Ulcers**

		148	Decubitus ulcer
		149	Decubitus ulcer or chronic skin ulcer
rv31	**2**		**Septicemia/shock**
rv34	**79**		**Cardio-respiratory failure or cardio-respiratory shock**
rv40	**32**		**Pancreatic disease**
rv41	**38**		**Rheumatoid arthritis and inflammatory connective tissue disease**
rv42	**77**		**Respirator dependence/tracheostomy status**
rv43	**128**		**Major organ transplant status**
rv44	**46**		**Coagulation defects and other specified hematological disorders**
rv45	**158**		**Hip fracture/dislocation**

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

- Removed
    1. **rv9 (Diabetes)**: Already adjust for in model
    2. **rv10 (Protein calorie malnutrition)**: Present in many ESRD patients, potentially modifiable
    3. **rv20 (CHF)**: Present in many ESRD patients, potentially modifiable
    4. **rv21 (CAD/CVD)**: Present in many ESRD patients
    5. **rv24 (Arrhythmia)**: Present in many ESRD patients
    6. **rv29 (Dialysis status)**: Inappropriate to adjust for in ESRD population
    7. **rv32 (Fluid/electrolyte disorders)**: Inappropriate to adjust for in ESRD population; most patients have it and thus essentially an indicator of ESRD
    8. **rv33 (Iron deficiency)**: Inappropriate to adjust for in ESRD population; most patients have it and thus essentially an indicator of ESRD
    9. **rv39 (Acute renal failure)**: Inappropriate to adjust for in ESRD population
- Modified
    1. **rv18 (split into two groups [–plegias and amputation], removed CCS102 [Speech, language, cognitive, perceptual])**: Because the effects for amputation status and the –plegias are similar—and given the TEP's opinion that combining these conditions is clinically inappropriate—we adjust separately for these two conditions and do not adjust for CCS 102, which was found to have a much smaller effect.
    2. **rv43 (removed CCS128 [Kidney transplant status])**: We assume that no patients in our population would have active kidney transplant status because all patients in our population are currently on dialysis.

Appendix D
Measure Calculation Code (R)

```
# calculate sample size for facility
m <- as.vector(sapply(split(data$readmit30_flag,factor(data$provfs)),length))


#n_i: sample size for facility; is a variable for all subjects; length(n_i)=number of indexes
n_i<-rep(m,m)


#delete facility with small number of index
data_sub=data[n_i>10,]



sum(is.na(data_sub$vincat2))
sum(is.na(data_sub$pct_nrshome))
sum(is.na(data_sub$risky_currentdx))

levels(factor(data_sub$hosp_urban))

data_sub$vincat2[is.na(data_sub$vincat2)==TRUE]=0
sum(is.na(data_sub$vincat2))

data_sub$vincat3[is.na(data_sub$vincat3)==TRUE]=0
sum(is.na(data_sub$vincat3))

data_sub$vincat4[is.na(data_sub$vincat4)==TRUE]=0
sum(is.na(data_sub$vincat4))


data_sub$vincat5[is.na(data_sub$vincat5)==TRUE]=0
sum(is.na(data_sub$vincat5))

data_sub$pct_nrshome[is.na(data_sub$pct_nrshome)==TRUE]=mean(data_sub$pct_nrshome[is.na(data_sub$
pct_nrshome)==FALSE])
sum(is.na(data_sub$pct_nrshome))
data_sub$risky_currentdx[is.na(data_sub$risky_currentdx)==TRUE]=0
sum(is.na(data_sub$risky_currentdx))




######adjustment variables
z2<-cbind(data_sub$sex, data_sub$agelt25, data_sub$age25_45, data_sub$age60_75,
        data_sub$agegt75,data_sub$esrdcause_diab, data_sub$bmi_under, data_sub$bmi_over,
        data_sub$bmi_obese, data_sub$vincat2, data_sub$vincat3, data_sub$vincat4,
data_sub$vincat5,
        data_sub$rv1, data_sub$rv2, data_sub$rv3, data_sub$rv4,  data_sub$rv11,
        data_sub$rv12, data_sub$rv14, data_sub$rv15, data_sub$rv18_plegia,
data_sub$rv18_functional, data_sub$rv19,
        data_sub$rv26, data_sub$rv27, data_sub$rv30, data_sub$rv31,
        data_sub$rv34, data_sub$rv40, data_sub$rv42, data_sub$rv43, data_sub$rv44,
        data_sub$risky_currentdx, data_sub$pct_nrshome, data_sub$timeinhosp,   data_sub$rv6,
data_sub$rv41, data_sub$rv45)

missing_z2<-is.na(z2)
dim(missing_z2)
sum(rowSums(missing_z2)>0)

rm(read09)

data_sub_complete<-data_sub[(rowSums(missing_z2)==0),]
data_sub_complete<-data_sub_complete[order(factor(data_sub_complete$provfs)),]
```

```
#quantile(data_sub_complete$timeinhosp)

data_sub_complete$timeinhosp_quantile1<-(data_sub_complete$timeinhosp<=2)
data_sub_complete$timeinhosp_quantile2<-
(data_sub_complete$timeinhosp>2)*(data_sub_complete$timeinhosp<=4)
data_sub_complete$timeinhosp_quantile3<-
(data_sub_complete$timeinhosp>4)*(data_sub_complete$timeinhosp<=8)
data_sub_complete$timeinhosp_quantile4<-(data_sub_complete$timeinhosp>8)


z<-cbind(data_sub_complete$sex, data_sub_complete$agelt25, data_sub_complete$age25_45,
data_sub_complete$age60_75,
        data_sub_complete$agegt75,data_sub_complete$esrdcause_diab, data_sub_complete$bmi_under,
data_sub_complete$bmi_over,
        data_sub_complete$bmi_obese, data_sub_complete$vincat2, data_sub_complete$vincat3,
data_sub_complete$vincat4, data_sub_complete$vincat5,
        data_sub_complete$rv1, data_sub_complete$rv2, data_sub_complete$rv3,
data_sub_complete$rv4,  data_sub_complete$rv11,
        data_sub_complete$rv12, data_sub_complete$rv14, data_sub_complete$rv15,
data_sub_complete$rv18_plegia,  data_sub_complete$rv18_functional, data_sub_complete$rv19,
        data_sub_complete$rv26, data_sub_complete$rv27, data_sub_complete$rv30,
data_sub_complete$rv31,
        data_sub_complete$rv34, data_sub_complete$rv40, data_sub_complete$rv42,
data_sub_complete$rv43, data_sub_complete$rv44,
        data_sub_complete$risky_currentdx,
        data_sub_complete$timeinhosp_quantile2, data_sub_complete$timeinhosp_quantile3,
data_sub_complete$timeinhosp_quantile4, data_sub_complete$rv6, data_sub_complete$rv41,
data_sub_complete$rv45)

#dim(z)
missing_z<-is.na(z)
dim(missing_z)
sum(rowSums(missing_z)>0)

dim=dim(z)[2]




#check number of facilities
unique.provfs_sub = unique(data_sub_complete$provfs)
F=length(unique.provfs_sub)

#check number of hospitals
unique.prov_hosp_sub = unique(data_sub_complete$prov_hosp)
H=length(unique.prov_hosp_sub)


#data_sub_complete<-data_sub_complete[order(data_sub_complete$provfs),]
m2 <-
as.vector(sapply(split(data_sub_complete$readmit30_flag,factor(data_sub_complete$provfs)),length)
)  #length(m_sub)=number of facility


n1<-rep(m2,m2)

min(m2)
max(m2)
mean(m2)
median(m2)
sd(m2)

######### (2.2) Continuity correction for facility/hospital with 0/all events
#check facility with 0 events
neg.inf_sub = unique.provfs_sub [ sapply(split(data_sub_complete$readmit30_flag,
factor(data_sub_complete$provfs)), sum) == 0 ]
length(neg.inf_sub)
```

```
#check for facilities with all events
inf_sub = unique.provfs_sub [ sapply(split(1- data_sub_complete$readmit30_flag,
factor(data_sub_complete$provfs)), sum) == 0 ]
length(inf_sub)


#label facilities with 0 events
index= (data_sub_complete$provfs %in% neg.inf_sub)

#continuity correction for facilities with 0 events; correction value depends on facility size
(number of index in each facility)
Y=data_sub_complete$readmit30_flag+(index==TRUE)*0.01/n1

#label facilities with 0 events
index2= (data_sub_complete$provfs %in% inf_sub)

#continuity correction for facility with 0 events; correction value depends on facility size
(number of index in each facility)
Y=Y-(index2==TRUE)*0.01/n1



neg.inf_sub22 = unique.provfs_sub [sapply(split(Y, factor(data_sub_complete$provfs)), sum) == 0 ]
length(neg.inf_sub22)

#check facilities with all events
inf_sub22 = unique.provfs_sub [ sapply(split(1- Y, factor(data_sub_complete$provfs)), sum) == 0 ]
length(inf_sub22)



#add response variable Y and facility size variable n_i_sub into the dataset, so that they can be
ordered for further analysis
data_sub_hosp<-cbind(data_sub_complete,Y, n1) #head(data_sub_hosp$n_i_sub)

#order dataset by hospital and facility
#order is important for further analysis
data_sub_sort=data_sub_hosp[order(
factor(data_sub_hosp$prov_hosp),factor(data_sub_hosp$provfs)),] #head(data_sub_sort$n_i_sub)


#get unique hospital index
#warning: unique() and factor() are necessary to handle hospital
unique.prov_hosp_sub = unique(data_sub_sort$prov_hosp)

#check hospitals with 0 events
neg.inf_hosp = unique.prov_hosp_sub [
sapply(split(data_sub_sort$Y,factor(data_sub_sort$prov_hosp)),sum) ==0 ]
length(neg.inf_hosp)

#check hospitals with all events
inf_hosp = unique.prov_hosp_sub [ sapply(split(1-
data_sub_sort$Y,factor(data_sub_sort$prov_hosp)),sum) ==0 ]
length(inf_hosp)

#hospital size: number of index in each hospital
m_j_sub <- as.vector(sapply(split(data_sub_sort$Y,factor(data_sub_sort$prov_hosp)),length))
#min(m_j_sub)=1

###before doing this, make sure data are ordered by hospital
n_j_sub<-rep(m_j_sub,m_j_sub)
length(n_j_sub)

#label hospitals with 0 events
index_hosp_neg.inf= (data_sub_sort$prov_hosp %in% neg.inf_hosp)
#continuty correction for hospital with 0 events; use 0.1/n_j_sub because some hospitals are
small
data_sub_sort$Y2=data_sub_sort$Y+(index_hosp_neg.inf==TRUE)*0.01/n_j_sub
#max((index_hosp_neg.inf==TRUE)*0.1/n_j_sub)=0.1
```

```r
#max(data_sub_sort$Y2)

#check hospitals with 0 events
neg.inf_hosp2 = unique.prov_hosp_sub [
sapply(split(data_sub_sort$Y2,factor(data_sub_sort$prov_hosp)),sum) ==0 ]
length(neg.inf_hosp2)

inf_hosp2 = unique.prov_hosp_sub [ sapply(split(1-
data_sub_sort$Y2,factor(data_sub_sort$prov_hosp)),sum) ==0 ]
length(inf_hosp2)

index_hosp_inf2= (data_sub_sort$prov_hosp %in% inf_hosp2)
data_sub_sort$Y3=data_sub_sort$Y2-(index_hosp_inf2==TRUE)*0.01/n_j_sub

neg.inf_hosp3 = unique.prov_hosp_sub [
sapply(split(data_sub_sort$Y3,factor(data_sub_sort$prov_hosp)),sum) == 0 ]
length(neg.inf_hosp3)

inf_hosp3 = unique.prov_hosp_sub [ sapply(split(1-
data_sub_sort$Y3,factor(data_sub_sort$prov_hosp)),sum) == 0 ]
length(inf_hosp3)
####################


####### (2.3) order data by hospital and facility
#####data structure: ordered by hospital first, then by facility within each hospital
#####this order is important for further analysis

data_sub_correction=data_sub_sort[order( factor(data_sub_sort$prov_hosp),
factor(data_sub_sort$provfs)),]

try2<-cbind(data_sub_sort$provfs, data_sub_sort$prov_hosp)

#write.csv(try2, file="[path]/[file].csv")




#######adjustment variables
z<-cbind(data_sub_correction$sex, data_sub_correction$agelt25, data_sub_correction$age25_45,
data_sub_correction$age60_75,
        data_sub_correction$agegt75,data_sub_correction$esrdcause_diab,
data_sub_correction$bmi_under, data_sub_correction$bmi_over,
        data_sub_correction$bmi_obese, data_sub_correction$vincat2, data_sub_correction$vincat3,
data_sub_correction$vincat4, data_sub_correction$vincat5,
        data_sub_correction$rv1, data_sub_correction$rv2, data_sub_correction$rv3,
data_sub_correction$rv4, data_sub_correction$rv11,
        data_sub_correction$rv12, data_sub_correction$rv14, data_sub_correction$rv15,
data_sub_correction$rv18_plegia, data_sub_correction$rv18_functional, data_sub_correction$rv19,
        data_sub_correction$rv26, data_sub_correction$rv27, data_sub_correction$rv30,
data_sub_correction$rv31,
        data_sub_correction$rv34, data_sub_correction$rv40, data_sub_correction$rv42,
data_sub_correction$rv43, data_sub_correction$rv44,
        data_sub_correction$risky_currentdx,
        data_sub_correction$timeinhosp_quantile2, data_sub_correction$timeinhosp_quantile3,
data_sub_correction$timeinhosp_quantile4, data_sub_correction$rv6, data_sub_correction$rv41,
data_sub_correction$rv45)


dim(z)
dim=dim(z)[2]


#######code to remove original data set (save memory)
#rm(data_sub)
rm(data_sub_hosp, read09)
rm(data_sub_sort, missing_z, missing_z2, data, data_sub, data_sub_complete)
rm(Y, index, index_hosp_neg.inf, inf, inf_hosp)
```

```
library(lme4)
library(arm)

data_sub_correction$provfs<-factor(data_sub_correction$provfs)
data_sub_correction$prov_hosp<-factor(data_sub_correction$prov_hosp)

random.fit2<-lmer(Y3~sex + agelt25 + age25_45 + age60_75 +
    agegt75+ esrdcause_diab +
    bmi_under + bmi_over + bmi_obese +
    vincat2 + vincat3 + vincat4 + vincat5 +
    rv1 + rv2 + rv3 + rv4 + rv11 +
    rv12 + rv14 + rv15 + rv18_plegia+rv18_functional+ rv19 + rv26 + rv27 + rv30 + rv31 +
    rv34 + rv40 + rv42 + rv43 + rv44 +risky_currentdx+ timeinhosp_quantile2
                    + timeinhosp_quantile3+ timeinhosp_quantile4+rv6+rv41+rv45+ (1|provfs)+
(1|prov_hosp), data_sub_correction, family=binomial(link=logit))


#############data1


##################################################################################


n_ij<- as.vector(ftable(table(factor(data_sub_correction$provfs),
factor(data_sub_correction$prov_hosp))))

dim(z)
# dim is the number of variables in the model (does not include facility or hospital effects)


#head(data_sub$provfs)

####variables for further analysis
Y3=data_sub_correction$Y3
provfs=factor(data_sub_correction$provfs)
prov_hosp=factor(data_sub_correction$prov_hosp)


model5<-read.csv(file="[path]/[file].csv", header=TRUE,  sep=",")
head(model5)

beta5<-read.csv(file="[path]/[file].csv ", header=TRUE,  sep=",")
head(beta5)


########## (2.4) point estimations of mixed effect model

NQ = 20 # number of quadrature points
GAMMA.HAT = NULL
BETA.HAT = NULL
SIGMA.HAT=NULL
ALPHA.HAT=NULL
V.HAT=NULL

gamma.hat = rep(0,F)
GAMMA.HAT= cbind(GAMMA.HAT,gamma.hat)
gamma.hat=expand.grid(gamma.hat,1:H)[,1]
gamma.hat= rep(gamma.hat,n_ij)

beta.hat=rep(0,dim)
beta.hat[1:39] =beta5$x
BETA.HAT=cbind(BETA.HAT,beta.hat)

 sigma.hat= sqrt(VarCorr(random.fit2)$prov_hosp)
SIGMA.HAT=cbind(SIGMA.HAT,sigma.hat)


library(statmod)
```

```
########## start loop
repeat{

  ghq=gauss.quad.prob(NQ,"normal", sigma=sigma.hat)

  Z.beta.hat = z%*%beta.hat

  ##########

  ghq.M=NULL
  for(i in 1:NQ){

    ghq.q = 1/(1+exp(ghq$nodes[i]+gamma.hat+Z.beta.hat))  #nodes: at which evaluate the function
    ghq.p = 1-ghq.q
    ghq.p.or.q = Y3*ghq.p + (1-Y3)*ghq.q

    ghq.M = cbind(ghq.M,
                  sapply( split( log(ghq.p.or.q), factor(prov_hosp) ), sum)
    ) ##end cbind
  }


  ghq.M=ghq.M-apply(ghq.M,1,max)
  ghq.M=exp(ghq.M)


  alpha.hat = ghq.M %*% (ghq$nodes*ghq$weights) / ghq.M %*% ghq$weights
  length( alpha.hat)
  max( alpha.hat)
  min( alpha.hat)


  ALPHA.HAT=cbind(ALPHA.HAT,alpha.hat)

  alpha.hat = expand.grid(1:F,alpha.hat)[,2]

  length(n_ij)   #
  alpha.hat = rep(alpha.hat,n_ij)


  v.hat = ghq.M %*% (ghq$nodes^2*ghq$weights) / ghq.M %*% ghq$weights -
    (ghq.M %*% (ghq$nodes*ghq$weights) / ghq.M %*% ghq$weights)^2


  V.HAT=cbind(V.HAT,v.hat)

  v.hat = expand.grid(1:F,v.hat)[,2]
  v.hat = rep(v.hat,n_ij)


   sigma.hat=sqrt(
     mean( ghq.M %*% (ghq$nodes^2*ghq$weights) / ghq.M %*% ghq$weights )
   )

  SIGMA.HAT=cbind(SIGMA.HAT,sigma.hat)

  q.hat = 1/(1+exp(alpha.hat+gamma.hat+Z.beta.hat))
  p.hat = 1-q.hat

  u.gamma = Y3-p.hat + 0.5*v.hat*p.hat*q.hat*(q.hat-p.hat)
  i.gamma = p.hat*q.hat + .5*v.hat*p.hat*q.hat*(p.hat^2+q.hat^2-4*p.hat*q.hat)

  gamma.update = sapply( split(u.gamma,provfs), sum) /
    sapply( split(i.gamma,provfs), sum)

  GAMMA.HAT = cbind(GAMMA.HAT, GAMMA.HAT[,ncol(GAMMA.HAT)] + gamma.update)

  gamma.update = expand.grid(gamma.update,1:H)[,1]
  gamma.update = rep(gamma.update,n_ij)

  gamma.hat = gamma.hat+gamma.update
```

```
  q.hat = 1/(1+exp(alpha.hat+gamma.hat+Z.beta.hat))
  p.hat = 1-q.hat

  u.beta = t( Y3-p.hat+ 0.5*v.hat*p.hat*q.hat*(q.hat-p.hat) ) %*% z
  i.beta = t(z)%*%(
    z* c( p.hat*q.hat +0.5*v.hat*p.hat*q.hat*(p.hat^2+q.hat^2-4*p.hat*q.hat) )
  )

  beta.hat=beta.hat+ solve(i.beta)%*%t(u.beta)
  BETA.HAT=cbind(BETA.HAT,beta.hat)

  dim(BETA.HAT)

  beta.distance = BETA.HAT[,ncol(BETA.HAT)-1]-BETA.HAT[,ncol(BETA.HAT)]
  gamma.dis = GAMMA.HAT[,ncol(GAMMA.HAT)-1]-GAMMA.HAT[,ncol(GAMMA.HAT)]

  # gamma.dis[ is.na(gamma.dis)]<-0  ###missing need check

  if(max(max(abs(beta.distance)), max(abs(gamma.dis)))<1e-7) break
}

#


###### (2.5). save output
#save point estimation for facility effects
#setwd('[path]')

gamma_mix<-GAMMA.HAT[,ncol(GAMMA.HAT)]
hist(gamma_mix)
min(gamma_mix)
max(gamma_mix)
length(gamma_mix)
mean(gamma_mix)
median(gamma_mix)


#save point estimation for adjustment variables
beta_mix<-BETA.HAT[,ncol(BETA.HAT)]
write.csv(beta_mix, file="[path]/[file].csv")


srr_mix3 <- as.numeric( sapply( split( data_sub_correction$readmit30_flag,
factor(data_sub_correction$provfs)),sum)) /
  as.numeric( sapply( split(plogis( median(gamma_mix)+ alpha.hat + z%*%beta.hat),
factor(data_sub_correction$provfs)),sum))



#### 5). code for one-tail P-value of gamma (resampling based on exact test) for empirical null

#sort dataset (Y (need original Y, not Y3), Z, alpha.hat)  by facility
data_sub_correction$alpha_hat<-alpha.hat
data_sub_correction$v_hat<-v.hat

data_sub_sort_provfs<-data_sub_correction[order(factor(data_sub_correction$provfs)),]


m2 <-
as.vector(sapply(split(data_sub_sort_provfs$readmit30_flag,factor(data_sub_sort_provfs$provfs)),l
ength))  #length(m_sub)=number of facility


length(m2)

z2<-cbind(data_sub_sort_provfs$sex, data_sub_sort_provfs$agelt25, data_sub_sort_provfs$age25_45,
data_sub_sort_provfs$age60_75,
```

```
data_sub_sort_provfs$agegt75,data_sub_sort_provfs$esrdcause_diab, data_sub_sort_provfs$bmi_under,
data_sub_sort_provfs$bmi_over,
                              data_sub_sort_provfs$bmi_obese, data_sub_sort_provfs$vincat2,
data_sub_sort_provfs$vincat3, data_sub_sort_provfs$vincat4, data_sub_sort_provfs$vincat5,
                              data_sub_sort_provfs$rv1, data_sub_sort_provfs$rv2,
data_sub_sort_provfs$rv3, data_sub_sort_provfs$rv4,  data_sub_sort_provfs$rv11,
                              data_sub_sort_provfs$rv12, data_sub_sort_provfs$rv14,
data_sub_sort_provfs$rv15, data_sub_sort_provfs$rv18_plegia,
data_sub_sort_provfs$rv18_functional, data_sub_sort_provfs$rv19,
                              data_sub_sort_provfs$rv26, data_sub_sort_provfs$rv27,
data_sub_sort_provfs$rv30, data_sub_sort_provfs$rv31,
                              data_sub_sort_provfs$rv34, data_sub_sort_provfs$rv40,
data_sub_sort_provfs$rv42, data_sub_sort_provfs$rv43, data_sub_sort_provfs$rv44,
                              data_sub_sort_provfs$risky_currentdx,
                              data_sub_sort_provfs$timeinhosp_quantile2,
data_sub_sort_provfs$timeinhosp_quantile3, data_sub_sort_provfs$timeinhosp_quantile4,
data_sub_sort_provfs$rv6, data_sub_sort_provfs$rv41, data_sub_sort_provfs$rv45)




P_summary<- NULL    #data for confidence interval

B <- 10000   # number of resampling
size<-0      # track the patients in each facility

for(j in 1:F) { #each loop focus on one facility: for loop j, only the subjectsin facility j are
used

start<-size+1  #the first patient in facility j
end<-size+m2[j]   #the last patient in facility j

# this part of code is the reason why data should be ordered by facility
   #function to calculate P-value
   get.sl <- function(gamma) {

prob_B=plogis(rep(gamma,B) +rnorm(m2[j]*B, mean=rep(data_sub_sort_provfs$alpha_hat[start:end],B),
sd=rep(data_sub_sort_provfs$v_hat[start:end],B))+rep(z2[start:end,]%*%beta.hat,B))

Y.star <- rbinom(n=m2[j]*B, size = 1, prob = prob_B)
Y.star <- matrix(Y.star,ncol=B)
Y.star.sum <- apply(Y.star,2,sum)
Y.sum = sum(data_sub_sort_provfs$readmit30_flag[start:end])
       return (
        (mean(Y.star.sum >= Y.sum)+mean(Y.star.sum > Y.sum))/2
              )
    }    #end fun


proposed.gamma <-  median(gamma_mix)    # median of facility effect as the target value (null
hypothesis) for P-value
P_value <- sapply(proposed.gamma, get.sl)  #call the function get.sl based on the target value
gt1 <- function(x) ifelse(x>1,1,x)       # If any P >1 (caused by two-side exact test), assign
them a value of 1.
P_value  <- gt1(P_value)
P_summary<-rbind(P_summary, P_value)                    #save P-values
size<-size+m2[j]   #update size so that it can track the patient in facility j
                     }          #end for loop


dim(P_summary)

data_sub_sort_provfs$pahy3_f2<-data_sub_sort_provfs$pahy3_f
data_sub_sort_provfs$pahy3_f2[is.na(data_sub_sort_provfs$pahy3_f2)==TRUE]=0
m_size <-
as.vector(sapply(split(data_sub_sort_provfs$pahy3_f2,factor(data_sub_sort_provfs$provfs)),max))
sum(is.na(m_size))
max(m_size)
mix_summary<-cbind(gamma_mix, srr_mix3, P_summary, m2, m_size)
mix_summary<-as.data.frame(mix_summary)
head(mix_summary)
```

```
colnames(mix_summary) = c("gamma_model5","srr_model5", "P_fix", "size", "median")
head(mix_summary)
write.csv(mix_summary, file="[path]/[file].csv")
```
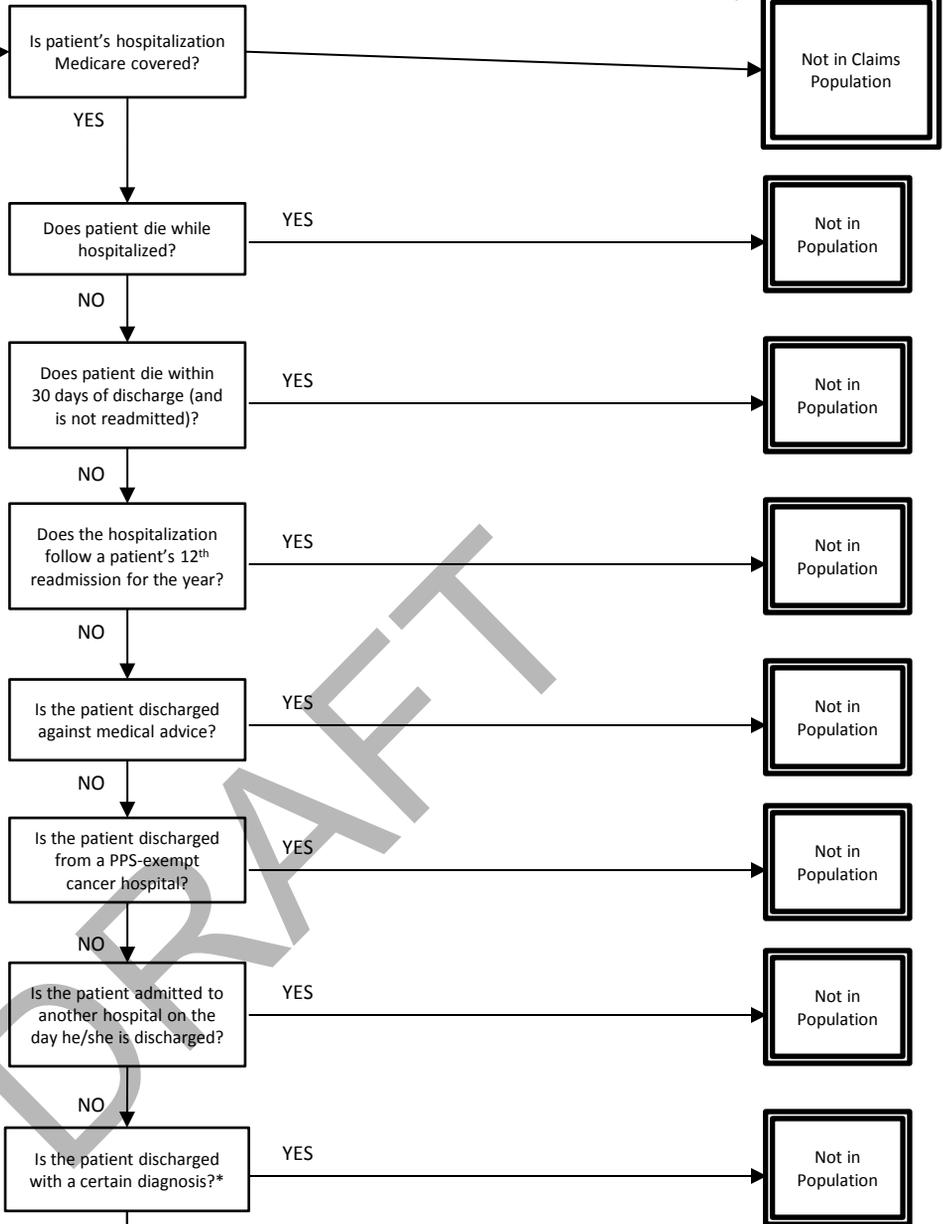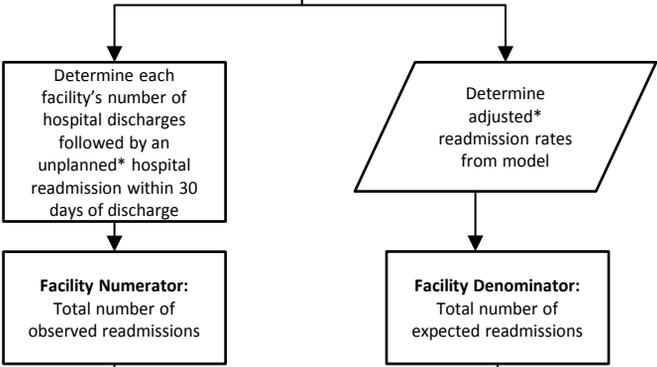
Appendix E
Measure Calculation Flowchart

```
┌─────────────────────┐                                                              NO
│                     │        ┌──────────────────┐                          ┌─────────────────────┐
│ • Hospital Inpatient│───────▶│ Is patient's     │─────────────────────────▶│   Not in Claims     │
│   Claims            │        │ hospitalization  │                          │   Population        │
│                     │        │ Medicare covered?│                          └─────────────────────┘
└─────────────────────┘        └──────────────────┘
                                        │ YES
                                        ▼
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Does patient die │─────────────────────────▶│   Not in            │
                               │ while            │                          │   Population        │
                               │ hospitalized?    │                          └─────────────────────┘
                               └──────────────────┘
                                        │ NO
                                        ▼
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Does patient die │─────────────────────────▶│   Not in            │
                               │ within 30 days of│                          │   Population        │
                               │ discharge (and   │                          └─────────────────────┘
                               │ is not readmitted)?│
                               └──────────────────┘
                                        │ NO
                                        ▼
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Does the         │─────────────────────────▶│   Not in            │
                               │ hospitalization  │                          │   Population        │
                               │ follow a patient's 12th│                    └─────────────────────┘
                               │ readmission for the year?│
                               └──────────────────┘
                                        │ NO
                                        ▼
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Is the patient   │─────────────────────────▶│   Not in            │
                               │ discharged       │                          │   Population        │
                               │ against medical advice?│                    └─────────────────────┘
                               └──────────────────┘
                                        │ NO
                                        ▼
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Is the patient   │─────────────────────────▶│   Not in            │
                               │ discharged from a│                          │   Population        │
                               │ PPS-exempt       │                          └─────────────────────┘
                               │ cancer hospital? │
                               └──────────────────┘
                                        │ NO
                                        ▼
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Is the patient   │─────────────────────────▶│   Not in            │
                               │ admitted to      │                          │   Population        │
                               │ another hospital │                          └─────────────────────┘
                               │ on the day he/she│
                               │ is discharged?   │
                               └──────────────────┘
                                        │ NO
                                        ▼
```

Certain cancers, mental health conditions or rehabilitation for prosthesis

```
                               ┌──────────────────┐      YES                 ┌─────────────────────┐
                               │ Is the patient   │─────────────────────────▶│   Not in            │
                               │ discharged with a│                          │   Population        │
                               │ certain diagnosis?*│                        └─────────────────────┘
                               └──────────────────┘
                                        │ NO
                             ┌──────────┴──────────┐
                             ▼                     ▼
```

*See Appendix E for how a readmission is considered planned.

Determine each facility's number of hospital discharges followed by an unplanned* hospital readmission within 30 days of discharge	Determine adjusted* readmission rates from model

*Adjusted for age, sex, duration of ESRD, BMI at incidence, past-year comorbidity status, diabetes as cause of ESRD, length of index hospitalization and presence of a high-risk diagnosis at discharge.

Facility Numerator: Total number of observed readmissions

Facility Denominator: Total number of expected readmissions

Sum predicted values across patients in each facility.

Facility SRR: Observed/Expected Readmissions