

Pediatric Lower Respiratory Infection Readmission Measure

NQF # 2414

Appendix

Center of Excellence for Pediatric Quality Measurement

Division of General Pediatrics

Boston Children's Hospital

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Detailed Specifications

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OVERVIEW

This report contains detailed measure specifications for calculating, using inpatient claims data, case-mix-adjusted, 30-day readmission rates following hospitalization for lower respiratory infection (LRI) in pediatric patients < 18 years old. Admissions for LRI are identified using a case definition of either a primary diagnosis of bronchiolitis, influenza, or community-acquired pneumonia or a secondary diagnosis of 1 of these LRIs plus a primary diagnosis of asthma, respiratory failure, or sepsis/bacteremia. The measure focuses on patients discharged from general acute care hospitals, including children's hospitals. The measure excludes the following: (a) specialty hospitals; (b) non-acute care institutions, such as rehabilitation and long-term care facilities; (c) admissions for obstetric conditions, mental health conditions, and birth of healthy newborns; and (d) readmissions for planned procedures and chemotherapy.

The model for this measure consists of a 2-level hierarchical logistic regression with fixed effects for patient-level characteristics and a random intercept for hospital. The first level of the model includes adjusters for hospital case-mix based on the patient-level characteristics of age, gender, and chronic disease comorbidity (identified using the Agency for Healthcare Research and Quality (AHRQ) Chronic Condition Indicator tool). The second level of the model consists of a random effect for hospital. The hierarchical modeling adjusts for differences in case-mix and sample size across hospitals.

TABLE 1– TERMINOLOGY

Term	Definition
Case-Mix	The age, gender, and chronic condition characteristics of the patients with index admissions at a given hospital. Differences in the distributions of these characteristics across hospitals may be associated with differences in readmission rates. The measure therefore adjusts readmission rates as if each hospital cared for the same patient case-mix.
Chronic Condition Indicator	A tool developed as part of the AHRQ Healthcare Cost and Utilization Project that categorizes International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) or International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) diagnosis codes into 1 of 18 “body systems” (organ systems, disease categories, or other categories) and designates them as chronic or not chronic. ICD-9-CM codes will henceforth be referred to in this document as ICD-9 codes. ICD-10-CM diagnosis codes and ICD-10 Procedure Coding System (PCS) codes will be referred to as ICD-10 diagnosis and ICD-10 procedure codes, respectively. Patients who have a primary ICD-9 or principal ICD-10 diagnosis code for an obstetric condition or any diagnosis or procedure code for delivery are excluded from the measure cohort (the rationale for this exclusion is provided below). We have found using various datasets that this exclusion leaves very few (or sometimes no) patients who have a secondary diagnosis code for a chronic condition falling into body system 11, “Complications of pregnancy, childbirth, and the puerperium,” which could create model-fitting problems if Chronic Condition Indicator 11 were included in the case-mix-adjustment model. The measure therefore does not include the Chronic Condition Indicator variable for body system 11.
Discharge Disposition	The data field on each record indicating the patient's status at time of end-of-service (e.g., left against medical advice, discharged home, deceased).
Episode of Care	A patient's complete period of inpatient care. Data for a single period of inpatient care may be covered by 1 claims record or may be contained in > 1 claims record because the patient (a) received services from > 1 cost center in the same hospital and/or (b) was transferred from 1 hospital to another. Therefore, constructing an <i>episode of care</i> for analysis as an index admission or readmission may require combining patient information across multiple records.
Index Admission	An eligible admission to an acute care hospital. The index admission serves as the starting point for enumerating readmissions.
Planned Procedure	A procedure that was judged by expert reviewers to generally be scheduled at least 24 hours in advance for an expected medical need in more than 80% of cases and to be a potential reason for hospitalization (see Data Dictionary for ICD-9 or ICD-10 procedure codes).
Planned Readmission	An admission to an acute care hospital with a primary ICD-9 or principal ICD-10 procedure code for a planned procedure, occurring

	within 30 days of discharge from a prior acute care hospitalization.
Readmission	An admission to an acute care hospital within 30 days of discharge from an acute care hospital.
Readmission Rate	The percentage of index admissions with ≥ 1 readmission within 30 days. The readmission rate, unadjusted for case-mix, is calculated as follows: $\frac{\text{number of index admissions with } \geq 1 \text{ readmission within 30 days}}{\text{total number of index admissions}}$

TABLE 2 – SAS FILES FOR MEASURE IMPLEMENTATION

Measure Implementation Step	SAS Files	Description
Data preparation (See Section 1 below.)	format_file_LRI_ICD9.sas7bdat format_file_LRI_ICD10.sas7bdat	Format file containing the ICD-9 or ICD-10 diagnosis and procedure codes required for defining variables in the measure.
	LowerRespiratoryInfection_PediatricReadmission_DataPrep_AllPayer.sas	Program for preparation of all-payer data, Steps 5-8 (details below).
	LowerRespiratoryInfection_PediatricReadmission_DataPrep_SinglePayer.sas	Program for preparation of single-payer data, Steps 5-8 (details below).
Fitting of case-mix adjustment model and estimation of hospital-level readmission rates (See Sections 2 and 3 below.)	LowerRespiratoryInfection_ZeroCell.sas	Macro program for dropping index admissions if all index admissions of a given case-mix variable (i.e., <i>cci15</i> = 1) have the same outcome (i.e., readmission = 1 or readmission = 0). This helps to prevent model-fitting issues.
	LowerRespiratoryInfection_PediatricReadmission_Model.sas	Program for fitting case-mix adjustment model and estimating hospital-level readmission rates.
Fitting of case-mix adjustment model and estimation of nationally comparable hospital- and state-level	LowerRespiratoryInfection_ZeroCell.sas	Macro program for dropping index admissions if all index admissions of a given case-mix variable (i.e., <i>cci15</i> = 1) have the same outcome (i.e., readmission = 1 or readmission = 0). This helps to prevent model-fitting issues.

readmission rates (See Section 4 below.)	max_lri_cov.sas7bdat max_lri_sample.sas7bdat max_lri_global_model_linux.sas7bitm max_lri_global_model_win.sas7bitm LowerRespiratoryInfection_PediatricReadmission_Nationally comparable rates.sas	Program and files for fitting case- mix adjustment model and estimating nationally comparable hospital- and state-level readmission rates
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SECTION I: DATA PREPARATION

This section describes the data preparation steps that should be implemented before fitting the pediatric lower respiratory infection readmission model to inpatient claims data.

PLEASE NOTE: Steps 1 through 4, below, describe how to prepare your dataset by applying certain exclusions and creating variables needed to construct the measure cohort and calculate readmission rates. We have provided a SAS data preparation program to perform the remaining data preparation steps, Steps 5 through 8.

STEP 1: IDENTIFY HOSPITALS ELIGIBLE FOR INCLUSION IN THE MEASURE

This measure focuses on calculating pediatric readmission rates for general acute care hospitalizations for LRI. Criteria for retaining only hospitals identified as general acute care facilities are specified below.

Exclusions at the Hospital Level:

- Drop records for specialty and non-acute care hospitals: See Data Dictionary for the list of American Hospital Association (AHA) hospital codes and Centers for Medicare & Medicaid Services (CMS) taxonomy codes for general acute care hospitals eligible for inclusion in the measure. Drop records for a hospital if the records contain only an AHA code or only a CMS code and the code is NOT for a general acute care hospital. If a hospital's records include both an AHA and a CMS code, drop the records for the hospital if either code is NOT for a general acute care hospital.
- Drop records for which hospital type is missing.

Rationale: The focus of the measure is admissions to hospitals that provide general pediatric acute care. Records for admissions to specialty and non-acute care hospitals are therefore omitted from the dataset. Because hospital type cannot be determined for records with missing data in the hospital type variable, these records are also removed from the dataset.

STEP 2: IDENTIFY HOSPITALS FOR WHICH READMISSION RATES SHOULD NOT BE CALCULATED

Hospitals with very incomplete data may lack adequate information to calculate accurate readmission rates. Readmission rates should therefore not be evaluated for these hospitals (i.e., their admissions should not be included in the measure as index admissions). To provide an accurate assessment based on the full dataset, data completeness at the hospital level should be assessed *before* excluding individual records for data quality or clinical criteria. Criteria for identifying hospitals for which readmission rates should not be calculated are listed below.

Exclusions at the Hospital Level for Calculating Readmission Rates:

- Hospitals with < 80% of records with complete unique patient identifier, admission date, and end-of-service date
- Hospitals with < 80% of records with complete primary ICD-9 or principal ICD-10 diagnosis code
- Out-of-state hospitals

Create a dichotomous variable named "*hosp_noindex*," coded 1 for hospitals meeting the above exclusion criteria (this variable will be used to exclude these hospitals' admissions from being evaluated as index admissions) and 0 for all other hospitals.

PLEASE NOTE: Although readmission rates should not be calculated for these hospitals, these hospitals' records should *remain in the dataset* so that their admissions can be evaluated as potential readmissions for other hospitals.

Rationale: Readmission rates are not calculated for hospitals missing large amounts of data for the above variables because these hospitals have limited data to accurately define the measure cohort and calculate case-mix-adjusted readmission rates. Assessing eligibility for the measure cohort and performing case-mix adjustment requires information on admission dates, end-of-service dates, and diagnosis codes. Identifying readmissions requires information on admission dates and end-of-service dates and the ability to link unique patient identifiers across inpatient claims records.

Regarding out-of-state hospital admissions, it is possible that a state inpatient claims database may contain records for admissions to out-of-state hospitals. Records for out-of-state hospital admissions are not excluded from the measure dataset because these records may meet criteria for being counted as readmissions as part of an in-state hospital's readmission rate. However, readmission rates are not calculated for out-of-state hospitals due to the lack of complete data for these hospitals.

STEP 3: EXCLUDE PATIENTS WHO HAVE MISSING OR INVALID DATA FOR ANALYZING READMISSIONS

Exclusions at the Patient Level:

- Drop all records for a patient if ANY record is missing patient identifier, hospital identifier, admission date, end-of-service date, or disposition status.
- Drop all records for a patient if date of birth is missing in ALL records.
- Drop all records for a patient if date of birth is not consistent across records.
- Drop all records for a patient if ANY record has an end-of-service date prior to the admission date.
- Drop all records for a patient if ANY record has an admission date or end-of-service date prior to the date of birth.
- Drop all records for a patient if ANY record uses codes other than ICD-9 or ICD-10 codes for the primary procedure.
- Drop all records for a patient if gender is missing in ALL records.
- Drop all records for a patient if gender is not consistent across records.

Rationale: Complete and valid information for the variables listed above is needed to define the measure cohort and calculate case-mix-adjusted readmission rates. Identifying readmissions within 30 days requires information on dates of admission and end-of-service dates and the ability to link unique patient identifiers across inpatient claims records. Hospital identifiers are needed to determine the hospital at which index admissions occurred. The disposition status is needed to determine whether a patient was discharged or experienced some other outcome (e.g., was transferred to another acute care hospital, left against medical advice, died). Establishing a patient's eligibility for membership in the pediatric cohort and performing case-mix adjustment requires an accurate date of birth and end-of-service date. ICD-9 or ICD-10 procedure codes are necessary for applying clinical exclusions (described below). Because gender is 1 of the variables used for case-mix adjustment, episodes of care with missing or inconsistent gender cannot be evaluated in the measure.

PLEASE NOTE: If working with a large dataset containing records for children and adults, the exclusion of records for patients >18 years, 29 days old, as described in Step 7, may be applied at this point to make the dataset more manageable.

STEP 4: SPECIFY VARIABLES DEFINED AT THE RECORD LEVEL

The variables listed in the table below are used to construct the measure cohort and/or to calculate readmission rates. These variables must be named and coded as specified below and should be created prior to identifying episodes of care and applying further exclusions to the data. All variables should be numeric unless otherwise specified. All dates should be Julian dates without times. Please see the Data Dictionary for all ICD-9 or ICD-10 code sets for the measure.

Table 3 – Variables Defined at the Record Level

Variable Name	Description
<i>patientid</i>	unique patient identifier Note: <i>patientid</i> will have no missing values due to the exclusion applied in Step 3.
<i>dob</i>	patient date of birth Note: If date of birth is missing in some records for a patient but present and consistent in others, then apply the date of birth from the records in which it is present to the records in which it is missing. This approach, together with the exclusion in Step 3 of patients with date of birth missing in all records, will result in no missing values for <i>dob</i> .
<i>hospitalid</i>	unique hospital identifier Note: <i>hospitalid</i> will have no missing values due to the exclusion applied in Step 3. <i>hospitalid</i> must be a character variable.
<i>admit_dt</i>	admission date Note: <i>admit_dt</i> will have no missing values due to the exclusion applied in Step 3.
<i>end_service_dt</i>	end-of-service date Note: <i>end_service_dt</i> will have no missing values due to the exclusion applied in Step 3.
<i>hasprimary</i>	dichotomous variable indicating whether the primary ICD-9 or principal ICD-10 diagnosis code is complete 1 = primary or principal diagnosis code is present 0 = primary or principal diagnosis code is missing Note: <i>hasprimary</i> will have no missing values.
<i>ccix</i> (where x represents the number of the AHRQ CCI body system, e.g., <i>cci1</i> , <i>cci2</i> , <i>cci3</i>)	17 dichotomous variables indicating the presence of a chronic condition in a particular body system (organ system, disease category, or other category) classified using the AHRQ CCI tool 1 = present 0 = otherwise Patients who have a primary ICD-9 or principal ICD-10 diagnosis

	code for an obstetric condition or any diagnosis or procedure code for labor and delivery are excluded from the measure cohort (the rationale for this exclusion is provided below). We have found using various datasets that this exclusion leaves very few (or sometimes no) patients who have a secondary diagnosis code for a chronic condition falling into body system 11, “Complications of pregnancy, childbirth, and the puerperium,” which could create model-fitting problems if Chronic Condition Indicator 11 were included in the case-mix-adjustment model. The measure therefore does not include the Chronic Condition Indicator variable for body system 11. See Table 4 below. Code a Chronic Condition Indicator as present if a diagnosis code for that body system is present as either a primary or secondary ICD-9 diagnosis or a principal or additional ICD-10 diagnosis. Note: <i>ccix</i> should have no missing values.
<i>planned</i>	dichotomous variable indicating the presence of a planned primary ICD-9 or principal ICD-10 procedure 1 = present 0 = otherwise Note: <i>planned</i> should have no missing values.
<i>chemo</i>	dichotomous variable indicating the presence of a primary ICD-9 or principal ICD-10 diagnosis code or procedure code for chemotherapy 1 = present 0 = otherwise Note: <i>chemo</i> should have no missing values.
<i>mh</i>	dichotomous variable indicating the presence of a primary ICD-9 or principal ICD-10 diagnosis code for a mental health condition 1 = present 0 = otherwise Note: <i>mh</i> should have no missing values.
<i>obstetric</i>	dichotomous variable indicating the presence of a non-delivery obstetric primary ICD-9 or principal ICD-10 diagnosis code or any labor and delivery diagnosis or procedure 1 = present 0 = otherwise Note: <i>obstetric</i> should have no missing values.
<i>newborn</i>	dichotomous variable indicating an admission for birth of a healthy newborn 1 = present 0 = otherwise For births by Cesarean section: Code a record as the birth admission for a healthy newborn if the birth diagnosis code is the primary ICD-9 or principal ICD-10 diagnosis and length of stay is <5 days. For births by vaginal or unspecified delivery: Code a record as the birth admission for a healthy newborn if the birth diagnosis code is the

	primary ICD-9 or principal ICD-10 diagnosis and length of stay is <3 days. Note: <i>newborn</i> should have no missing values.
<i>disp_status</i>	categorical variable indicating disposition status 0 = other (any disposition status not accounted for below) 1 = discharge 2 = transfer to an acute care hospital 3 = left against medical advice 4 = died Note: <i>disp_status</i> will have no missing values due to the exclusion applied in Step 3.
<i>male</i>	categorical variable indicating patient gender 0 = female 1 = male Note: Female serves as the reference group. If gender is missing in some records for a patient but present and consistent in other records, then apply the value of gender from the records in which it is present to the records in which it is missing. This approach, together with the exclusion in Step 3 of patients with gender missing in all records, will result in no missing values for <i>male</i>.
<i>ins_end</i>	variable containing the end date of the period of insurance coverage that includes the record's end-of-service date For example: If a patient was insured from 1/1 to 1/31 and from 4/15 to 12/31: • For a record with an end-of-service date of 1/29, the value of <i>ins_end</i> would be 1/31. • For a record with an end-of-service date of 7/23, the value of <i>ins_end</i> would be 12/31. Note: This variable should only be included in single-payer analyses. It will be used to determine whether a patient has insurance coverage for at least 30 days after discharge from an index hospitalization and thus has 30 days of follow-up data to evaluate readmissions. It will have no missing values because it is calculated using the end-of-service date, which should never be missing due to the exclusion applied in Step 3.
<i>lri</i>	dichotomous variable indicating the presence of either (1) a primary ICD-9 or principal ICD-10 diagnosis code for LRI or (2) a secondary ICD-9 or additional ICD-10 diagnosis code for LRI plus a primary ICD-9 or principal ICD-10 diagnosis code for asthma, respiratory failure, or sepsis/bacteremia 1 = present 0 = otherwise Note: <i>lri</i> should have no missing values.

Table 4 – Chronic Condition Indicator Body Systems

Body System Indicator	Body System
1	Infectious and parasitic disease
2	Neoplasms
3	Endocrine, nutritional, and metabolic diseases and immunity disorders
4	Diseases of blood and blood-forming organs
5	Mental disorders
6	Diseases of the nervous system and sense organs
7	Diseases of the circulatory system
8	Diseases of the respiratory system
9	Diseases of the digestive system
10	Diseases of the genitourinary system
11	Complications of pregnancy, childbirth, and the puerperium – The Chronic Condition Indicator for this body system is not included in the measure.
12	Diseases of the skin and subcutaneous tissue
13	Diseases of the musculoskeletal system
14	Congenital anomalies
15	Certain conditions originating in the perinatal period
16	Symptoms, signs, and ill-defined conditions
17	Injury and poisoning
18	Factors influencing health status and contact with health services

For convenience, we have provided SAS format files containing all of the ICD-9 or ICD-10 diagnosis and procedure codes required to define variables for the measure.

Instructions for Using the SAS Format File to Define Variables Based on ICD-9 or ICD-10 Codes

1. Define a libname where you can save the SAS format file, “format_file_LRI_ICD9.sas7bdat” or “format_file_LRI_ICD10.sas7bdat” (i.e., libname format “c:\Format Files”;).
2. Save the format file in the location you designated in step 1.
3. Bring the format file into the SAS work drive by using the procedure format. For example:

```
proc format library=work cntlin=format. format_file_LRI_ICD9;
run;
```

or

```
proc format library=work cntlin=format. format_file_LRI_ICD10;
run;
```

4. Table 5 lists the SAS format names and labels in the format file.

Table 5 – SAS Format Names and Labels

Variable	Type of ICD-9 Code	Type of ICD-10 Code	Format Name	Label
cci1- cci10, cci12- cci18	primary or secondary diagnosis	principal or additional diagnosis	\$CHRONF	chronic
	primary or secondary diagnosis	principal or additional diagnosis	\$SYSTEMF	cci1, cci2, cci3, cci4, cci5, cci6, cci7, cci8, cci9, cci10, cci11, cci12, cci13, cci14, cci15, cci16, cci17, cci18 Note: The variable cci11 is not used in the measure, but the label cci11 is included in the format file so that as the CCI variables are created, the program must run through the records only once. (If instead the variables cci1-cci10 were created in

				1 step and <i>cci12-cci18</i> were created in a second step, the program would have to run through the records twice.) However, even though <i>cci11</i> is created as a variable, it is then dropped using the SAS code below.
<i>planned</i>	primary procedure	principal procedure	\$PLANNEDF	planned
<i>chemo</i>	primary diagnosis	principal diagnosis	\$CHEMODX1F	chemo
	primary procedure	principal procedure	\$CHEMOPR1F	chemo
<i>mh</i>	primary diagnosis	principal diagnosis	\$MHDX1F	mh
<i>obstetric</i>	primary diagnosis	principal diagnosis	\$OBSTETRICDX1F	obstetric
	primary or secondary diagnosis	principal or additional diagnosis	\$OBSTETRICDXF	obstetric
	primary or secondary procedure	principal or additional procedure	\$OBSTETRICPRF	obstetric
<i>newborn</i>	primary diagnosis	principal diagnosis	\$NEWBORNCF	newborn
	primary diagnosis	principal diagnosis	\$NEWBORNNOCF	newborn
<i>lri</i>	primary or secondary diagnosis	principal or additional diagnosis	\$LRIDXF	lri
	primary diagnosis	primary diagnosis	\$OTHERLRIDXSECF	lri

Use the *put* function with the SAS formats to define the variables *cc1-cci10* and *cci12-cci18*, *planned*, *chemo*, *mh*, *obstetric*, *newborn*, and *lri*. We have provided examples of the SAS code to define each variable in Table 6.

Table 6 – Examples of Using SAS Formats to Define Variables

Variable	Formats Used to Define Variable	SAS Code Example In the examples below, diagnosis variable names start with DX and procedure variable names start with PR. For the variables <i>cci1-cci10</i> and <i>cci12-cci18</i> , <i>obstetric</i> , and <i>lri</i> , 25 diagnosis and procedure fields are used in the example, but more than 25 codes may be used to define the variable.
<i>cci1-cci10</i> , <i>cci12-cci18</i>	\$CHRONF \$SYSTEMF	<pre>/*creates cci1-cci10 and cci12-cci18*/ array cci_systems [18] cci1-cci18; array DXS[*] \$ DX1-DX25; array PRS[*] \$ PR1-PR25;</pre>

		<pre> do i=1 to 18; cci_systems[i]=0; end; do i=1 to 25; if put(dxs[i],\$CHRONF.)='chronic' then do j=1 to 18; if input(substr(put(dxs[i],\$SYSTEMF.),4,2),2.0)=j then cci_systems[j]=1; end; end; drop cci11; </pre>
<i>planned</i>	\$PLANNEDF	<pre> /*creates planned*/ planned=0; if put(pr1,\$PLANNEDF.)='planned' then planned=1; </pre>
<i>chemo</i>	\$CHEMODX1F \$CHEMOPR1F	<pre> /*creates chemo*/ chemo=0; if put(DX1,\$CHEMODX1F.)='chemo' or put(PR1,\$CHEMOPR1F.)='chemo' then chemo=1; </pre>
<i>mh</i>	\$MHDX1F	<pre> /*creates mh*/ mh=0; if put(dx1,\$MHDX1F.)='mh' then mh=1; </pre>
<i>obstetric</i>	\$OBSTETRICDX1F \$OBSTETRICDXF \$OBSTETRICPRF	<pre> /*creates obstetric */ obstetric=0; if put(dx1,\$OBSTETRICDX1F.)='obstetric' then obstetric=1; do i=1 to 25; if put(dxs{i},\$OBSTETRICDXF.)='obstetric' then obstetric=1; end; do i=1 to 25; if put(prs{i},\$OBSTETRICPRF.)='obstetric' then </pre>

		<pre> obstetric=1; end; </pre>
<i>newborn</i>	\$NEWBORNCF (C-section) \$NEWBORNNOCF (No C-section)	<pre> /*creates newborn*/ newborn=0; if (put(dx1,\$NEWBORNNOCF.)='newborn' and 0=<(end_service_dt-admit_dt)<3) or (put(dx1,\$NEWBORNCF.)='newborn' and 0=<(end_service_dt-admit_dt)<5) then newborn=1; </pre>
<i>lri</i>	\$LRIDXF \$OTHERLRIDXSECF	<pre> /*creates lri*/ lri=0; if put(dx1,\$LRIDXF.)='lri' then lri=1; do i=2 to 25; if put(dxs{i},\$LRIDXF.)='lri' and put(dx1,\$OTHERLRIDXSECF.)='lri' then lri=1; end; </pre>

PLEASE NOTE: Steps 1 through 4, above, describe how to prepare your dataset by applying certain exclusions and creating variables needed to construct the measure cohort and calculate readmission rates. We have provided a SAS data preparation program to perform the remaining data preparation steps, Steps 5 through 8.

STEP 5: DEFINE EPISODES OF CARE

Data for a single period of inpatient care may be contained in > 1 claims record. It therefore may be necessary to collapse instances of multiple claims for the same hospitalization into a single episode of care prior to applying some exclusion criteria and evaluating readmissions. This allows all data relevant to a given hospitalization to be appropriately evaluated for measure cohort exclusion. The process for defining episodes of care is detailed below.

Process for Defining Episodes of Care:

1. IDENTIFY TRUE DUPLICATES AND DROP ALL BUT 1.
 - True duplicates are records that have identical values for all key variables needed to assess cohort eligibility and calculate case-mix-adjusted readmission rates, where these key variables include all variables listed in Table 3 except *hasprimary*. Combine true duplicates, using the MAXIMUM value of *hasprimary*.
2. IDENTIFY AND COMBINE MULTIPLE VALID RECORDS FROM THE SAME HOSPITAL FOR THE SAME HOSPITALIZATION.
 - Sort records by the following variables, in the specified order: *patientid*, *hospitalid*, *admit_dt*, *end_service_dt*, and *disp_status*.
 - Define records to be part of the same hospitalization at the same hospital if (a) *patientid* and *hospitalid* are equal to those in the previous record and (b) admission dates and end-of-service dates indicate consecutive time periods or nesting of 1 time period within another because any of the following is true:
 - admission date is before the previous record's end-of-service date
 - admission date is equal to the previous record's end-of-service date AND the previous record's disposition status is other (i.e., *disp_status* = 0) or transfer to an acute care hospital (i.e., *disp_status* = 2)
 - admission date is 1 day after the previous record's end-of-service date AND the previous record's disposition status is other (i.e., *disp_status* = 0) or transfer to an acute care hospital (i.e., *disp_status* = 2)
 - admission and end-of-service dates are both the same as those of the previous record, and admission date is equal to end-of-service date (i.e., the records are for a same-day discharge)

Example:

hospitalid	admit_dt	end_service_dt
1700181814	18427	18427
1700181814	18427	18427

If the above criteria for multiple valid records from the same hospital for the same hospitalization are met, combine all of the records. Retain the variables *patientid*, *dob*, *hospitalid*, *male*, and *hosp_noindex*, which will be the same across records by this step. Use the MINIMUM value for *admit_dt*. Use the MAXIMUM value for *end_service_dt*, *hasprimary*, *cci1-cci10* and *cci12-cci18*, *planned*, *chemo*, *mh*, *obstetric*, *newborn*, and *Iri*. Use the value of *disp_status* and *ins_end* (this variable is only used in single-payer analyses) from the record with the

MAXIMUM end-of-service date. If multiple records have the same maximum end-of-service date but inconsistent values for *disp_status*, use the MAXIMUM value of *disp_status* within those records. Using the maximum value for *end_service_dt* captures the discharge date that serves as the starting point for the 30-day follow-up period for evaluating readmissions. Using the maximum value for the case definition, chronic condition indicator, and clinical exclusion variables across records captures the presence of a condition or clinical exclusion for the entire episode of care. For example, if 1 record contains a primary ICD-9 or principal ICD-10 mental health diagnosis, this diagnosis will be applied to the entire episode of care, and the entire episode of care will be excluded.

3. IDENTIFY AND COMBINE MULTIPLE VALID RECORDS FROM MULTIPLE HOSPITALS FOR HOSPITALIZATIONS THAT INCLUDED TRANSFERS.

- Sort records by the following variables, in the specified order: *patientid*, *admit_dt*, *end_service_dt*, and *disp_status*.
- Define records to be in the same episode of care if (a) *patientid* is equal to *patientid* in the previous record, (b) the previous record's disposition status is transfer to an acute care hospital (i.e., *disp_status* = 2), and (c) the admission date is equal to or is 1 day after the previous record's end-of-service date. If the above criteria for connected hospitalizations are met, combine all of the records. Retain the variables *patientid*, *dob*, and *male*, which will be the same across records by this step. Use the MINIMUM value for *admit_dt*. Use the MAXIMUM value for *end_service_dt*, *hasprimary*, *cci1-cci10* and *cci12-cci18*, *planned*, *chemo*, *mh*, *obstetric*, and *newborn*. Use the value of *hospitalid*, *disp_status*, *ins_end*, *lri*, and *hosp_noindex* from the last record.

4. IDENTIFY AND EXCLUDE INVALID EPISODES OF CARE

There may be episodes of care that are temporally overlapping, (i.e., in which it appears that a patient was in 2 different hospitals at the same time). These episodes should be dropped.

- Drop all episodes of care that share the same patient identifier, admission date, and end-of-service date but have different hospital identifiers.
- For each patient identifier, drop all temporally adjacent episodes of care if there are overlapping dates (i.e., admission date is before the end-of-service date for the preceding episode of care) but different hospital identifiers.

STEP 6: SPECIFY VARIABLES DEFINED AT THE EPISODE-OF-CARE LEVEL

Because multiple records may be combined to create an episode of care, some variables used for measure cohort exclusions and readmission analysis should be defined only *after* defining valid episodes of care. This sequencing assures that the variable values accurately represent information for the entire hospitalization, rather than capturing only a subset of information for the hospitalization. These variables should be created as specified below, prior to applying further exclusion criteria to the data.

Table 7 – Variables Defined at the Episode-of-Care Level

Variable Name	Description
<i>cci_count</i>	ordinal variable that consists of the total number of body systems affected by a chronic condition Constructed using the AHRQ CCI tool and top-coded (has an upper limit defined) at 4 or more body systems. 1 = 0 or 1 body system 2 = 2 body systems 3 = 3 body systems 4 = 4+ body systems Note: For analysis, 0 or 1 body system serves as the reference group.
<i>dob18</i>	date of the patient's 18 th birthday, expressed as a Julian date
<i>ageyrs_disch</i>	continuous variable containing age in years at discharge
<i>agegroup</i>	ordinal variable that consists of age in years at discharge with 5 groupings of age 1 = 0 ≤ age < 1 2 = 1 ≤ age < 5 3 = 5 ≤ age < 8 4 = 8 ≤ age < 12 5 = 12 ≤ age < 18 Note: For analysis, age 0 to < 1 serves as the reference group.

STEP 7: DEFINE EPISODES OF CARE ELIGIBLE FOR INCLUSION IN MEASURE COHORT

PLEASE NOTE: If working with a large dataset containing records for children and adults, records for patients >18 years, 29 days old may be excluded after Step 3, above, to make the dataset more manageable. Apply all other exclusions listed below only after defining episodes of care (in Step 5) and defining variables at the episode-of-care level (in Step 6).

Exclusions at the Patient Level Based on Data Completeness Criteria:

- Drop all episodes of care for a patient if the primary ICD-9 or principal ICD-10 diagnosis code is missing (i.e., *hasprimary* = 0) for ANY episode of care for that patient.

Rationale: Primary ICD-9 or principal ICD-10 diagnosis codes are needed to determine whether an index admission meets the LRI case definition, to assess chronic conditions for case-mix adjustment, and to evaluate for clinical exclusions.

Exclusions at the Episode-of-Care Level Based on Data Quality Criteria:

- Drop episodes of care with admission dates that occur after a discharge status of death during a prior episode of care.

Rationale: Episodes of care with admission dates that occur after a prior hospitalization ending in death suggest poor data quality that could result in inaccurate readmission rates.

Exclusions at the Episode-of-Care Level Based on Clinical Criteria:

- Drop episodes of care for patients > 18 years, 29 days old at the time of admission.
- Drop episodes of care for birth of healthy newborns (i.e., *newborn* = 1).

- Drop episodes of care with a primary ICD-9 or principal ICD-10 non-delivery obstetrics diagnosis or any labor and delivery diagnosis or procedure (i.e., *obstetric* = 1).
- Drop episodes of care with a primary ICD-9 or principal ICD-10 mental health diagnosis (i.e., *mh* = 1).

Rationale: Applying the above exclusions increases the fidelity of fitting the model to the intended population of interest. The age exclusion limits the population to pediatric patients and prevents inclusion of records that overlap with adult readmission measures. (Age eligibility for inclusion in the measure is based on age at the time of discharge from the index admission. Because the focus of the measure is pediatric patients, patients' hospitalizations are ineligible for inclusion in the measure as *index admissions* if the patients are ≥ 18 years old at the time of discharge. Because the subsequent observation period for readmissions is 30 days, patients' hospitalizations are ineligible for inclusion in the measure as *readmissions* if the patients are > 18 years, 29 days old at the start of the readmission.)

Hospitalizations for birth of healthy newborns are excluded because these hospitalizations, unlike all others, are not for evaluation and management of disease.

Hospitalizations for obstetric conditions are excluded because care related to pregnancy does not generally fall within the purview of pediatric providers. We have found using various datasets that this exclusion leaves very few (or sometimes no) patients who have a secondary ICD-9 or additional ICD-10 diagnosis code for a chronic condition falling into body system 11, "Complications of pregnancy, childbirth, and the puerperium," which could create model-fitting problems if Chronic Condition Indicator 11 were included in the case-mix-adjustment model. We therefore do not include the Chronic Condition Indicator variable for body system 11 in the measure because model-fitting problems could result.

Hospitalizations for mental health conditions are excluded because we found that hospitals with high readmission rates for mental health hospitalizations tend to have low readmission rates for hospitalizations for other conditions, and vice versa. Specifically, to evaluate the relationship between the primary diagnosis and the readmission outcome, we fitted a hierarchical random slopes regression model to the data. The model consisted of patients nested within hospitals at the first level and 2 random slope indicator variables at the second level: (a) an indicator variable for the primary diagnosis of interest alone and (b) an indicator variable for all other possible primary diagnoses. For primary diagnoses other than mental health conditions, the regression coefficient for the primary diagnosis of interest had a positive correlation with the regression coefficient for all other diagnoses, suggesting that performance on readmissions for the primary diagnosis of interest tends to correspond with performance on readmissions for all other diagnoses (the converse is also true). However, the regression coefficient for primary mental health diagnoses had a negative correlation with the coefficient for non-mental-health diagnoses, suggesting that performance on readmissions for mental health conditions does not tend to correspond with performance on readmissions for non-mental-health conditions.

Although hospitalizations with a primary ICD-9 or principal ICD-10 mental health diagnosis are excluded from the measure, the Chronic Condition Indicator for body system 5, "Mental disorders," is still used in the measure. We have found using various datasets that even after exclusion of hospitalizations with a primary mental health diagnosis, several hospitalizations remain with secondary diagnoses that fall into body system 5 (i.e., patients are commonly admitted with secondary diagnoses of mental health conditions and primary diagnoses in other body systems). Using Chronic Condition Indicator 5 in the case-mix-adjustment model therefore

does not pose the same potential model-fitting problems as using Chronic Condition Indicator 11.

STEP 8: DEFINE INDEX ADMISSIONS AND READMISSIONS

A clean dataset containing only *eligible admissions* must be prepared before defining index admissions and readmissions. This dataset should consist of all admissions that are eligible for inclusion in the measure cohort based on the criteria detailed in data preparation steps 1 through 7, above.

Exclusions at the Episode-of-Care Level for Defining Index Admissions:

- Episodes of care that either do not have a primary ICD-9 or principal ICD-10 LRI diagnosis or do not have a secondary ICD-9 or additional ICD-10 LRI diagnosis plus a primary ICD-9 or principal ICD-10 diagnosis of asthma, respiratory failure, or sepsis/bacteremia (i.e., *lri* = 0)
- Episodes of care for patients ≥ 18 years, 0 days old at the time of discharge
- Episodes of care with a discharge disposition of death
- Episodes of care with a discharge disposition of leaving the hospital against medical advice
- Episodes of care for which 30 days of follow-up data are unavailable, either (a) because the dataset's time range for claims does not include the full 30 days, or (b) because, for single-payer analyses, the patient was not enrolled with the payer for the full 30 days (i.e., the difference between *ins_end* and *end_service_dt* is less than 30 days).

PLEASE NOTE: When applying the above exclusions, it is important to do so *without deleting the records from the dataset* as these episodes of care may still meet criteria for readmissions, outlined below.

Rationale: This measure focuses on readmissions following hospitalization for LRI. Episodes of care that do not meet the case definition for an LRI hospitalization are therefore excluded from index admissions.

Age eligibility for inclusion in the measure is based on age at the time of discharge from the index admission. Because the focus of the measure is pediatric patients, patients' hospitalizations are ineligible for inclusion in the measure *as index admissions* if the patients are ≥ 18 years old at the time of discharge.

A patient must be discharged alive from an index admission in order to be readmitted. Therefore, any record with a discharge disposition of death cannot serve as an index admission.

A discharge disposition of leaving against medical advice indicates that a patient left care before the hospital determined that the patient was ready to leave.

Identifying readmissions within 30 days requires a full 30 days of follow-up data.

Exclusions at the Hospital Level for Defining Index Admissions:

- Hospitals with $< 80\%$ of records with complete unique patient identifier, admission date, and end-of-service date

- Hospitals with < 80% of records with complete primary ICD-9 or principal ICD-10 diagnosis code
- Out-of-state hospitals

Hospitals meeting the above exclusion criteria were identified in Step 2, above. The dichotomous variable *hosp_noindex* was created in Step 2 and coded 1 for hospitals meeting the above criteria and 0 for all other hospitals. Episodes of care for hospitals with *hosp_noindex* = 1 are therefore excluded from index admissions.

PLEASE NOTE: Although these hospitals' episodes of care should not be evaluated as index admissions (i.e., readmission rates should not be calculated for these hospitals), their episodes of care should *remain in the dataset* so they can be evaluated as potential readmissions for other hospitals.

Rationale: Readmission rates are not calculated for hospitals missing large amounts of data for the above variables because these hospitals have limited data to accurately define the measure cohort and calculate case-mix-adjusted readmission rates. Assessing eligibility for the measure cohort and performing case-mix adjustment requires information on admission dates, end-of-service dates, and diagnosis codes. Identifying readmissions requires information on admission dates and end-of-service dates and the ability to link unique patient identifiers across inpatient claims records.

Regarding out-of-state hospital admissions, it is possible that a state inpatient claims database may contain records for admissions to out-of-state hospitals. Records for out-of-state hospital admissions are not excluded from the measure cohort dataset because these records may meet criteria for being counted as readmissions as part of an in-state hospital's readmission rate. However, readmission rates will not be calculated for out-of-state hospitals due to the lack of complete data for these hospitals.

Exclusions at the Episode-of-Care Level for Defining Readmissions:

- Episodes of care with a primary ICD-9 or principal ICD-10 procedure code for a planned procedure (i.e., *planned* = 1)
- Episodes of care with a primary ICD-9 or principal ICD-10 diagnosis code or procedure code for chemotherapy (i.e., *chemo* = 1)

PLEASE NOTE: When applying these exclusions, it is important to do so *without deleting the records from the dataset* as these episodes of care may still meet criteria for index admissions, outlined above.

Rationale: Readmissions for planned procedures and for chemotherapy are part of a patient's intended course of care and thus unlikely to be related to health system quality. The purpose of this measure is to identify readmissions that may be attributable to poor quality of care. This measure therefore focuses on *unplanned* readmissions because they are more likely to be related to a defect in quality of care during the index admission or during the interval between the index admission and readmission. In adult and pediatric medicine, most planned readmissions are for planned procedures or chemotherapy; therefore, these exclusions are intended to capture the majority of planned readmissions.

SECTION 2: MODEL SPECIFICATION

This section describes the detailed specifications of the regression model used to obtain estimates of 30-day LRI hospital-level readmission rates for the pediatric population aged < 18 years old. We have provided a SAS program that fits the model, as described in this section, and performs direct standardization, as described in Section 3. We have also provided a program that estimates hospital- and state-level readmission rates that can be compared at a national level, as described in Section 4.

The model consists of a 2-level logistic regression model with fixed effect variables for patient case-mix at the first level and random intercepts for hospitals at the second level.

The model estimates 3 types of parameters. First, the coefficients of patient demographic and clinical characteristics represent the influence of these characteristics on predicted probabilities of readmission for an individual patient. Second, hospital-level random intercept estimates (evaluated for each hospital) represent the greater or lesser adjusted probability of readmission not explained by patient-level fixed effects for patients discharged from each hospital within a given state. Finally, variance estimates of the hospital random effects summarize the amount of variation among the intercepts for different hospitals and hence summarize the amount of variation in adjusted readmission rates across hospitals, at least some of which may be due to variation in health system quality.

After the case-mix-adjusted coefficients and hospital-level random intercept for each record are calculated, the hospital-specific case-mix-adjusted readmission rate is estimated through direct standardization using a case-mix representative of all hospitals in the entire dataset. The resulting estimates represent the readmission rate that each hospital would have if it served the same representative case-mix and are therefore conducive to comparisons among hospitals (for details, see Section 3).

DEFINITION OF OUTCOME

The model outcome, pediatric LRI readmission, is operationalized as the first unplanned admission to any acute care hospital within 30 days of discharge from a hospitalization for LRI at an acute care hospital. This prior admission, which serves as the reference point for enumerating 30-day readmissions, is the *index admission*. Additional admissions within 30 days from discharge from an index admission are not counted as index admissions. An admission more than 30 days from discharge from an index admission is counted as a new index admission.

We chose 30 days as the follow-up period during which to evaluate readmissions for multiple reasons. Readmissions within 30 days seem likely to reflect the quality of care provided both in the hospital and following discharge, which is consistent with the measure's intended purpose of assessing quality not just for a hospital but also for its wider health system. A follow-up period of 30 days is consistent with many readmission measures already in use, including the CMS readmission measures for adults. In addition, when we used a time-to-event curve to evaluate the proportion of readmissions within 1 year that occur within timeframes from 1 day up to 365 days, we observed a smooth curve with no obvious break to suggest an alternative follow-up period.

If a planned or chemotherapy readmission occurs within 30 days of an index admission, it *does not* count as a readmission against the index admission, and no subsequent admissions

occurring within 30 days of discharge from the index admission count as readmissions against the index admission. After 30 days from discharge from the index admission, a new index admission can be counted.

CASE-MIX VARIABLES INCLUDED IN THE MODEL

The following case-mix variables, defined from the index admission, have been selected for inclusion in the model and are specified in Tables 3 and 7 in Section 1.

- Age group
- Gender
- Presence of chronic conditions in each of 17 body systems (organ systems, disease categories, or other categories)
- Number of body systems affected by chronic conditions

Detailed Model Specification

$$\ln\left(\frac{y_{ij}}{1-y_{ij}}\right) = \beta_0 + \beta_1 x_{1ij} + \cdots + \beta_n x_{nij} + u_{0j}$$

Where:

- y_{ij}
 - represents a readmission event for an index admission i in hospital j
 - $y_{ij} \sim \text{Bernoulli}(\pi_{ij})$, where π_{ij} represents the probability of readmission for the i^{th} admission in the j^{th} hospital
 - takes on the following values for each index admission:
 - 0 = non-readmission
 - 1 = readmission
- β_0 is the intercept representing the overall readmission rate
- u_{0j} represents the j^{th} hospital's deviation from β_0 and $u_{0j} \sim \text{iid } N(0, \tau_{00})$
- $\beta_1 x_{1ij}$ to $\beta_n x_{nij}$ represent the n case-mix adjustment constant values for the i^{th} index admission in the j^{th} hospital

The first level of the model, which adjusts for hospital case-mix, includes patient gender and the following patient-level characteristics identified from the index admission: age group in years at the time of discharge, presence of a chronic condition in each of 17 body systems as identified by the AHRQ CCI tool, and the number of body systems affected by chronic conditions. The second level of the model consists of an estimate of a hospital-specific random effect that represents each hospital's systematic deviation from an average intercept across all hospitals. Estimates from this 2-level model can be used to calculate the hospital-specific readmission rate after accounting for patient case-mix by taking the average of the predicted probabilities of readmission that the model produces for each record by hospital.

In summary, the model specification used in this measure accounts for hospital case-mix, the clustering of certain types of patients within hospitals, and differences in sample size across hospitals. In theory, after adjusting for patient case-mix, the hospital intercepts should be equal across all hospitals if the patient case-mix has been correctly specified and hospitals are providing comparable quality of care. Therefore, variation among the hospital intercepts is presumed to capture systematic differences in hospital readmission rates.

IDENTIFYING AND TROUBLESHOOTING MODEL-FITTING ISSUES

We found while testing the measure that model-fitting issues may occur if, for a given level of a case-mix variable (e.g., $cci15 = 1$), all index admissions for which that level is present have the same outcome (e.g., all index admissions for which $cci15 = 1$ are followed by a readmission, or none of the index admissions for which $cci15 = 1$ are followed by a readmission). We have included a macro program to be used with the SAS model program that evaluates each variable for this condition and excludes the involved index admissions from the analysis. The program should therefore prevent the majority of model-fitting issues. As a precaution, however, we recommend reviewing the SAS log notes and output after running the model program for signs that may indicate problems with the model.

Below are indicators that a model-fitting problem may have occurred. If 1 or more of these indicators is present, we recommend reviewing the rich text file, named “lowerrespiratoryinfection_crosstabs.rtf,” generated by the model program. This file shows cross-tabulations of each case-mix variable with the readmission outcome. If any variable has a level with very few index admissions having a particular outcome (readmission or no readmission), consider dropping all of those index admissions and running the model program again.

1. The Covariance Parameter Estimate is > 0 and its standard error is missing (example below).

Covariance Parameter Estimates			
Cov Parm	Subject	Estimate	Standard Error
Intercept	hospitalid	0.06709	.

2. The SAS output includes a coefficient with a standard error of 0 (which will also result in a t-statistic of infinity).

Effect		Estimate	Standard Error	DF	t Value	Pr > t
male	Male	0.01700	0	18791	Infty	<.0001
male	_Female	0	.	.	.	.

3. The SAS output includes a coefficient with an extremely large standard error relative to those of the other coefficients.

Solutions for Fixed Effects					
Effect	Estimate	Standard Error	DF	t Value	Pr > t
cci13	-11.9677	327.76	18808	-0.04	0.9709

PLEASE NOTE: As you review the SAS log notes and output, the following are not reasons for concern.

1. In the log file, the following note will appear after the Glimmix procedure because cases with missing outcomes are intentionally generated as part of the direct standardization process.

“NOTE: Some observations are not used in the analysis because of: missing response values (n = 363909).”

2. The SAS output may include an estimate of 0 and a missing standard error for the Covariance Parameter Estimate. The SAS log may also contain the note, “NOTE: Estimated G matrix is not positive definite.” This means that evidence of variation across hospitals was not found (for example, because few hospitals had readmissions) but does not indicate a problem with model fitting.

Covariance Parameter Estimates			
Cov Parm	Subject	Estimate	Standard Error
Intercept	hospitalid	0	.

3. The log file may include notes such as "WARNING: Attempt to delete macro variable VAR 4 failed. Variable not found." These notes result from 1 of the steps of the macro program used with the SAS model program and do not indicate a problem.
4. The log file will include the note, "NOTE: Variable makeup_var is uninitialized." This note results from 1 of the steps of the macro program used with the SAS model program and does not indicate a problem.

SECTION 3: DIRECT STANDARDIZATION

Hospital populations in the dataset have differing case-mix compositions, making meaningful interpretations of comparisons of readmission rates across hospitals challenging. The hospital estimate from the fitted equation above is an estimate of the random effects intercept u_{0j} , which is not a readily interpretable quantity. We therefore use direct standardization to generate readmission rates that have a meaningful interpretation across hospitals. The interpretation that can be posited from this methodology is that the predicted readmission rate estimated for each hospital represents the readmission rate it would have if the hospital treated a patient cohort with the case-mix composition of all eligible index admissions within the entire dataset.

As described in Section 2 above, we fit a 2-level hierarchical logistic regression model to the observed data to obtain hospital-specific random intercepts that are adjusted for each hospital's case-mix. In order to implement direct standardization, we apply the estimates from the model to a hypothetical dataset in which (a) all admissions are re-coded as if they are from the hospital for which a readmission rate is being estimated and (b) the readmission outcome has been set to missing. Otherwise, the dataset is identical to the actual observed data from all hospitals in the cohort. This methodology uses the hospital's own random intercept, which is case-mix adjusted by its own specific index admission population, to determine the probability that a record in the dataset will generate a readmission.

Each hospital's predicted probabilities for all records are summed by hospital and divided by the total number of index admissions in the dataset to produce the hospital-specific standardized readmission rate. The upper confidence bound for this estimate is calculated as the mean of the

upper confidence bound for each index admission's probability of leading to a readmission. The corresponding procedure is followed to estimate the lower confidence bound.

Finally, the point estimate and bound values are multiplied by a factor that corrects for estimation error produced by transformations used during estimation. The bias correction factor is a constant value specified as the observed number of readmissions across all hospitals in the dataset divided by the predicted number of readmissions across all hospitals in the dataset. After calculating the point estimates and confidence intervals of hospital-specific readmission rates for each hospital using this methodology, hospitals are identified as outliers if the confidence bounds around their predicted readmission rates do not overlap with the overall observed readmission rate across the entire dataset.

Detailed Methods for Implementing Direct Standardization in SAS

One method to implement direct standardization in SAS involves obtaining the predicted values of every patient in the dataset in each hospital using the steps listed below. This is the method used in the SAS program provided.

1. For each hospital being standardized, create a duplicate copy of the original dataset. The duplicate dataset should contain exactly the same variables and records as the original data for all hospitals.
2. Set the outcome (readmissions) in the duplicate dataset to missing. This prevents these duplicate records from being used in model estimation.
3. For ALL records in the duplicate dataset, set the hospital identifier to the hospital identifier of the hospital being standardized. Add a variable to the dataset that indicates these records contain hypothetical data.
4. Concatenate the duplicate datasets to the original dataset. If the concatenated dataset is too large to handle, the same procedure may be conducted for subgroups of hospitals, or for 1 hospital at a time, and the results combined afterward.
5. Fit the model as specified in Section 2 of this document to the dataset created in step 4. In SAS, the model will be fitted only on the original data since the outcome is missing for the duplicate data. This process will produce a case-mix-adjusted random intercept for each hospital. However, the procedure will also produce predicted probabilities for both original and duplicate records (SAS calculates predicted probabilities for any record in which the predictors are not missing, regardless of whether the outcome is missing).
6. Calculate the mean predicted probability and lower and upper bounds for only the duplicate records (those flagged as containing hypothetical data) in order to obtain the predicted readmission rate for the hospital being standardized. This rate represents the readmission rate for this hospital if it were to treat the *entire dataset's* population mix.

SECTION 4: CALCULATION OF NATIONALLY COMPARABLE HOSPITAL- AND STATE-LEVEL RATES

Pediatric inpatient claims data are widely available, but the data are presently aggregated at the hospital, payer, or state (e.g., for Medicaid or all-payer databases) level but not at the federal level. Although Medicaid claims are compiled into Medicaid Analytic eXtract (MAX) files for research use, MAX is nevertheless comprised of 51 separate state-specific datasets, with variability in completeness of data elements and inconsistencies in provider identifiers and coding practices across states.^{1,2} In addition, MAX data availability lags by about 3 years, preventing assessment of quality for more recent time periods.¹ Thus, while Medicare data serve as a national database for quality measurement in adult patients, no analogous national database of pediatric claims from all states and all types of hospitals currently exists.

In order for hospital, payer, or state outcome measures to be comparable at the national level, they must be case-mix adjusted with a model derived from data from all states. Comparisons of readmission rates calculated and standardized with data from 1 state with those calculated and standardized with data from another state are not fully valid because the case-mix coefficients may differ in health systems in 1 state versus another state. Without a unified dataset, an individual state can calculate, case-mix adjust, and compare readmission rates among its own health systems, but it cannot compare its rates with those of other states.

In the absence of a national pediatric claims database, we have developed a method for calculating hospital- or state-level readmission rates for Medicaid-insured patients that can be compared across states. We have provided a SAS program to implement this method. Readmission rates are standardized using a reference dataset, consisting of MAX data for 26 states (Alabama, Arizona, Connecticut, Idaho, Indiana, Iowa, Kansas, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Montana, New Jersey, New Mexico, New York, North Carolina, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Vermont, Virginia, Wisconsin, and Wyoming). The 26 states, which are diverse in size and represent each geographic region (Northeast, Midwest, South, West), were chosen based on quality and completeness of their data for readmission analyses; to our knowledge, the combined data for these states comprise the most nationally representative dataset available to standardize readmission rates for Medicaid-insured children.

The case-mix adjustment model used in our method consists of a 2-level logistic regression model with fixed effect variables for patient case-mix at the first level and random intercepts for hospitals at the second level. Our analyses showed no state-level variation in LRI readmission rates, so we do not include random intercepts for states in the model.

The model estimates 3 types of parameters. First, the coefficients of patient demographic and clinical characteristics represent the influence of these characteristics on predicted probabilities of readmission for an individual patient. Second, hospital-level random intercept estimates (evaluated for each hospital) represent the greater or lesser adjusted probability of readmission, not explained by patient-level fixed effects, for patients discharged from each hospital. Finally, variance estimates of the hospital random effects summarize the amount of variation among the intercepts for different hospitals and hence summarize the amount of variation in adjusted readmission rates across hospitals, at least some of which may be due to variation in health system quality.

Detailed Methods for Calculating Nationally Comparable Hospital-Level Readmission Rates for Medicaid-Insured Patients

After the case-mix-adjusted coefficients and hospital-level random intercepts for each record are calculated, the hospital-specific case-mix-adjusted readmission rate is estimated through direct standardization using a case-mix representative of all hospitals in the entire 26-state MAX reference dataset. The resulting estimates represent the readmission rate that each hospital would have if it served the same representative case-mix and are therefore conducive to rate comparisons.

The following describes a method to use SAS procedures to approximate the posterior predictive distribution of hospital-level rates.

1. Fit the case-mix adjustment model to the *26-state MAX reference dataset* and retain estimates for:

- a. hospital-level random intercept variance: $\sigma^2_{\text{hospital}}$
 - b. fixed effect coefficients: $\beta_{\text{reference}}$
2. Refit a hierarchical logistic regression model using the dataset for which nationally comparable readmission rates are to be calculated, hereafter referred to as the *analysis dataset*, as follows:
 - a. Fix hospital-level variance and fixed effect coefficients to estimates from Step 1.
 - b. Output hospital-level estimates for units in the *analysis dataset*. (It is acceptable for the *analysis dataset* to contain only 1 state.)
3. Next, perform direct standardization using the reference dataset. Note that patient case-mix enters the regression through the fixed effects portion of the linear predictor. Rather than requiring the actual reference dataset to perform direct standardization, one can use a representative subset of βX_i , $i \in \text{reference}$ from the reference dataset. To obtain the representative subset, calculate the fixed effects βX_i for all records in the reference dataset, sort records by this value, and sample 1,000 equally spaced values, where "equally spaced" refers to rank order (e.g., if sampling 1,000 values from 100,000 ranked values, the 100th smallest, 200th smallest, 300th smallest, etc., value would be selected).
4. Perform direct standardization as described in Section 3, applying each hospital's random effect estimate 1 at a time to the subset of 1,000 βX_i values (retained from Step 3) to obtain an average probability for 1 hospital as if its case-mix were that of the entire dataset. For each of the 1,000 βX_i values, a new predicted value, P_{analysis} , will be generated that is a combination of βX_i and the random effect for the hospital of interest (this process would be repeated for each hospital). Upper and lower confidence bounds for P_{analysis} will also be calculated.
5. Transform the values of P_{analysis} from the logit to the probability scale, and then take the mean of those probabilities to get the nationally comparable adjusted readmission rate for that hospital. Take the means of those upper and lower bounds to get the upper and lower bounds for the hospital-level rate.

Detailed Methods for Calculating Nationally Comparable State-Level Readmission Rates for Medicaid-Insured Patients

State-level readmission rates are calculated by taking the mean of the nationally comparable readmission rates of all hospitals within a state, weighted by hospital volume. To calculate confidence bounds for the state-level readmission rate, the method below is used.

1. Fit the case-mix adjustment model as in Step 3 above, to the *analysis dataset*, as follows, which will provide estimates and standard errors for each hospital's effect.
 - a. Specify hospital effect using the hospital variance estimate from the reference dataset.
 - b. The model contains no intercept and no fixed effects.
 - c. Specify an "offset" – essentially, an intercept that is different for each record – where the offset = Y_{analysis} and

$$Y_{\text{analysis}} = \text{intercept}_{\text{analysis}} + (\beta_{\text{reference}} * X_{\text{analysis}})$$

2. For each hospital, generate a random draw from the distribution defined by the estimate and standard error from step 2. Add this random value to Y_{analysis} from step 1c, then perform direct standardization as described in Section 3, using the *subset of 1,000 $Y_{\text{reference}}$ values*. For each of the 1,000 $Y_{\text{reference}}$ values, a new predicted value, P_{analysis} , will be generated that is a combination of $Y_{\text{reference}}$ and the random effect for the hospital of

interest (this process would be repeated for each hospital). Upper and lower confidence bounds for P_{analysis} will also be calculated.

3. Inverse-logit transform the values of P_{analysis} to obtain probabilities, and then take the mean of those probabilities to get the nationally comparable adjusted readmission rate for that hospital.
4. Generate the state-level adjusted readmission rate by calculating the mean rate across hospitals, weighted by hospital volume.
5. Repeat steps 2 through 4 1,000 times, then calculate a confidence interval from the distribution of the rates generated in step 4.

REFERENCES

1. Centers for Medicare & Medicaid Services. Medicaid Analytic eXtract (MAX) general information. 2013. Available at: <http://www.cms.gov/Research-Statistics-Data-and-Systems/Computer-Data-and-Systems/MedicaidDataSourcesGenInfo/MAXGeneralInformation.html>. Accessed October 7, 2013.
2. Bencio D. *Medicaid Analytic Extract Provider Characteristics (MAXPC) evaluation report, 2010 - final report*. Mathematica Policy Research; 2013. Available at: <http://www.mathematica-mpr.com/publications/>. Accessed September 24, 2013.

```
*****
*****
*****;
* PROGRAM FOR STEPS 5-8: TAKES DATA AFTER STEPS 1 THROUGH 4,
COLLAPSES RECORDS, CLEANS OVERLAPPING RECORDS AND EPISODES OF
CARE, AND DEFINES INDEX AND READMISSIONS.
* 'LowerRespiratoryInfection PediatricReadmission DataPrep
AllPayer.sas'
```

Programmers: Jisun Jang, David Klein, and Jeremy Feng
 Boston Children's Hospital
 Center of Excellence for Pediatric
 Quality Measurement

Division of General Pediatrics

Date: February 5, 2014

How to run this program::

- 1) Insert the name of the dataset prepared by following STEP 1-4 in the Measure Specification in DATASET.
- 2) Insert a path where the final output dataset will be saved in FINALPATH.
- 3) Insert a path where the step4 dataset (dataset from 1) is saved in STEP4PATH.
- 4) Insert the beginning date (year, month and day) of index admissions you would like to define. (For example, BEGINYEAR=2012)
- 4) Insert the end date (year, month and day) of index admissions you would like to define. (For example, ENDYEAR=2013)
- 6) Insert the desired name of final index dataset.

```
*****
*****
*****;
```

```
options compress=yes;
```

```
/*1*/ %let DATASET=step4data;
/*2*/ %let FINALPATH=c:\location;
/*3*/ %let STEP4PATH=c:\location;
/*4*/ %let BEGINYEAR=2012; %let BEGINMONTH=3; %let BEGINDAY=1;
/*5*/ %let ENDYEAR=2013; %let ENDMONTH=2; %let ENDDAY=28;
/*6*/ %let FINALDATA=finaldata;
```

```
libname final "&finalpath";
libname STEP4 "&step4path";
```

```
/*STEP 5: Define Episode of Care*/
```

```
/*Process for Defining Episode of Care*/
```

```
/*1. IDENTIFY TRUE DUPLICATES AND DROP ALL BUT ONE.*/
```

```
proc sort data=step4.&DATASET (keep=PatientID HospitalID
Hosp_noindex admit_dt end_service_dt disp_status DOB hasprimary
CCI1-CCI10 CCI12-CCI18 Planned Chemo MH Obstetric
LRI male newborn) out=step5_1; by PatientID HospitalID
admit_dt end_service_dt disp_status;
run;
data step5_1; set step5_1;
retain duplicate_cnt;
if PatientID ne lag1(PatientID) OR HospitalID ne
lag1(HospitalID) OR admit_dt ne lag1(admit_dt) OR end_service_dt
ne lag1(end_service_dt) OR disp_Status ne lag1(disp_Status) OR
CCI1 ne lag1(CCI1) OR CCI2 ne lag1(CCI2) OR CCI3 ne
lag1(CCI3) OR CCI4 ne lag1(CCI4) OR CCI5 ne lag1(CCI5) OR CCI6
ne lag1(CCI6) OR CCI7 ne lag1(CCI7) OR CCI8 ne lag1(CCI8) OR
CCI9 ne lag1(CCI9) OR CCI10 ne lag1(CCI10) OR CCI12 ne
lag1(CCI12) OR CCI13 ne lag1(CCI13) OR CCI14 ne lag1(CCI14) OR
CCI15 ne lag1(CCI15) OR
CCI16 ne lag1(CCI16) OR CCI17 ne lag1(CCI17) OR CCI18 ne
lag1(CCI18) or dob ne lag1(dob) OR planned ne lag1(planned) OR
chemo ne lag1(chemo) OR MH ne lag1(MH) OR Obstetric ne
lag1(Obstetric) OR Newborn ne lag1(Newborn) OR male ne
lag1(male) OR lri ne lag1(lri)
then duplicate_cnt+1;
run;

proc sort data=step5_1; by duplicate_cnt;
data step5_1 (drop=duplicate_cnt ephasprimary); set step5_1; by
duplicate_cnt;
retain ephasprimary;
if first.duplicate_cnt then ephasprimary=0;
if hasprimary then ephasprimary=1;

if last.duplicate_cnt then do;
hasprimary=ephasprimary;
output;
end;

run;
```

```

/*STEP 5*/
/*2. IDENTIFY AND COMBINE MULTIPLE VALID RECORDS FROM THE SAME
HOSPITAL FOR THE SAME HOSPITALIZATION.*/
/*• Sort records by the following variables, in the specified
order: PatientID, HospitalID, admit_dt, end_service_dt, and
disp_status.*/
/*• Define records to be part of the same hospitalization at the
same hospital if */
/*(a) PatientID and HospitalID are equal to those in the
previous record and */
/*(b) admission dates and end-of-service dates indicate
consecutive time periods or nesting of one time period within
another because one of the following is true:*/
/*1) admission date is before the previous record's end-of-
service date*/
/*2) admission date is equal to the previous record's end-of-
service date AND the previous record's disposition status is
equal to 0 (other) or 2 (transfer to an acute-care hospital)*/
/*3) admission date is one day after the previous record's end-
of-service date AND the previous record's disposition status is
equal to 0 (other) or 2 (transfer to an acute-care hospital)*/
/*4) admission and end-of-service dates are both the same as
those of the previous record, and admission date is equal to
end-of-service date (i.e., the records are for a same-day
discharge on the same date)*/

```

```

proc sort data=step5_1 out=step5_2; by PatientID HospitalID
admit_dt end_service_dt disp_status;
data step5_2(drop=i); set step5_2; by PatientID HospitalID
admit_dt end_service_dt disp_status;
    array eps [*] epCCI1-epCCI10 epCCI12-epCCI18 epplanned
epchemo epMH epObstetric epnewborn ephasprimary eplri;
    array recs [*] CCI1-CCI10 CCI12-CCI18 planned chemo MH
Obstetric newborn hasprimary lri;
    retain epcnt epadat epddat epdisp epCCI1-epCCI10 epCCI12-
epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri;
    if first.HospitalID then epcnt=0;
    if first.HospitalID
        OR (admit_dt - epddat > 1)
        OR (admit_dt-epddat=1 AND epdisp NOT IN (0,2))
        OR (admit_dt-epddat=0 AND epdisp NOT IN (0,2) AND
admit_dt^=end_service_dt) then do;
        epcnt+ 1;
        epadat=admit_dt;
        epdisp=disp_status;
        epddat=end_service_dt;
    end;

```

```

        do i=1 to dim(eps);
        eps[i]=recs[i];
        end;
    end;
    /* CONTINUING RETAINED EPISODE */
    else do;
        /* For all subsequent admissions that do not count as a
        start of an episode, take the max of necessary casemix
        covariates. */
        do i=1 to dim(eps);
        eps[i] = max(eps[i], recs[i]);
        end;
        /* In the case where current admission has an end date
        later than the retained episode end date,
        extend episode end date to current admission's end date,
        use discharge date/ins_end of the admission with latest service
        end date.*/
        if end_service_dt>=epddat then do;
            epddat = end_service_dt;
            epdisp = disp_status;

        end;
    end;
run;

proc sort data=step5_2; by PatientID HospitalID epcnt;
data step5_2 (drop=i epadat epddat epdisp epcnt epCCI1-epCCI10
epCCI12-epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri);
set step5_2; by PatientID HospitalID epcnt;
if last.epcnt;
array olds [*] admit_dt end_service_dt disp_status CCI1-CCI10
CCI12-CCI18 planned chemo MH Obstetric newborn hasprimary lri;
array news [*] epadat epddat epdisp epCCI1-epCCI10 epCCI12-
epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri;
do i=1 to dim(olds);
    olds[i]=news[i];
end;
run;

/*STEP 5*/
/*3. IDENTIFY AND COMBINE MULTIPLE VALID RECORDS FROM MULTIPLE
HOSPITALS FOR HOSPITALIZATIONS THAT INCLUDED TRANSFERS */

```

```

/*• Sort records by the following variables, in the specified
order: patient ID, admission date, end-of-service date,
disposition status.*/
/*• Define records to be in the same episode of care if patient
ID is equal to patient ID in the previous record, the previous
record's disposition status is a transfer, and the admission
date is equal to or is one day after the previous record's end-
of-service date.*/

proc sort data=step5_2 out=step5_3;
by PatientID admit_dt end_service_dt disp_status; /*do not sort
by HospitalID because we do NOT want the same hospitals next to
each other*/
data step5_3; set step5_3; by PatientID admit_dt end_service_dt
disp_status;
    array eps [*] epCCI1-epCCI10 epCCI12-epCCI18 epplanned epchemo
epMH epObstetric epnewborn ephasprimary eplri;
    array recs [*] CCI1-CCI10 CCI12-CCI18 planned chemo MH
Obstetric newborn hasprimary lri;
    retain epcnt epadat epddat epdisp epCCI1-epCCI10 epCCI12-
epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri;

    if first.PatientID then epcnt=0;

    /* STARTING NEW EPISODE: first record of patient at hospital
or NOT a transfer */
    if first.PatientID
        OR not (admit_dt-epddat in (0,1) AND epdisp IN (0,2)) then
do;
    epcnt+ 1;
    epadat=admit_dt;
    epdisp=disp_status;
    epddat=end_service_dt;
    do i=1 to dim(eps);
        eps[i]=recs[i];
    end;
end;
    /* CONTINUING RETAINED EPISODE */
    else do;
        /* For all subsequent admissions that do not count as a
start of an episode, take the max of necessary casemix
covariates. */
        do i=1 to dim(eps);
            eps[i] = max( eps[i], recs[i]);
        end;
    end;
end;

```

```

        /* In the case where current admission has an end date
        later than the retained episode end date, extend episode end
        date to current
            admission's end date, use discharge date/ins_end of the
        admission with the latest service end date*/
        if end_service_dt >= epddat then do;
            epddat = end_service_dt;
            epdisp = disp_status;

        end;
    end;
run;

proc sort data=step5_3; by PatientID epcnt;
data step5_3 (drop=epadat epddat epdisp epcnt epCCI1-epCCI10
epCCI12-epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri);
    set step5_3;
    by PatientID epcnt; /*Use the value for HospitalID
hosp_noindex*/
    if last.epcnt;
    array olds [*] admit_dt end_service_dt disp_status CCI1-CCI10
CCI12-CCI18 planned chemo MH Obstetric newborn hasprimary lri;
    array news [*] epadat epddat epdisp epCCI1-epCCI10 epCCI12-
epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri;
    do i=1 to dim(olds);
        olds[i]=news[i];
    end;
run;

/*STEP 5*/
/*4. IDENTIFY AND EXCLUDE INVALID EPISODES OF CARE*/
/*There may be episodes of care that are temporally overlapping,
i.e., it appears that a patient is in two different hospitals at
the same time. These episodes should be dropped.*/
/*• Drop all episodes of care that share the same patient ID,
admission date, and end-of-service date but have different
hospital IDs.*/
/*• For each patient ID, drop all temporally adjacent episodes
of care if there are overlapping dates
(i.e., admission date is before the end-of-service date for the
preceding episode of care) but different hospital IDs.*/

proc sort data= step5_3 out=step5_4;
by PatientID admit_dt end_service_dt;

```



```

run;

data step5_4; set step5_4; by PatientID admit_dt end_service_dt;
  retain epcnt epddat;

  if first.PatientID then epcnt=0;

  /* STARTING NEW EPISODE: first record of patient at hospital
or NOT a transfer */
  if first.PatientID
    /*Even if a new episode is on the same day as the previous,
consider it a potential readmission since we have already taken
care of the transfers in the previous steps*/
    OR ( admit_dt >= epddat)    then do;
    epcnt+ 1;
    epddat=end_service_dt;
  end;
run;

proc sort data=step5_4; by PatientID epcnt;
data step5_4 (drop=epddat);
  set step5_4;
  by PatientID epcnt;
  if first.epcnt=1 and last.epcnt=1; /*When there are
overlapping EOCs, epcnt will be repeated*/
run;

/*STEP 6:  SPECIFY VARIABLES DEFINED AT THE EPISODE OF CARE
LEVEL*/
/*a) CCI_count*/
/*ordinal variable that consists of the total number of body
systems affected by a chronic condition constructed using the
AHRQ CCI tool and top-coded at 4 or more body systems*/
/*1 = 0 or 1 body systems*/
/*2 = 2 body systems*/
/*3 = 3 body systems*/
/*4 = 4+ body systems*/

/*b) create DOB18*/

/*c) ageyrs_disch continuous variable containing age in years at
discharge*/

/*d) agegroup*/
/*ordinal variable that consists age in years at discharge with
5 groupings of age*/
/*1= 0<=age <1*/

```

```

/*2= 1<=age<5*/
/*3= 5<=age<8*/
/*4= 8<=age<12*/
/*5= 12<=age<18*/

/*6.a)*/
data step6; set step5_4;

CCI_count=.;
if (sum(of CCI1-CCI10)+ sum(of CCI12-CCI18)) in (0,1) then
CCI_count=1;
else if (sum(of CCI1-CCI10)+ sum(of CCI12-CCI18)) =2 then
CCI_count=2;
else if (sum(of CCI1-CCI10)+ sum(of CCI12-CCI18)) =3 then
CCI_count=3;
else if 4<=(sum(of CCI1-CCI10)+ sum(of CCI12-CCI18))<=18 then
CCI_count=4;
label CCI_count="Number of CCI's 1= 0 or 1 CCI; 2= 2 CCI's; 3=3
CCI's; 4= 4 or More CCI's";

/*6.b)*/
if month(dob)=2 and day(dob)=29 then dob18=mdy(3, 1,
year(dob)+18);
    else dob18=mdy(month(dob), day(dob), year(dob)+18);

/*6.c)*/
ageyrs_disch= floor ((intck('month',dob,end_service_dt) -
(day(end_service_dt) < day(dob))) / 12);

/*6.d)*/
agegroup=.;
if 0<=ageyrs_disch <1 then agegroup=1;
else if 1<=ageyrs_disch<5 then agegroup=2;
else if 5<=ageyrs_disch<8 then agegroup=3;
else if 8<=ageyrs_disch<12 then agegroup=4;
else if 12<=ageyrs_disch<18 then agegroup=5;
label agegroup="Age group (Age at Discharge) 1= age <1; 2= age
1-4; 3= age 5-7; 4= age 8-11; 5= age 12 and older";

run;

/*STEP 7:  DEFINE EPISODES OF CARE ELIGIBLE FOR INCLUSION IN
COHORT*/

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON DATA
COMPLETENESS OR DATA QUALITY CRITERIA:*/

```

```
/*1) Episodes of care with admission dates that occur after a
discharge or death during a prior hospitalization*/
```

```
/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON CLINICAL
CRITERIA:*/
```

```
/*1) Drop episodes of care for patients aged >18 years, 29 days
old AT THE TIME OF ADMISSION.*/
```

```
/*3) Drop episodes of care with a primary non-delivery
Obstetrics diagnosis or any delivery diagnosis or procedure
(i.e., Obstetric = 1).*/
```

```
/*4) Drop episodes of care with a primary mental health
diagnosis (i.e., MH = 1).*/
```

```
proc sort data=step6; by PatientID;
data ptdrop (keep=PatientID dx_miss); set step6; by PatientID;
  retain dx_miss;
  if first.patientid then do;
dx_miss= 0;
  end;
```

```
  if hasprimary=0 then dx_miss=1;
```

```
  if last.patientid;
  label dx_miss="Primary DX missing for any episode";
```

```
proc sort data=ptdrop; by PatientID;
proc sort data=step6; by PatientID;
data step7a (drop=dx_miss); merge step6 ptdrop; by PatientID;
  if dx_miss=0;
run;
```

```
proc sort data=step7a; by PatientID admit_dt end_service_dt
disp_status;
data step7 (where=(data_quality_bad=0 and clinical_exc=0)
drop=death sum_died); set step7a;
  by PatientID admit_dt end_service_dt disp_status;
  death= 0;
  if disp_status=4 then death=1;
  retain sum_died;
  if first.PatientID then do;
    sum_died= 0;
  end;
  sum_died=sum_died+death;
  label sum_died="Number of records with death within the same
PatientID";
```

```

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON DATA
COMPLETENESS OR DATA QUALITY CRITERIA:*/
data_quality_bad= 0;
if /*1)*/(sum_died>death) then data_quality_bad=1;
label data_quality_bad="EXCLUSIONS AT THE EPISODE OF CARE
LEVEL BASED ON DATA COMPLETENESS OR DATA QUALITY CRITERIA";

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON CLINICAL
CRITERIA:*/
clinical_exc= 0;
if admit_dt>(dob18+29) or newborn=1 or Obstetric=1 or MH=1
then clinical_exc=1;
label clinical_exc="EXCLUSIONS AT THE EPISODE OF CARE LEVEL
BASED ON CLINICAL CRITERIA";
run;

/*STEP 8:  DEFINE INDEX ADMISSIONS AND READMISSIONS*/

*****Index
Admissions*****
/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL FOR DEFINING INDEX
ADMISSIONS:*/
/*• Episodes of care for patients aged 18 years, 0 days or older
at the time of discharge*/
/*• Episodes of care with a discharge disposition of death*/
/*• Episodes of care with a discharge disposition of leaving the
hospital against medical advice*/
/*• Episodes of care for which a full 30 days of follow-up are
unavailable, either
(a) because the dataset's available time range for claims does
not include the full 30 days, or
(b) because, for single-payer analyses, the patient was not
enrolled for the full 30 days
(i.e., the difference between ins_end and end_service_dt is less
than 30 days)*/

/*EXCLUSIONS AT THE HOSPITAL LEVEL FOR DEFINING INDEX
ADMISSIONS:*/
/*• Hospitals with <80% of records with complete unique patient
identifier, admission date, and end-of-service date*/
/*• Hospitals with <80% of records with complete primary
diagnosis code*/
/*• Out-of-state hospitals*/

```

```

*****Readmissions*****
*****
/*EXCLUSIONS FOR DEFINING READMISSIONS AT THE EPISODE OF CARE
LEVEL:*/
/*• Episodes of care with a primary ICD-9-CM procedure code for
a planned procedure (i.e., planned = 1)*/
/*• Episodes of care with a primary ICD-9-CM diagnosis or
procedure code for chemotherapy (i.e., chemo = 1)*/
;

proc sort data=step7 out=step8; by PatientID admit_dt
end_service_dt;
run;

data step8;
set step8;
by patientID admit_dt end_service_dt;

range=(mdy(&BEGINMONTH,&BEGINDAY,&BEGINYEAR)<=end_service_dt<=md
y(&ENDMONTH,&ENDDAY,&ENDYEAR));

index_exclusion=1;
if ageyrs_disch<18 and disp_status in (1,2,0) and range=1 and
hosp_noindex=0 and lri=1 then index_exclusion=0;

retain eoc_end_date;
if (first.PatientID and index_exclusion=0) or
(admit_dt>eoc_end_date and index_exclusion=0)
then eoc_end_date=end_service_dt+30;
else if (first.PatientID and index_exclusion=1) or
(admit_dt>eoc_end_date and index_exclusion)=1
then eoc_end_date=.;

run;

data step8(drop=lag_eoc_end_date);
set step8(where=(eoc_end_date ne .)); /*I am deleting the
records that can't be index admission but also can't be
readmission*/
by patientID admit_dt end_service_dt;

retain eoc;
lag_eoc_end_date=lag(eoc_end_date);
if first.patientID then eoc=1;
else if lag_eoc_end_date ne eoc_end_date then eoc=eoc+1;

```

```

readmission_exclusion=(chemo=1 or planned=1);
run;

proc sort data=step8; by patientID eoc;
run;

data step8;
  _N_ ++ 1;
  IF _N_ <= N THEN DO;
    Set step8 POINT=_N_;
    lead_PatientID=PatientID;
    lead_eoc=eoc;
    lead_readmission_exclusion= readmission_exclusion;
    lead_hospitalID=hospitalID;
  END;
  ELSE do;
    lead_PatientID= .;
    lead_eoc= .;
    lead_readmission_exclusion= .;
    lead_hospitalID= .;
  end;
  Set step8 nobs = n;
run;

proc sort data=step8; by patientID eoc;
run;
data step8;
set step8;

by PatientID eoc;

readmission=0;
if first.eoc and patientID=lead_PatientID and eoc=lead_eoc and
lead_readmission_exclusion =0 then readmission=1;

index=0;
if first.eoc=1 then index=1;
run;

*PUT FINAL BACK IN AFTER TESTING;
data final.&finaldata(keep=PatientID index readmission
HospitalID admit_dt end_service_dt DOB CCI1-CCI10 CCI12-CCI18
planned chemo MH Obstetric newborn disp_status agegroup
CCI_count ageyrs_disch male LRI
where=(index=1));
set step8;

```

```

label PatientID="unique patient ID"
HospitalID= "unique hospital ID"
admit_dt= "admission date"
end_service_dt= "service end date"
dob= "Date of Birth"
planned= "dichotomous variable indicating presence of planned
procedure 0= not present 1= present"
chemo= "dichotomous variable indicating presence of
chemotherapy ICD-9-CM code 0= not present 1= present"
MH= "dichotomous variable indicating mental health primary
diagnosis 0= not present 1= present"
Obstetric= "dichotomous variable indicating Obstetric primary
diagnosis 0= not present 1= present"
newborn= "dichotomous variable indicating birth of healthy
newborn 0= not present 1= present"
disp_status = "dichotomous variable identifying disposition
status 0=other 1=discharge 2=transfer to an acute-care hospital
3=left against medical advice 4=died"
male = "variable indicating patient sex 0=female 1=male
.=missing"
CCI1= "Infectious and parasitic disease"
CCI2= "Neoplasms"
CCI3= "Endocrine, nutritional, and metabolic diseases and
immunity disorders"
CCI4= "Diseases of blood and blood-forming organs"
CCI5= "Mental disorders"
CCI6= "Diseases of the nervous system and sense organs"
CCI7= "Diseases of the circulatory system"
CCI8= "Diseases of the respiratory system"
CCI9= "Diseases of the digestive system"
CCI10= "Diseases of the genitourinary system"
CCI12= "Diseases of the skin and subcutaneous tissue"
CCI13= "Diseases of the musculoskeletal system"
CCI14= "Congenital anomalies"
CCI15= "Certain conditions originating in the perinatal period"
CCI16= "Symptoms, signs, and ill-defined conditions"
CCI17= "Injury and poisoning"
CCI18= "Factors influencing health status and contact with
health services"
Index= "Index Admission"
Readmission= "30day Readmission"
ageyrs_disch= "Age at Discharge in years"
LRI= "Lower Respiratory Infection";
run;

```

```
*****
*****
*****;
* PROGRAM FOR STEPS 5-8: TAKES DATA AFTER STEPS 1 THROUGH 4,
COLLAPSES RECORDS, CLEANS OVERLAPPING RECORDS AND EPISODES OF
CARE, AND DEFINES INDEX AND READMISSIONS.
* 'LowerRespiratoryInfection PediatricReadmission DataPrep
SinglePayer.sas'
```

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Division of General Pediatrics

Date: February 5, 2014

How to run this program::

- 1) Insert the name of the dataset prepared by following STEP 1-4 in the Measure Specification in DATASET.
- 2) Insert a path where the final output dataset will be saved in FINALPATH.
- 3) Insert a path where the step4 dataset (dataset from 1) is saved in STEP4PATH.
- 4) Insert the beginning date (year, month and day) of index admissions you would like to define. (For example, BEGINYEAR=2012)
- 4) Insert the end date (year, month and day) of index admissions you would like to define. (For example, ENDYEAR=2013)
- 6) Insert the desired name of final index dataset.

```
*****
*****
*****;
```

```
options compress=yes;
```

```
/*1*/ %let DATASET=step4data;
/*2*/ %let FINALPATH=c:\location;
/*3*/ %let STEP4PATH=c:\location;
/*4*/ %let BEGINYEAR=2012; %let BEGINMONTH=3; %let BEGINDAY=1;
/*5*/ %let ENDYEAR=2013; %let ENDMONTH=2; %let ENDDAY=28;
/*6*/ %let FINALDATA=finaldata;
```

```
libname final "&finalpath";
libname STEP4 "&step4path";
```



```
/*STEP 5: Define Episode of Care*/
```

```
/*Process for Defining Episode of Care*/
```

```
/*1. IDENTIFY TRUE DUPLICATES AND DROP ALL BUT ONE.*/
```

```
proc sort data=step4.&DATASET (keep=PatientID HospitalID
Hosp_noindex admit_dt end_service_dt disp_status DOB hasprimary
CCI1-CCI10 CCI12-CCI18 Planned Chemo MH Obstetric
LRI ins_end male newborn) out=step5_1; by PatientID
HospitalID admit_dt end_service_dt disp_status;
run;
data step5_1; set step5_1;
retain duplicate_cnt;
if PatientID ne lag1(PatientID) OR HospitalID ne
lag1(HospitalID) OR admit_dt ne lag1(admit_dt) OR end_service_dt
ne lag1(end_service_dt) OR disp_Status ne lag1(disp_Status) OR
CCI1 ne lag1(CCI1) OR CCI2 ne lag1(CCI2) OR CCI3 ne
lag1(CCI3) OR CCI4 ne lag1(CCI4) OR CCI5 ne lag1(CCI5) OR CCI6
ne lag1(CCI6) OR CCI7 ne lag1(CCI7) OR CCI8 ne lag1(CCI8) OR
CCI9 ne lag1(CCI9) OR CCI10 ne lag1(CCI10) OR CCI12 ne
lag1(CCI12) OR CCI13 ne lag1(CCI13) OR CCI14 ne lag1(CCI14) OR
CCI15 ne lag1(CCI15) OR
CCI16 ne lag1(CCI16) OR CCI17 ne lag1(CCI17) OR CCI18 ne
lag1(CCI18) or dob ne lag1(dob) OR planned ne lag1(planned) OR
chemo ne lag1(chemo) OR MH ne lag1(MH) OR Obstetric ne
lag1(Obstetric) OR ins_end ne lag1(ins_end) OR Newborn ne
lag1(Newborn) OR male ne lag1(male) OR lri ne lag1(lri)
then duplicate_cnt+1;
run;

proc sort data=step5_1; by duplicate_cnt;
data step5_1 (drop=duplicate_cnt ephasprimary); set step5_1; by
duplicate_cnt;
retain ephasprimary;
if first.duplicate_cnt then ephasprimary=0;
if hasprimary then ephasprimary=1;

if last.duplicate_cnt then do;
hasprimary=ephasprimary;
output;
end;

run;
```

```

/*STEP 5*/
/*2. IDENTIFY AND COMBINE MULTIPLE VALID RECORDS FROM THE SAME
HOSPITAL FOR THE SAME HOSPITALIZATION.*/
/*• Sort records by the following variables, in the specified
order: PatientID, HospitalID, admit_dt, end_service_dt, and
disp_status.*/
/*• Define records to be part of the same hospitalization at the
same hospital if */
/*(a) PatientID and HospitalID are equal to those in the
previous record and */
/*(b) admission dates and end-of-service dates indicate
consecutive time periods or nesting of one time period within
another because one of the following is true:*/
/*1) admission date is before the previous record's end-of-
service date*/
/*2) admission date is equal to the previous record's end-of-
service date AND the previous record's disposition status is
equal to 0 (other) or 2 (transfer to an acute-care hospital)*/
/*3) admission date is one day after the previous record's end-
of-service date AND the previous record's disposition status is
equal to 0 (other) or 2 (transfer to an acute-care hospital)*/
/*4) admission and end-of-service dates are both the same as
those of the previous record, and admission date is equal to
end-of-service date (i.e., the records are for a same-day
discharge on the same date)*/

```

```

proc sort data=step5_1 out=step5_2; by PatientID HospitalID
admit_dt end_service_dt disp_status;
data step5_2(drop=i); set step5_2; by PatientID HospitalID
admit_dt end_service_dt disp_status;
    array eps [*] epCCI1-epCCI10 epCCI12-epCCI18 epplanned
epchemo epMH epObstetric epnewborn ephasprimary eplri;
    array recs [*] CCI1-CCI10 CCI12-CCI18 planned chemo MH
Obstetric newborn hasprimary lri;
    retain epcnt epadat epddat epdisp epins_end epCCI1-epCCI10
epCCI12-epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri;
    if first.HospitalID then epcnt=0;
    if first.HospitalID
        OR (admit_dt - epddat > 1)
        OR (admit_dt-epddat=1 AND epdisp NOT IN (0,2))
        OR (admit_dt-epddat=0 AND epdisp NOT IN (0,2) AND
admit_dt^=end_service_dt) then do;
        epcnt+ 1;
        epadat=admit_dt;
        epdisp=disp_status;
        epins_end=ins_end;
    end;

```

```

epddat=end_service_dt;
  do i=1 to dim(eps);
    eps[i]=recs[i];
  end;
end;
/* CONTINUING RETAINED EPISODE */
  else do;
    /* For all subsequent admissions that do not count as a
start of an episode, take the max of necessary casemix
covariates. */
    do i=1 to dim(eps);
      eps[i] = max(eps[i], recs[i]);
    end;
    /* In the case where current admission has an end date
later than the retained episode end date,
    extend episode end date to current admission's end date,
use discharge date/ins_end of the admission with latest service
end date.*/
    if end_service_dt>=epddat then do;
      epddat = end_service_dt;
      epdisp = disp_status;
      if not missing(ins_end) then epins_end=ins_end;
    end;
  end;
run;

proc sort data=step5_2; by PatientID HospitalID epcnt;
data step5_2 (drop=i epadat epddat epdisp epcnt epCCI1-epCCI10
epCCI12-epCCI18 epplanned epchemo epMH epObstetric epnewborn
epins_end ephasprimary eplri);
  set step5_2; by PatientID HospitalID epcnt;
  if last.epcnt;
  array olds [*] admit_dt end_service_dt disp_status CCI1-CCI10
CCI12-CCI18 planned chemo MH Obstetric newborn ins_end
hasprimary lri;
  array news [*] epadat epddat epdisp epCCI1-epCCI10 epCCI12-
epCCI18 epplanned epchemo epMH epObstetric epnewborn epins_end
ephasprimary eplri;
  do i=1 to dim(olds);
    olds[i]=news[i];
  end;
run;

/*STEP 5*/

```

```

/*3. IDENTIFY AND COMBINE MULTIPLE VALID RECORDS FROM MULTIPLE
HOSPITALS FOR HOSPITALIZATIONS THAT INCLUDED TRANSFERS */
/*• Sort records by the following variables, in the specified
order: patient ID, admission date, end-of-service date,
disposition status.*/
/*• Define records to be in the same episode of care if patient
ID is equal to patient ID in the previous record, the previous
record's disposition status is a transfer, and the admission
date is equal to or is one day after the previous record's end-
of-service date.*/

proc sort data=step5_2 out=step5_3;
by PatientID admit_dt end_service_dt disp_status; /*do not sort
by HospitalID because we do NOT want the same hospitals next to
each other*/
data step5_3; set step5_3; by PatientID admit_dt end_service_dt
disp_status;
    array eps [*] epCCI1-epCCI10 epCCI12-epCCI18 epplanned epchemo
epMH epObstetric epnewborn ephasprimary eplri;
    array recs [*] CCI1-CCI10 CCI12-CCI18 planned chemo MH
Obstetric newborn hasprimary lri;
    retain epcnt epadat epddat epdisp epins_end epCCI1-epCCI10
epCCI12-epCCI18 epplanned epchemo epMH epObstetric epnewborn
ephasprimary eplri;

    if first.PatientID then epcnt=0;

    /* STARTING NEW EPISODE: first record of patient at hospital
or NOT a transfer */
    if first.PatientID
        OR not (admit_dt-epddat in (0,1) AND epdisp IN (0,2)) then
do;
    epcnt+ 1;
    epadat=admit_dt;
    epdisp=disp_status;
    epins_end=ins_end;
    epddat=end_service_dt;
    do i=1 to dim(eps);
        eps[i]=recs[i];
    end;
end;
    /* CONTINUING RETAINED EPISODE */
    else do;
        /* For all subsequent admissions that do not count as a
start of an episode, take the max of necessary casemix
covariates. */
        do i=1 to dim(eps);

```

```

    eps[i] = max( eps[i], recs[i]);
    end;
    /* In the case where current admission has an end date
    later than the retained episode end date, extend episode end
    date to current
    admission's end date, use discharge date/ins_end of the
    admission with the latest service end date*/
    if end_service_dt >= epddat then do;
        epddat = end_service_dt;
        epdisp = disp_status;
        if not missing(ins_end) then epins_end=ins_end;
    end;
end;
run;

proc sort data=step5_3; by PatientID epcnt;
data step5_3 (drop=epadat epddat epdisp epcnt epCCI1-epCCI10
epCCI12-epCCI18 epplanned epchemo epMH epObstetric epnewborn
epins_end ephasprimary eplri);
set step5_3;
by PatientID epcnt; /*Use the value for HospitalID
hosp_noindex*/
if last.epcnt;
array olds [*] admit_dt end_service_dt disp_status CCI1-CCI10
CCI12-CCI18 planned chemo MH Obstetric newborn ins_end
hasprimary lri;
array news [*] epadat epddat epdisp epCCI1-epCCI10 epCCI12-
epCCI18 epplanned epchemo epMH epObstetric epnewborn epins_end
ephasprimary eplri;
do i=1 to dim(olds);
    olds[i]=news[i];
end;
run;

/*STEP 5*/
/*4. IDENTIFY AND EXCLUDE INVALID EPISODES OF CARE*/
/*There may be episodes of care that are temporally overlapping,
i.e., it appears that a patient is in two different hospitals at
the same time. These episodes should be dropped.*/
/*• Drop all episodes of care that share the same patient ID,
admission date, and end-of-service date but have different
hospital IDs.*/
/*• For each patient ID, drop all temporally adjacent episodes
of care if there are overlapping dates
(i.e., admission date is before the end-of-service date for the
preceding episode of care) but different hospital IDs.*/

```

```

proc sort data= step5_3 out=step5_4;
by PatientID admit_dt end_service_dt;
run;

data step5_4; set step5_4; by PatientID admit_dt end_service_dt;
  retain epcnt epddat;

  if first.PatientID then epcnt=0;

  /* STARTING NEW EPISODE: first record of patient at hospital
or NOT a transfer */
  if first.PatientID
    /*Even if a new episode is on the same day as the previous,
consider it a potential readmission since we have already taken
care of the transfers in the previous steps*/
    OR ( admit_dt >= epddat) then do;
    epcnt+ 1;
    epddat=end_service_dt;
  end;
run;

proc sort data=step5_4; by PatientID epcnt;
data step5_4 (drop=epddat);
  set step5_4;
  by PatientID epcnt;
  if first.epcnt=1 and last.epcnt=1; /*When there are
overlapping EOCs, epcnt will be repeated*/
run;

/*STEP 6: SPECIFY VARIABLES DEFINED AT THE EPISODE OF CARE
LEVEL*/
/*a) CCI_count*/
/*ordinal variable that consists of the total number of body
systems affected by a chronic condition constructed using the
AHRQ CCI tool and top-coded at 4 or more body systems*/
/*1 = 0 or 1 body systems*/
/*2 = 2 body systems*/
/*3 = 3 body systems*/
/*4 = 4+ body systems*/

/*b) create DOB18*/

/*c) ageyrs_disch continuous variable containing age in years at
discharge*/

/*d) agegroup*/

```

```
/*ordinal variable that consists age in years at discharge with
5 groupings of age*/
/*1= 0<=age <1*/
/*2= 1<=age<5*/
/*3= 5<=age<8*/
/*4= 8<=age<12*/
/*5= 12<=age<18*/
```

```
/*6.a)*/
```

```
data step6; set step5_4;
```

```
CCI_count=.;
```

```
if (sum(of CCI1-CCI10)+ sum(of CCI12-CCI18)) in (0,1) then
```

```
CCI_count=1;
```

```
else if (sum(of CCI1-CCI10)+ sum(of CCI12-CCI18)) =2 then
```

```
CCI_count=2;
```

```
else if (sum(of CCI1-CCI10)+ sum(of CCI12-CCI18)) =3 then
```

```
CCI_count=3;
```

```
else if 4<=(sum(of CCI1-CCI10)+ sum(of CCI12-CCI18))<=18 then
```

```
CCI_count=4;
```

```
label CCI_count="Number of CCI's 1= 0 or 1 CCI; 2= 2 CCI's; 3=3
CCI's; 4= 4 or More CCI's";
```

```
/*6.b)*/
```

```
if month(dob)=2 and day(dob)=29 then dob18=mdy(3, 1,
```

```
year(dob)+18);
```

```
else dob18=mdy(month(dob), day(dob), year(dob)+18);
```

```
/*6.c)*/
```

```
ageyrs_disch= floor ((intck('month',dob,end_service_dt) -
(day(end_service_dt) < day(dob))) / 12);
```

```
/*6.d)*/
```

```
agegroup=.;
```

```
if 0<=ageyrs_disch <1 then agegroup=1;
```

```
else if 1<=ageyrs_disch<5 then agegroup=2;
```

```
else if 5<=ageyrs_disch<8 then agegroup=3;
```

```
else if 8<=ageyrs_disch<12 then agegroup=4;
```

```
else if 12<=ageyrs_disch<18 then agegroup=5;
```

```
label agegroup="Age group (Age at Discharge) 1= age <1; 2= age
1-4; 3= age 5-7; 4= age 8-11; 5= age 12 and older";
```

```
run;
```

```
/*STEP 7: DEFINE EPISODES OF CARE ELIGIBLE FOR INCLUSION IN
COHORT*/
```

```

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON DATA
COMPLETENESS OR DATA QUALITY CRITERIA:*/
/*1) Episodes of care with admission dates that occur after a
discharge of death during a prior hospitalization*/

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON CLINICAL
CRITERIA:*/
/*1) Drop episodes of care for patients aged >18 years, 29 days
old AT THE TIME OF ADMISSION.*/

/*3) Drop episodes of care with a primary non-delivery
Obstetrics diagnosis or any delivery diagnosis or procedure
(i.e., Obstetric = 1).*/
/*4) Drop episodes of care with a primary mental health
diagnosis (i.e., MH = 1.)*/

proc sort data=step6; by PatientID;
data ptdrop (keep=PatientID dx_miss); set step6; by PatientID;
    retain dx_miss;
    if first.patientid then do;
dx_miss= 0;
    end;

    if hasprimary=0 then dx_miss=1;

    if last.patientid;
    label dx_miss="Primary DX missing for any episode";

proc sort data=ptdrop; by PatientID;
proc sort data=step6; by PatientID;
data step7a (drop=dx_miss); merge step6 ptdrop; by PatientID;
    if dx_miss=0;
run;

proc sort data=step7a; by PatientID admit_dt end_service_dt
disp_status;
data step7 (where=(data_quality_bad=0 and clinical_exc=0)
drop=death sum_died); set step7a;
    by PatientID admit_dt end_service_dt disp_status;
    death= 0;
    if disp_status=4 then death=1;
    retain sum_died;
    if first.PatientID then do;
    sum_died= 0;
    end;

```



```

sum_died=sum_died+death;
label sum_died="Number of records with death within the same
PatientID";

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON DATA
COMPLETENESS OR DATA QUALITY CRITERIA:*/
data_quality_bad= 0;
if /*1)*/(sum_died>death) then data_quality_bad=1;
label data_quality_bad="EXCLUSIONS AT THE EPISODE OF CARE
LEVEL BASED ON DATA COMPLETENESS OR DATA QUALITY CRITERIA";

/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL BASED ON CLINICAL
CRITERIA:*/
clinical_exc= 0;
if admit_dt>(dob18+29) or newborn=1 or Obstetric=1 or MH=1
then clinical_exc=1;
label clinical_exc="EXCLUSIONS AT THE EPISODE OF CARE LEVEL
BASED ON CLINICAL CRITERIA";
run;

/*STEP 8:  DEFINE INDEX ADMISSIONS AND READMISSIONS*/

*****Index
Admissions*****
/*EXCLUSIONS AT THE EPISODE OF CARE LEVEL FOR DEFINING INDEX
ADMISSIONS:*/
/*• Episodes of care for patients aged 18 years, 0 days or older
at the time of discharge*/
/*• Episodes of care with a discharge disposition of death*/
/*• Episodes of care with a discharge disposition of leaving the
hospital against medical advice*/
/*• Episodes of care for which a full 30 days of follow-up are
unavailable, either
(a) because the dataset's available time range for claims does
not include the full 30 days, or
(b) because, for single-payer analyses, the patient was not
enrolled for the full 30 days
(i.e., the difference between ins_end and end_service_dt is less
than 30 days)*/

/*EXCLUSIONS AT THE HOSPITAL LEVEL FOR DEFINING INDEX
ADMISSIONS:*/
/*• Hospitals with <80% of records with complete unique patient
identifier, admission date, and end-of-service date*/
/*• Hospitals with <80% of records with complete primary
diagnosis code*/
/*• Out-of-state hospitals*/

```

```

*****Readmissions*****
*****
/*EXCLUSIONS FOR DEFINING READMISSIONS AT THE EPISODE OF CARE
LEVEL:*/
/*• Episodes of care with a primary ICD-9-CM procedure code for
a planned procedure (i.e., planned = 1)*/
/*• Episodes of care with a primary ICD-9-CM diagnosis or
procedure code for chemotherapy (i.e., chemo = 1)*/
;

proc sort data=step7 out=step8; by PatientID admit_dt
end_service_dt;
run;

data step8;
set step8;
by patientID admit_dt end_service_dt;

range=(mdy(&BEGINMONTH,&BEGINDAY,&BEGINYEAR)<=end_service_dt<=md
y(&ENDMONTH,&ENDDAY,&ENDYEAR));

index_exclusion=1;
if ageyrs_disch<18 and disp_status in (1,2,0) and range=1 and
hosp_noindex=0 and ins_end-end_service_dt>=30 and lri=1 then
index_exclusion=0;

retain eoc_end_date;
if (first.PatientID and index_exclusion=0) or
(admit_dt>eoc_end_date and index_exclusion=0)
then eoc_end_date=end_service_dt+30;
else if (first.PatientID and index_exclusion=1) or
(admit_dt>eoc_end_date and index_exclusion)=1
then eoc_end_date=.;

run;

data step8(drop=lag_eoc_end_date);
set step8(where=(eoc_end_Date ne .)); /*I am deleting the
records that can't be index admission but also can't be
readmission*/
by patientID admit_dt end_service_dt;

retain eoc;
lag_eoc_end_date=lag(eoc_end_date);

```

```

if first.patientID then eoc=1;
else if lag_eoc_end_date ne eoc_end_date then eoc=eoc+1;

readmission_exclusion=(chemo=1 or planned=1);
run;

proc sort data=step8; by patientID eoc;
run;

data step8;
  _N_ ++ 1;
  IF _N_ <= N THEN DO;
    Set step8 POINT=_N_;
    lead_PatientID=PatientID;
    lead_eoc=eoc;
    lead_readmission_exclusion= readmission_exclusion;
    lead_hospitalID=hospitalID;
  END;
  ELSE do;
    lead_PatientID= .;
    lead_eoc= .;
    lead_readmission_exclusion= .;
    lead_hospitalID= .;
  end;
  Set step8 nobs = n;
run;

proc sort data=step8; by patientID eoc;
run;
data step8;
set step8;

by PatientID eoc;

readmission=0;
if first.eoc and patientID=lead_PatientID and eoc=lead_eoc and
lead_readmission_exclusion =0 then readmission=1;

index=0;
if first.eoc=1 then index=1;
run;

*PUT FINAL BACK IN AFTER TESTING;
data final.&finaldata(keep=PatientID index readmission
HospitalID admit_dt end_service_dt DOB CCI1-CCI10 CCI12-CCI18
planned chemo MH Obstetric newborn disp_status agegroup
CCI_count ins_end ageyrs_disch male LRI

```

```

where=(index=1));
set step8;
label PatientID="unique patient ID"
HospitalID= "unique hospital ID"
admit_dt= "admission date"
end_service_dt= "service end date"
dob= "Date of Birth"
planned= "dichotomous variable indicating presence of planned
procedure 0= not present 1= present"
chemo= "dichotomous variable indicating presence of
chemotherapy ICD-9-CM code 0= not present 1= present"
MH= "dichotomous variable indicating mental health primary
diagnosis 0= not present 1= present"
Obstetric= "dichotomous variable indicating Obstetric primary
diagnosis 0= not present 1= present"
newborn= "dichotomous variable indicating birth of healthy
newborn 0= not present 1= present"
disp_status = "dichotomous variable identifying disposition
status 0=other 1=discharge 2=transfer to an acute-care hospital
3=left against medical advice 4=died"
male = "variable indicating patient sex 0=female 1=male
.=missing"
CCI1= "Infectious and parasitic disease"
CCI2= "Neoplasms"
CCI3= "Endocrine, nutritional, and metabolic diseases and
immunity disorders"
CCI4= "Diseases of blood and blood-forming organs"
CCI5= "Mental disorders"
CCI6= "Diseases of the nervous system and sense organs"
CCI7= "Diseases of the circulatory system"
CCI8= "Diseases of the respiratory system"
CCI9= "Diseases of the digestive system"
CCI10= "Diseases of the genitourinary system"
CCI12= "Diseases of the skin and subcutaneous tissue"
CCI13= "Diseases of the musculoskeletal system"
CCI14= "Congenital anomalies"
CCI15= "Certain conditions originating in the perinatal period"
CCI16= "Symptoms, signs, and ill-defined conditions"
CCI17= "Injury and poisoning"
CCI18= "Factors influencing health status and contact with
health services"
Index= "Index Admission"
Readmission= "30day Readmission"
ageyrs_disch= "Age at Discharge in years"
LRI= "Lower Respiratory Infection";
run;

```

```
*****
*****
*****;
```

```
* PROGRAM FOR RUNNING A LOWER RESPIRATORY INFECTION MODEL AND
CALCULATING ADJUSTED HOSPITAL READMISSION RATES.
* 'LowerRespiratoryInfection PediatricReadmission Model.sas'
```

Programmers: Jisun Jang, David Klein, and Jeremy Feng

The Center of Excellence for Pediatric
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Boston Children's Hospital
Division of General Pediatrics

Date: October 24, 2013

How to run this program::

1) Insert a path where the final output dataset will be saved.

2) Insert a path where the SAS output documents, including Cross Tabulation of Casemix Variables and Readmission (LowerRespiratoryInfection_Crosstabs.rtf), PROC GLIMMIX output (LowerRespiratoryInfection_ModelOutput.rtf), and Adjusted Hospital-Level Readmission Rates (LowerRespiratoryInfection_Adjusted_Hospital_Rates.rtf) will be saved.

3) Insert a path where LowerRespiratoryInfection_Zerocell.sas is saved.

4) Insert the Final Index dataset name (DATASET created through the DATA PREP program)

```
*****
*****
*****;
```

```
options compress=yes;
```

```
/*1*/ %let FINALPATH=c:\location;
/*2*/ %let OUTPUT=c:\another location;
/*3*/ %let ZEROCELL=c:\another location;
/*4*/ %let FINALDATA=finaldata;
```

```
libname final "&finalpath";
libname output "&output";
```

```

/* Wipe previous WORK files */
proc datasets lib=work kill nolist memtype=data;
quit;
/* End wipe */

/* FYI: In SAS, one can create 'value formats' that gives
'labels' to variables. It doesn't change the variable in the
dataset, but when they are specified in a SAS procedure, eg
GLIMMIX, SAS will display the labels instead of the numerical
values. The underscores are there to defined reference groups -
- unfortunately SAS didn't fully implement the ability to define
a specific reference, but choses the 'label' that's sorted last
alphabetically (and underscores are sorted after letters). */
proc format;
    value cci_countf
        1 = '_0 or 1 body systems'
        2 = '_2 body systems'
        3 = '3 body systems'
        4 = '4+ body systems';
    value agegroupf
        1 = '_0 year'
        2 = '1-4 years'
        3 = '5-7 years'
        4 = '8-11 years'
        5 = '12-17 years';
    value malef
        0 = '_Female'
        1 = 'Male';
run;

%include "&ZEROCELL\LowerRespiratoryInfection_Zerocell.sas";
/*You will get a temporary SAS dataset called INDEX after
running LowerRespiratoryInfection_Zerocell.sas*/

ods rtf file="&output./LowerRespiratoryInfection_Crosstabs.rtf";

TITLE;
TITLE1 "CaseMix variable that has a 0 cell";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC(DATE()), NLDATE20.) at
%TRIM(%SYSFUNC(TIME()), TIMEAMPM12.)";

proc print data=zerocell noobs label;
where zerocell ne "madeup_var";

```

```

run;

TITLE;
TITLE1 "Cross Tabulation of Casemix Variables and Readmission
among Lower Respiratory Infection Index Admissions";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC (DATE()), NLDATE20.) at
%TRIM(%SYSFUNC (TIME()), TIMEAMPM12.)";
proc freq data=index;
    tables readmission*agegroup;
    tables readmission*cci_count;
    tables readmission*cci1;
    tables readmission*cci2;
    tables readmission*cci3;
    tables readmission*cci4;
    tables readmission*cci5;
    tables readmission*cci6;
    tables readmission*cci7;
    tables readmission*cci8;
    tables readmission*cci9;
    tables readmission*cci10;
    tables readmission*cci12;
    tables readmission*cci13;
    tables readmission*cci14;
    tables readmission*cci15;
    tables readmission*cci16;
    tables readmission*cci17;
    tables readmission*cci18;
    format    cci_count cci_countf. agegroup agegroupf.;
run;
ods rtf close;

/* Making mock dataset as before with (number of hospitals + 1)
copies of our index observations. */

/* Change index0 to the single INDEX dataset from the single
program.
The file needs the variables: hospitalid, readmission, male,
agegroup, cci1-cci10 cci12-cci18, cci_count */
data index1;
    set index (keep=hospitalid readmission male agegroup cci1-
cci10 cci12-cci18 cci_count);
    fake=0;
run;

proc sql;

```

```

        CREATE TABLE hosplist AS
            SELECT DISTINCT hospitalid, 1 AS fake, . AS
readmission
                FROM index1
                    ORDER BY hospitalid;
        CREATE TABLE index2 AS
            SELECT *
                FROM hosplist t1
                    CROSS JOIN index1(drop=hospitalid
readmission fake) t2;
quit;

proc append base=index2 data=index1;
run;

proc sort data=index2;
    by hospitalid;
run;

/*This is to create a RTF document that has model fitting
information. RTF files can be opened in MS WORD*/
ods rtf
file="&output./LowerRespiratoryInfection_ModelOutput.rtf";
TITLE;
TITLE1 "Casemix Adjustment Lower Respiratory Infection Model";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC(DATE()), NLDATE20.) at
%TRIM(%SYSFUNC(TIME()), TIMEAMPM12.)";

proc glimmix data=index2 method=quad;
    class hospitalid agegroup male cci_count;
    model readmission = agegroup male cci_count cci1-cci10
cci12-cci18 / dist=binomial solution;
    random intercept / subject=hospitalid solution;
    nloptions technique=NRRIDG;
    id _XBETA_ _ZGAMMA_ _VARIANCE_ hospitalid readmission fake;

    output out=hosp1b (keep=p1 l1 u1 p0 l0 u0 hospitalid
readmission fake _XBETA_ _ZGAMMA_ _VARIANCE_)
        pred(    blup ilink)=p1 lcl(blup ilink)=l1 ucl(blup
ilink)=u1
            pred(noblup ilink)=p0 lcl(noblup ilink)=l0 ucl(noblup
ilink)=u0;
    ods output CovParms=cov;

    format    cci_count cci_countf. agegroup agegroupf. male
malef.;

```



```

run;

quit;

ods rtf close;

/* Get hospital level means */
PROC MEANS DATA=hosp1b(where=(fake=1)) NOPRINT MEAN NONOBS;
    VAR p1 l1 u1;
    BY hospitalid;
    OUTPUT    out=hosp_fake  MEAN()=    SUM()= /autoname;
RUN;

PROC MEANS DATA=hosp1b(where=(fake=0)) NOPRINT MEAN;
    VAR readmission p1;
    BY hospitalid;
    OUTPUT    out=hosp_real  (rename=(_FREQ_=n_index)) MEAN()=
    SUM()= /autoname;
RUN;

PROC SQL;
    CREATE TABLE hosp_ac_direct AS
        SELECT t1.hospitalid LABEL='Hospital ID',

                (sum(t2.readmission_Sum)/sum(t2.p1_Sum)) AS
smearing_factor, /* Bias correction factor -- analogous to
Duan's smearing estimate (see Duan N, JASA, 1983) */
                (t1.p1_Mean*(CALCULATED smearing_factor))
LABEL='Adjusted rate' AS adj_rate,
                (t1.l1_Mean*(CALCULATED smearing_factor))
LABEL='Adjusted 95% CI upper limit' AS adj_lower,
                (t1.u1_Mean*(CALCULATED smearing_factor))
LABEL='Adjusted 95% CI lower limit' AS adj_upper,
                t2.readmission_Mean LABEL='Unadjusted rate' AS
unadj_rate,
                t2.n_index LABEL='Number of index admissions' AS
admissions,
                t2.readmission_Sum LABEL='Number of index
admissions followed by an eligible readmission' AS readmissions,
                sum(t2.readmission_Sum)/sum(t2.n_index) AS
unadj_overall
        FROM HOSP_FAKE t1
        INNER JOIN HOSP_REAL t2 ON (t1.hospitalid =
t2.hospitalid);
QUIT;

```

```

DATA LowerRespiratoryInfection_rates;
set hosp_ac_direct (keep = hospitalid adj_rate adj_lower
adj_upper unadj_rate admissions readmissions);
run;

/*This is to create a RTF document that has overall readmission
rates. RTF files can be opened in MS WORD*/
ods rtf
file="&output./LowerRespiratoryInfection_Adjusted_Hospital_Rates
.rtf";

/* Make hospital rate report */
TITLE;
TITLE1 "Casemix-Adjusted Hospital-Level Readmission Rates (Lower
Respiratory Infection Model)";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC (DATE()), NLDATE20.) at
%TRIM(%SYSFUNC (TIME()), TIMEAMPM12.)";

PROC PRINT DATA=LowerRespiratoryInfection_rates NOOBS LABEL;
VAR adj_rate adj_lower adj_upper unadj_rate admissions
readmissions;
ID hospitalid;
FORMAT adj_rate adj_lower adj_upper unadj_rate
PERCENTN7.5;
RUN;

ods rtf close;

```

```
*****
*****
*****;
* PROGRAM FOR DROPPING INDEX ADMISSIONS IF ALL INDEX ADMISSIONS
OF A GIVEN LEVEL CASE-MIX VARIABLE (e.g., AGEGROUP = 2) HAVE THE
SAME OUTCOME
  (READMISSION=1, OR READMISSION=0).
```

```
* 'LowerRespiratoryInfection_ZeroCell.sas'
```

```
Programmers:      Jisun Jang
```

```
                  The Center of Excellence for Pediatric
Quality Measurement
                  Boston Children's Hospital
                  Division of General Pediatrics
```

```
Date:            October 24, 2013
```

```
*****
*****
*****;
```

```
%SYMDEL v1      v2      v3      v4      v5      v6      v7      v8      v9      v10     v11
          v12     v13     v14     v15     v16     v17     v18     v19     v20
var1      var2     var3     var4     var5     var6     var7     var8     var9     var10
          var11     var12     var13     var14     var15     var16
          var17     var18     var19     var20
level1    level2    level3    level4    level5    level6
          level7    level8    level9    level10   level11   level12
          level13   level14   level15   level16   level17   level18
          level19   level20
varnum;
```

```
/*Even if you get warning messages in SAS log (i.e.,WARNING:
Attempt to delete macro variable VAR4 failed. Variable not
found.), you can ignore them*/
```

```
proc contents data=FINAL.&finaldata out=contents noprint;
run;
```

```
data contents (keep=name);
set contents;
name_upcase=upcase(name);
if name_upcase in: ("CCI", "AGEGROUP", "MALE");
run;
```

```

data _null_;
set contents;
suffix=put(_n_, 5.);
call symput(cats('v',suffix), name);
run;

%macro zerocell1;
%do i=1 %to 20;

proc freq data=FINAL.&finaldata;
tables &&v&i*readmission/sparse out=data&i;
run;

data data&i;
set data&i;
length zerocell $20;
zerocell=" ";
if COUNT=0 then do;
    zerocell="&&v&i";
    level=&&v&i;
end;
id=&i;
run;

%end;
%mend;
%zerocell1;

data data0;
length zerocell $20;
zerocell="madeup_var";
level=0;
obs=0;

data zerocell(keep=zerocell level obs);
set data0 data1-data20;
where zerocell ne " ";
obs=_n_;
label zerocell = "CaseMix variable that has a 0 cell";
run;

data _null_;
set zerocell;
suffix=put(_n_, 5.);
call symput(cats('var',suffix), zerocell);
call symput(cats('level',suffix), level);

```

```
data _null_;  
set zerocell;  
call symput('varnum',obs); /*This only outputs the last  
observation number as the macro variable*/  
run;  
  
%macro zerocell2;  
DATA index;  
set FINAL.&finaldata;  
%do q = 1 %to &varnum;  
if &&var&q=&&level&q then delete;  
%END;  
%mend;%zerocell2;  
run;  
  
/*Even if you get a SAS log note saying NOTE: Variable  
madeup_var is uninitialized, you can ignore it.*/
```

```
*****
*****
*****;
```

```
* PROGRAM FOR NATIONALLY COMPARABLE RATES FOR A STATE (Lower
Respiratory Infection)
```

```
* 'LowerRespiratoryInfection_PediatricReadmission_Nationally
comparable rates.sas'
```

Programmers: Jeremy Feng, and Jisun Jang

 The Center of Excellence for Pediatric Quality
Measurement
 Boston Children's Hospital
 Division of General Pediatrics

Date: October 24, 2013

How to run this program::

1) Insert a path where the Final Index dataset (DATASET created through the DATA PREP program) is saved and the final output dataset will be saved.

2) Insert a path where max_lri_global_model_linux.sas7bitm, max_lri_global_model_win.sas7bitm, max_lri_sample.sas7bdat, and max_lri_cov.sas7bdat are saved.

max_lri_global_model_linux.sas7bitm is for linux users and max_lri_global_model_win.sas7bitm is for 64-bit Windows users (It will not work on 32-bit Windows).

3) Insert a path where you would like to save LowerRespiratoryInfection_Nationally comparable rates.rtf. LowerRespiratoryInfection_Nationally comparable rates.rtf

will include both Nationally Comparable Adjusted State-Level and Hospital-Level Readmission Rates.

4) Insert a path where LowerRespiratoryInfection_Zerocell.sas is saved.

5) Insert the Final Index dataset name (DATASET created through the DATA PREP program)

6) Insert the name of the global model file

max_lri_global_model_win.sas7bitm) depending on the operating system you use.

Default is max_lri_global_model_win.sas7bitm.

```
*****
*****
*****;
```

```
options compress=yes;
```

```
/*1*/ %let FINALPATH=c:\location;
```

```

/*2*/ %let INPUT=c:\location;
/*3*/ %let OUTPUT=c:\location;
/*4*/ %let ZEROCELL=c:\location;
/*5*/ %let FINALDATA=finaldata;
/*6*/ %let GLOBAL=max_lri_global_model_win;

libname final "&finalpath";
libname max "&INPUT";

/* Wipe previous WORK files */
proc datasets lib=work kill nolist memtype=data;
quit;
/* End wipe */

/* FYI: In SAS, one can create 'value formats' that gives 'labels' to
variables. It doesn't change the variable in the dataset, but when
they are specified in a SAS procedure, eg GLIMMIX, SAS will display
the labels instead of the numerical values. The underscores are there
to defined reference groups -- unfortunately SAS didn't fully
implement the ability to define a specific reference, but choses the
'label' that's sorted last alphabetically (and underscores are sorted
after letters). */
proc format;
  value cci_countf
    1 = '_0 or 1 body systems'
    2 = '2 body systems'
    3 = '3 body systems'
    4 = '4+ body systems';
  value agegroupf
    1 = '_0 year'
    2 = '1-4 years'
    3 = '5-7 years'
    4 = '8-11 years'
    5 = '12-17 years';
  value malef
    0 = '_Female'
    1 = 'Male';
run;

%include "&ZEROCELL\LowerRespiratoryInfection_Zerocell.sas";
/*You will get a temporary SAS dataset called INDEX after running
LowerRespiratoryInfection_Zerocell.sas. this program will use the
dataset final.&finaldata and creates output dataset work.INDEX*/

data newdata; set index(rename=(readmission=readmission_enr));

proc sort data=newdata; by state_num hospitalid; run;

/* Get fixed effect predictors using coefficients from the provided
GLOBAL MODEL */

```

```

/* IMPORTANT: model file source=max_lri_global_model_linux should be
used in Linux architectures and source=max_lri_global_model_win should
be used in Windows systems. */
proc plm source=max.&global;
  SCORE data=newdata out=newdata_scored predicted=XB_global;
run;

/* BEGIN RATE CALCULATION */
/* Direct standardization by recycled predictions */

data index1;
  set newdata_scored (keep=state_num hospitalid readmission_enr
XB_global);
  fake= 0;
run;

proc sql;
  CREATE TABLE hosplist AS
  SELECT DISTINCT state_num, hospitalid, 1 AS fake, . AS
readmission_enr
  FROM index1
  ORDER BY state_num, hospitalid;
quit;

proc sql;
  CREATE TABLE index2 AS
  SELECT *
  FROM hosplist t1
  CROSS JOIN max.max_lri_sample t2;
quit;

proc append base=index2 data=index1 nowarn;
run;

proc sort data=index2;
  by hospitalid;

TITLE;
TITLE1 "Random effect estimation for hospitals in the analyzed state
(Lower Respiratory Infection)";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC(DATE()), NLDATE20.) at
%TRIM(%SYSFUNC(TIME()), TIMEAMPM12.)";

proc glimmix data=index2 method=laplace;
  class hospitalid;
  model readmission_enr = / noint dist=binomial link=logit
offset=XB_global solution;
  random intercept / subject=hospitalid solution;
  parms / noiter pdata=max.max_lri_cov;
  nloptions tech=none;

```



```

    id _XBETA_ _ZGAMMA_ _VARIANCE_ state_num hospitalid readmission_enr
fake;

    output out=hosp1b (keep=p1 l1 u1 state_num hospitalid

        pred(      blup ilink)=p1 lcl(blup ilink)=l1 ucl(blup ilink)=u1;
run;
quit;

/* Get hospital-level means */
PROC MEANS DATA=hosp1b(where=(fake=1)) NOPRINT MEAN NONOBS;
    VAR p1 l1 u1;
    BY state_num hospitalid;
    OUTPUT out=hosp_fake MEAN()= SUM()= /autoname;
RUN;

PROC MEANS DATA=hosp1b(where=(fake=0)) NOPRINT MEAN;
    VAR readmission_enr p1;
    BY state_num hospitalid;
    OUTPUT out=hosp_real (rename=( _FREQ_ =n_index)) MEAN()= SUM()=
/autoname;
RUN;

PROC SQL;
    CREATE TABLE hosp_lri_direct AS
        SELECT
            t1.state_num LABEL=    'State ID',
            t1.hospitalid LABEL=   'Hospital ID',

            (sum(t2.readmission_enr_Sum)/sum(t2.p1_Sum))      AS smearing_factor,
/* Bias correction factor -- analogous to Duan's smearing estimate
(see Duan N, JASA, 1983) */
            (t1.p1_Mean*(CALCULATED smearing_factor)) LABEL=   'Adjusted rate'
AS adj_rate,
            (t1.l1_Mean*(CALCULATED smearing_factor)) LABEL=   'Adjusted 95% CI
upper limit' AS adj_lower,
            (t1.u1_Mean*(CALCULATED smearing_factor)) LABEL='Adjusted 95% CI
lower limit' AS adj_upper,
            t2.readmission_enr_Mean LABEL=    'Unadjusted rate' AS unadj_rate,
            t2.n_index LABEL=    'Number of index admissions' AS admissions,
            t2.readmission_enr_Sum LABEL=    'Number of readmissions' AS
readmissions,
            sum(t2.readmission_enr_Sum)/sum(t2.n_index)      AS unadj_overall
        FROM HOSP_FAKE t1
            INNER JOIN HOSP_REAL t2 ON (t1.state_num = t2.state_num AND
t1.hospitalid = t2.hospitalid);
QUIT;

/* BEGIN ADJUSTED STATE-LEVEL RATE CALCULATION */
/* COUNT volume of each hospital. */
PROC MEANS DATA=newdata NOPRINT MEAN;

```

```

VAR readmission_enr;
BY state_num hospitalid;
OUTPUT out=newdata_specs (rename=(_FREQ_=n_index)) MEAN()= SUM()=
/autoname;
RUN;

```

```

data max_cov_hosponly;
set max.max_lri_cov;
Subject = 'hospitalid';
run;

```

```

* NOTE: THIS CODE WILL ONLY WORK FOR AN ANALYSIS OF HOSPITALS IN ONE
STATE.

```

```

* START OF STATE RATE SAMPLER;
%let iternum = 1000; /* Set the number of iterations -- DEFAULT:
1000 */

```

```

%macro state_rate_sampler;

```

```

%do iter = 1 %to &iternum;

```

```

proc glimmix data=index1 method=laplace;
class hospitalid;
model readmission_enr = / noint dist=binomial link=logit
offset=XB_global solution;
random intercept / subject=hospitalid solution;
parms / noiter pdata=max_cov_hosponly;
nloptions tech=none;

```

```

ods output SolutionR=hosp_raneff;

```

```

run;
quit;

```

```

proc sql;
CREATE TABLE hosp_draws AS
SELECT      substr(t1.Subject, 12) AS hospitalid,
            logistic(rand('NORMAL', t1.Estimate, t1.StdErrPred) +
t2.XB_global) AS hosp_prob
FROM hosp_raneff t1
CROSS JOIN max.max_lri_sample t2;
quit;

```

```

proc sql;
CREATE TABLE hosp_draws2 AS
SELECT      t1.hospitalid,
            t2.n_index
FROM hosp_draws t1
LEFT JOIN newdata_specs t2

```

```

                                ON (left(t1.hospitalid) = left(t2.hospitalid));
quit;

PROC MEANS DATA=hosp_draws2 NOPRINT MEAN;
  VAR hosp_prob;
  WEIGHT n_index;
  OUTPUT out=state_rate_collect(drop=_TYPE_ _FREQ_) MEAN()= /autoname;
RUN;

%if &iter = 1 %then %do;
  data state_rate_draws; set state_rate_collect; run;
%end;
%else %do;
  proc append base=state_rate_draws data=state_rate_collect; run;
%end;

%end;
%mend;

options nonotes; /* Notes from the sampler iterations might fill the
SAS log buffer, so it is turned off here. Errors will still be
printed.*/
%state_rate_sampler;
options notes; /* Notes are turned back on, after the sampler macro
runs. */

/* Calculate state-level means */
proc means data=state_rate_draws
  noprint
  chartype
  vardef=df
          mean
          std nonobs;
output   out=state_rate_adj

          std()=
          / autoname autolabel inherit
          ;
run;

PROC SQL;
  CREATE TABLE state_rate_unadj AS
  SELECT DISTINCT
    sum(t1.admissions)      AS admissions,
    sum(t1.readmissions)    AS readmissions,
    (CALCULATED readmissions)/(CALCULATED admissions)      AS unadj_rate
  FROM hosp_lri_direct t1;
QUIT;

data state_rate; merge state_rate_adj(keep=hosp_prob_mean_mean
hosp_prob_Mean_StdDev

```

```

        rename=(hosp_prob_mean_mean=adj_rate
                hosp_prob_Mean_StdDev=adj_stderr))
                state_rate_unadj(    keep=unadj_rate
admissions readmissions);
adj_lcl = adj_rate - 1.96*adj_stderr;
adj_ucl = adj_rate + 1.96*adj_stderr;

label      adj_rate='Adjusted readmission rate'

           adj_ucl='Adjusted 95% CI upper limit'
           unadj_rate='Unadjusted readmission rate'
           adj_stderr='Standard error of adjusted readmission rate'
           admissions='Number of index admissions'
           readmissions='Number of readmissions';

run;

/* BEGIN GENERATION OF REPORTS */
ods rtf file="&OUTPUT\LowerRespiratoryInfection_Nationally comparable
rates.rtf";

/* Make state-level rate report */
TITLE;
TITLE1 "Nationally Comparable Adjusted State-Level Lower Respiratory
Infection Readmission Rate";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC(DATE()), NLDATE20.)) at
%TRIM(%SYSFUNC(TIME()), TIMEAMPM12.))";

PROC PRINT DATA=state_rate NOOBS LABEL;
  VAR adj_rate adj_lcl adj_ucl unadj_rate readmissions admissions;
  FORMAT      adj_rate PERCENTN7.5
              adj_lcl PERCENTN7.5
              adj_ucl PERCENTN7.5
              unadj_rate PERCENTN7.5;

RUN;

/* Make hospital-level rates report */
TITLE;
TITLE1 "Nationally Comparable Adjusted Hospital-Level Lower
Respiratory Infection Readmission Rate";
FOOTNOTE;
FOOTNOTE1 "Generated on %TRIM(%QSYSFUNC(DATE()), NLDATE20.)) at
%TRIM(%SYSFUNC(TIME()), TIMEAMPM12.))";

PROC PRINT DATA=hosp_lri_direct
  NOOBS
  LABEL

```

```
;
VAR adj_rate adj_lower adj_upper unadj_rate readmissions admissions;
ID hospitalid;
FORMAT adj_rate PERCENTN7.5
adj_lower PERCENTN7.5
adj_upper PERCENTN7.5
unadj_rate PERCENTN7.5;
RUN;

ods rtf close;
```

EVIDENCE FOR THE PEDIATRIC LOWER RESPIRATORY INFECTION READMISSION MEASURE

Process Used to Identify the Evidence

We performed a literature review using the PubMed, Google Scholar, and Google search engines to find evidence for the relationship between hospital readmission for LRI and quality of care. For the PubMed searches, we identified relevant Medical Subject Headings [MeSH] in combination with other appropriate search terms. We used the following search strategies: "Patient Readmission [MeSH]"; Patient Readmission [MeSH] AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Intervention AND readmission AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Intervention AND rehospitalization AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Quality Improvement [MeSH] AND readmission"; "Quality Improvement [MeSH] AND rehospitalization"; "Intervention Studies [MeSH] AND readmission"; "Intervention Studies [MeSH] AND rehospitalization"; ["Outcome Assessment (Health Care)"] [MeSH] OR ("Outcome Assessment (Health Care)/epidemiology" [MeSH] OR "Outcome Assessment (Health Care)/methods" [MeSH] OR "Outcome Assessment (Health Care)/statistics and numerical data" [MeSH] OR "Outcome Assessment (Health Care)/utilization" [MeSH])) AND readmission AND quality AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Interventions to improve quality of care in children AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Care transitions" AND readmission AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Discharge AND readmission AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Discharge process AND readmission AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Discharge AND rehospitalization AND "bronchiolitis" OR "pneumonia" OR "influenza"; "Discharge process AND rehospitalization AND "bronchiolitis" OR "pneumonia" OR "influenza". Initially, we filtered all of our results by age (0-18 years old) and language to include only pediatric studies and those published in English. We focused on studies that were conducted in the United States but considered studies from other countries if the intervention seemed generalizable. We did not restrict our searches to a particular time frame. For searches that yielded minimal findings in the pediatric literature, we broadened our search strategy to include studies conducted in the adult population. For particularly relevant studies, we used the reference lists of the articles, as well as the "related citations" search tool in PubMed, to find other similar articles. Two reviewers conducted independent searches to ensure a comprehensive capture of relevant evidence. The types of evidence we found included meta-analyses, randomized controlled studies, prospective cohort studies, retrospective cohort studies, survey studies, case-controlled studies, and prospective pre-post observational studies.

Evidence for the Relationship between LRI Readmission and Quality of Care

Type of Evidence	Key Findings	Citation
Randomized Controlled Trial	Investigators examined the impact of implementing a 3-step critical pathway for CAP hospitalization on duration of intravenous antibiotic therapy, length of hospital stay, and 30-day readmission rates. The pathway involved early mobilization and criteria for switching to oral antibiotics and	Carratalà J, Garcia-Vidal C, Ortega L, Fernández-Sabé N, Clemente M, Albero G, López M, Castellsagué X, Dorca J, Verdaguer R, Martínez-Montauti J, Manresa F, Gudiol F. Effect of a 3-step critical pathway to reduce duration of intravenous antibiotic therapy and length of stay in community-acquired pneumonia: a randomized controlled trial. <i>Arch</i>

	hospital discharge. 401 adults hospitalized with CAP in 2 tertiary hospitals in Barcelona, Spain were randomly assigned to receive either care with the 3-step critical pathway or standard care. While the 3-step critical pathway reduced intravenous antibiotic therapy duration and length of stay, it did not significantly change readmission rates (18% in intervention group vs. 15% in control group, $p = .59$).	<i>Intern Med.</i> 2012;172(12):922–928.
Prospective & Retrospective Pre-Post Observational Study	Investigators analyzed implementation of a clinical pathway for treatment of infants hospitalized for acute viral bronchiolitis. The intervention consisted of specific management and discharge criteria. Eligible patients were <12 months old and admitted to a tertiary children's hospital in Australia. Data were retrospectively analyzed for 207 infants pre-pathway implementation and prospectively analyzed for 229 infants post-pathway implementation. There was a significant reduction in the 14-day readmission rate from pre- to post-pathway implementation (7.2% vs. 0.9%, $p = .001$).	Cheney J, Barber S, Altamirano L, Medico Cirujano, Cheney M, Williams C, Jackson M, Yates P, O'Rourke P, Wainwright C. A clinical pathway for bronchiolitis is effective in reducing readmission rates. <i>J Pediatr.</i> 2005;147(5):622–626.
Combined Prospective and Retrospective Cohort Study	Investigators analyzed the impact of implementing a clinical practice guideline (CPG) for bronchiolitis inpatient care on 7-day readmission rates. The practice guideline outlined scientific best practices described in the literature. Eligible patients were < 12 months old and were hospitalized	Kotagal UR, Robbins JM, Kini NM, Schoettker PJ, Atherton HD, Kirschbaum MS. Impact of a bronchiolitis guideline: a multisite demonstration project. <i>Chest.</i> 2002;121(6): 1789–1797.

	for bronchiolitis at 1 of 11 study hospitals. Administrative data were retrospectively analyzed for 846 patients treated pre-guideline implementation. Data for 792 patients were prospectively analyzed post-guideline implementation. Mean 7-day hospital readmission rates did not change significantly over the course of guideline implementation (1.7% to 1.9%, $p = .84$).	
Retrospective Pre-Post Observational Study	Investigators evaluated the effects of implementing a literature-based diagnosis and management algorithm for the treatment of complicated pneumonia in children. Eligible patients were 3 months to 20 years old and were admitted to a tertiary children's hospital with a principal or secondary diagnosis code for empyema and/or pleural effusion from bacterial pneumonia. Clinical and billing data were analyzed for 83 children admitted 15 months pre-algorithm implementation and 87 children admitted 15 months post-algorithm implementation. There was a significant reduction in readmission rate from pre- to post-algorithm implementation (7.7% vs. 0%, $p = .01$).	Pillai D, Song X, Pastor W, Ottolini M, Powell D, Wiedermann BL, DeBiasi RL. Implementation and impact of a consensus diagnostic and management algorithm for complicated pneumonia in children. <i>J Investig Med</i>. 2011;59(8):1221–1227.
Retrospective Cohort Study	Investigators evaluated the impact of implementing a pneumonia guideline on 30-day readmission rates for patients hospitalized with pneumonia. The guideline outlined local best practices with recommendations from the American Thoracic Society and the Infectious Diseases Society of America. Eligible patients were ≥ 66 years	Dean NC, Bateman KA, Donnelly SM, Silver MP, Snow GL, Hale D. Improved clinical outcomes with utilization of a community-acquired pneumonia guideline. <i>Chest</i>. 2006;130(3):794–799.

	old and were hospitalized for a definitive diagnosis of pneumonia. Utah Medicare and Medicaid data were collected for 17,728 patients hospitalized between 1993 and 2003. Hospitals in which the guideline was implemented had lower readmission rates than hospitals that did not implement the guideline (OR 0.86, $p = .006$).	
Retrospective Cohort Study	Investigators studied the relationship between institutional CPGs for CAP and quality of care in children hospitalized with CAP. Eligible children were between 1 and 18 years old and were hospitalized with CAP. Patient data from 41 hospitals were obtained from the Pediatric Health Information System. Surveys were sent to participating hospitals to determine whether a CAP CPG was utilized. Investigators did not find a significant relationship between 14-day readmission rates and the presence of a CAP CPG (2.3% vs. 2.1%, $p = .4$).	Neuman MI, Hall M, Hersh AL, Brogan TV, Parikh K, Newland JG, Blaschke AJ, Williams DJ, Grijalva CG, Tyler A, Shah SS. Influence of hospital guidelines on management of children hospitalized with pneumonia. <i>Pediatrics</i>. 2012;130(5):e823–830.
Retrospective Cohort Study	Investigators examined the impact of observation units for home oxygen therapy on hospital length of stay and readmission rates for bronchiolitis hospitalizations. Eligible patients were 3 to 24 months old, had bronchiolitis not complicated by a serious bacterial infection, were tolerating nasal cannula oxygen (i.e., not requiring face mask or high-flow nasal cannula oxygen), and had hypoxia or an anticipated eventual need for oxygen supplementation.	Sandweiss DR, Mundorff MB, Hill T, Wolfe D, Greene T, Andrews S, Glasgow TS. Decreasing hospital length of stay for bronchiolitis by using an observation unit and home oxygen therapy. <i>JAMA Pediatr</i>. 2013;167(5):422–428.

	Administrative data were analyzed for 692 patients pre-implementation and 725 patients post-implementation in a single children's hospital in Utah. While the mean length of stay decreased significantly over the intervention period, readmission rates did not change.	
Retrospective Cohort Study	Investigators examined why some states have pneumonia readmission rates that are higher than the national average. Multivariate regression analyses were conducted using Medicare fee-for-service state-level data. The following variables were found to be associated with decreased 30-day readmission rates: (1) discharge information given to the patient and (2) recommended initial antibiotics used.	Schmeida M, Savrin RA. Pneumonia rehospitalization of the Medicare fee-for-service patient: a state-level analysis: exploring 30-day readmission factors. <i>Prof Case Manag.</i> 2012;17(3):126–131.
Quality Improvement Study	Pediatric hospitalists formed a voluntary collaborative to benchmark resource utilization for bronchiolitis care. Resources were shared within the collaborative to establish benchmarks for resource utilization, and data on 11,568 hospitalizations at 17 different centers were analyzed during the 2-year intervention period. Benchmarking for resource utilization did not cause a significant change in 3-day readmission rates. 3-day readmission rates did not vary significantly throughout the intervention and ranged from 1.2% to 1.7%.	Ralston S, Garber M, Narang S, Shen M, Pate B, Pope J, Lossius M, Croland T, Bennett J, Jewell J, Krugman S, Robbins E, Nazif J, Liewehr S, Miller A, Marks M, Pappas R, Pardue J, Quinonez R, Fine BR, Ryan M. Decreasing unnecessary utilization in acute bronchiolitis care: results from the value in inpatient pediatrics network. <i>J Hosp Med.</i> 2013;8(1):25–30.

Evidence for the Relationship between Readmission and Quality of Care

TYPE OF EVIDENCE	KEY FINDINGS	CITATION
Readmission and Quality of Care Coordination, Discharge, and Care Transition Processes		
Meta-analysis	Investigators reviewed randomized controlled studies of structured telephone support or telemonitoring compared with standard practice for patients with congestive heart failure (CHF) in order to quantify the effects of these interventions as compared with standard care. Study participants were ≥ 18 years old and had a definitive diagnosis of CHF. The mean age of the participants ranged from 44.5 years to 78 years old. Eligible studies had readmission rates as the primary outcome. Of the eligible studies, 16 evaluated structured telephone support (5,613 patients), 11 evaluated telemonitoring (2,710 patients), and 2 tested both interventions. Structured telephone support (relative risk (RR) 0.77 [95% CI 0.68 to 0.87], $p < .0001$) and telemonitoring (RR 0.79 [95% CI 0.67 to 0.94], $p = 0.008$) reduced chronic heart failure-related hospitalizations.	Inglis SC, Clark RA, McAlister FA, Ball J, Lewinter C, Cullington D, Stewart S, Cleland JG. Structured telephone support or telemonitoring programmes for patients with chronic heart failure. <i>Cochrane Database Syst Rev Online</i>. 2010;(8):CD007228.
Meta-analysis	Investigators reviewed 18 studies with data from 8 countries to evaluate the effect of comprehensive discharge planning plus post-discharge support on readmission rates in patients with CHF. Eligible studies were English-language publications of randomized controlled clinical trials with detailed descriptions of interventions intended to modify hospital discharge for older inpatients. The mean age of participants in each study was ≥ 55 years old. Eligible studies specifically addressed CHF, described components for inpatient care plus post-discharge support, compared the effects with routine care, and reported readmission rates as the primary outcome. Patients with CHF who received comprehensive discharge planning plus post-discharge support had fewer readmissions than controls who received routine care (555/1,590 vs. 741/1,714; RR 0.75 [95% CI 0.64 to 0.88]).	Phillips CO, Wright SM, Kern DE, Singa RM, Shepperd S, Rubin HR. Comprehensive discharge planning with postdischarge support for older patients with congestive heart failure: a meta-analysis. <i>JAMA</i>. 2004;291(11):1358–1367.
Meta-analysis	Investigators identified controlled trials or systematic reviews that assessed interventions targeting hospitalized patients and measured readmission	Scott IA. Preventing the rebound: improving care

	rates. The search yielded 2,776 articles including 378 systematic reviews, 7 of which were published after 2000 and served as key sources of data. Eligible studies were controlled trials or systematic reviews that reported data on interventions targeting adult hospitalized patients and measured readmission rates. Intense self-management and transition coaching of patients at high risk of readmission, and the use of home visits or telephone support for patients with heart failure were the only single-component strategies consistently associated with reduced readmissions. The meta-analysis suggested discharge processes are effective in reducing readmissions if they include the following components: 1) early assessment of discharge needs and medication reconciliation; 2) enhanced patient education; 3) early post-acute follow-up within 24-72 hours for high risk patients; 4) early post-discharge nurse or pharmacist phone calls or home visits to confirm understanding of follow-up plans; and 5) appropriate referral for home care and community support services when needed.	transition in hospital discharge processes. <i>Aust Health Rev.</i> 2010;34(4):445–451.
Meta-analysis	Investigators reviewed 24 randomized controlled trials that compared an individualized discharge plan with routine non-tailored discharge care in an elderly population of hospitalized patients who had been admitted with a medical diagnosis. In the 12 trials that analyzed readmissions to the hospital within three months of discharge, patients who received discharge planning were readmitted at a reduced rate (RR 0.82 [95% CI 0.73 to 0.92]) compared with those patients who received routine non-tailored discharge care.	Shepperd S, Lannin NA, Clemson LM, McCluskey A, Cameron ID, Barras SL. Discharge planning from hospital to home. <i>Cochrane Database Syst Rev Online.</i> 2013;1:CD000313.
Meta-analysis	Investigators reviewed and reanalyzed data from 10 randomized controlled trials of heart failure care management programs to determine how program delivery methods contribute to patient outcomes. The 10 trials assessed the effect of chronic care management programs for heart failure patients discharged from a recent hospital stay on readmission rates. Study participants were adult patients with heart failure who had recently been discharged from the hospital. Patients enrolled in chronic care management programs using a multi-disciplinary team approach	Sochalski J, Jaarsma T, Krumholz HM, Laramée A, McMurray JJV, Naylor MD, Rich MW, Riegel B, Stewart S. What works in chronic care management: the case of heart failure. <i>Health Aff (Millwood).</i> 2009;28(1):179–189.

	had significantly fewer hospital readmissions than routine care patients and experienced a 2.9% reduction in readmissions per month. In-person communication rather than telephonic communication led to a significant reduction of 2.5% fewer readmissions per month.	
Systematic Review	Investigators performed a systematic review of the literature and found that interventions with multiple components (e.g., patient needs assessment, medication reconciliation, patient education, arranging timely outpatient appointments, and providing telephone follow-up) have successfully reduced readmission rates for patients discharged to home. Interventions were most successful at reducing readmission rates if they employed multiple components. Single-component interventions are unlikely to reduce readmissions significantly. For patients discharged to post-acute care facilities, multicomponent interventions have reduced readmissions through enhanced communication, medication safety, advanced care planning, and enhanced training to manage medical conditions that commonly precipitate readmission.	Kripalani S, Theobald CN, Anctil B, Vasilevskis EE. Reducing Hospital Readmission Rates: Current Strategies and Future Directions. <i>Annu Rev Med.</i> 2013.
Randomized controlled trial	Investigators studied 121 patients with CHF to determine the effectiveness of a targeted inpatient CHF education program coupled with comprehensive discharge planning and immediate outpatient reinforcement through a coordinated nurse-driven home health care program on reducing readmission rates and cost. Study participants were > 50 years old, admitted to a single hospital site with a primary diagnosis of CHF, and able to participate in home health care after discharge. Members of the intervention group had an 11.4% readmission rate within 6 months, compared with a 44.2% readmission rate in the control group ($p = .01$). 30-day readmission rates were lower in the intervention group, as well (6.0% vs. 22.1% in the control group; $p = .01$).	Anderson C, Deepak BV, Amoateng-Adjepong Y, Zarich S. Benefits of comprehensive inpatient education and discharge planning combined with outpatient support in elderly patients with congestive heart failure. <i>Congest Heart Fail.</i> 2005;11(6):315–321.
Randomized controlled trial	Investigators studied 122 patients at a single hospital to test the effectiveness of a low-cost discharge intervention. The control group received the standard discharge protocol. The intervention group received: 1) a comprehensive, user-friendly patient discharge form; 2) electronic transfer of the patient discharge form to nurses at the primary care provider site; 3) telephone contact by a primary care nurse; and 4)	Balaban RB, Weissman JS, Samuel PA, Woolhandler S. Redefining and redesigning hospital discharge to enhance patient care: a

	primary care provider review and modification of the discharge-transfer plan. Participants had an established relationship with their PCP, defined as having had 2 or more visits with their PCP or one visit with their PCP and at least 2 RN contacts within the prior year. Only patients discharged to home were included in the analysis, and the average age of the patients in the intervention group was 58 years old. Four patients (8.5%) in the intervention group (n = 47) were readmitted within 31 days compared with 14 patients (14.0%) in the historical control group (n = 100) (p = .34), and 4 patients (8.2%) in the concurrent control group (n = 49) (p = .96). Results from the intervention show that a systematic transfer of patient care to the primary care provider is an integral part of the discharge process and can lead to a reduction in readmission rates and improved outcomes.	randomized controlled study. <i>J Gen Intern Med.</i> 2008;23(8):1228–1233.
Randomized controlled trial	Investigators identified 750 patients at the time of hospitalization and randomized them to receive routine care or a care transition intervention. The intervention consisted of: 1) tools to promote cross-site communication; 2) encouragement to take a more active role in self-care; and 3) continuity across settings and guidance from a transition coach. Readmission rates were measured at 30, 90, and 180 days. Eligible patients were ≥ 65 years old, admitted to the participating delivery system's contract hospital during the study period for a non-psychiatric condition, and community dwelling (i.e., not from a long-term care facility). They had to reside within a predefined geographic radius of the hospital, have access to a working telephone, be English speaking, show no documentation of dementia in the medical record, and have no plans to enter hospice. Patients in the intervention group had lower readmission rates at 30 days (8.3% vs. 11.9%, p = .048) and at 90 days (16.7% vs. 22.5%, p = .04) than control subjects. Patients in the intervention group also had lower readmission rates for the same condition that precipitated the index hospitalization at 90 days (5.3% vs. 9.8%, p = .04), and at 180 days (8.6% vs. 13.9%, p = .046) than patients in the control group.	Coleman EA, Parry C, Chalmers S, Min S-J. The care transitions intervention: results of a randomized controlled trial. <i>Arch Intern Med.</i> 2006;166(17):1822–1828.

Randomized controlled trial	Investigators performed a randomized controlled trial to evaluate the effectiveness of an early discharge planning protocol on reducing hospital readmission rates. The intervention was initiated on day 3 of the hospital stay for the experimental group (n = 417). Patients in the control group (n = 418) received service only upon referral by medical staff, averaging the 9th day of the hospital stay, with some patients not receiving the service at all. Eligible patients for the experimental group had been admitted to medical, neurologic, or surgical services at the Department of Veteran Affairs Medical Center in Seattle, WA during a 21-month period. Forty-four percent of patients in the experimental group and 47% of patients in the control group were ≥ 70 years old. Fewer patients in the experimental group were readmitted during the month post-discharge (24% vs. 35%, $p < .001$). This trend toward fewer readmissions in the experimental group was also observed at 9 months (55% vs. 61%, $p = .08$), and the average length of stay during rehospitalization was significantly less for patients in the intervention group.	Evans RL, Hendricks RD. Evaluating hospital discharge planning: a randomized clinical trial. <i>Med Care</i>. 1993;31(4):358–370.
Randomized controlled trial	Investigators randomized 749 hospitalized patients at a single institution to receive routine care or an intervention consisting of a nurse discharge advocate who worked with patients during their hospital stay to arrange follow-up appointments, confirm medication reconciliation, and conduct patient education with an individualized instruction booklet that was also sent to the patient's primary care provider. A clinical pharmacist called the patients 2 to 4 days after discharge to reinforce the discharge plan and review medications. Eligible patients were English-speaking, 18 years old or older, had access to a telephone and had plans to be discharged to a U.S. community. Patients in the intervention group (n = 370) had a lower rate of hospitalization than those receiving routine care (n = 368) (0.314 vs. 0.451 visit per person per month; incidence rate ratio 0.695 [95% CI 0.515 to 0.937], $p = .009$). The intervention was most effective among participants who had been previously hospitalized during the 6 months before the index admission ($p = .014$).	Jack BW, Chetty VK, Anthony D, Greenwald JL, Sanchez GM, Johnson AE, Forsythe SR, O'Donnell JK, Paasche-Orlow MK, Manasseh C, Martin S, Culpepper L. A reengineered hospital discharge program to decrease rehospitalization: a randomized trial. <i>Ann Intern Med</i>. 2009;150(3):178–187.
Randomized controlled	Investigators studied 41 medical inpatients at a single hospital to determine the effectiveness of a	Koehler BE, Richter KM, Youngblood L,

trial	supplemental care bundle implemented by hospital-based care coordinators and clinical pharmacists working with the study team. The intervention began within 24 hours of a patient's enrollment and continued up to 1 week after hospital discharge. Eligible patients were ≥ 70 years old, used 5 or more medications regularly, had 3 or more chronic comorbid conditions, required assistance in 1 or more activities of daily living, lived at home or in assisted living prior to admission, and had a reasonable expectation of returning to the same environment after discharge. Intervention group readmission rates and ED visit rates were reduced at 30 days compared with the control group (10.0% vs. 38.1%, $p = .04$). For those patients who had a readmission or a post-discharge ED visit, the time interval to this event was longer in the intervention group compared with routine care patients (36.2 vs. 15.7 days, $p = .05$).	Cohen BA, Prengler ID, Cheng D, Masica AL. Reduction of 30-day postdischarge hospital readmission or emergency department (ED) visit rates in high-risk elderly medical patients through delivery of a targeted care bundle. <i>J Hosp Med.</i> 2009;4(4):211–218.
Randomized controlled trial	Investigators studied 276 patients and 125 caregivers at a single site. Patients were randomized to receive either the hospital's routine discharge plan or the routine discharge plan plus a comprehensive, individualized discharge planning protocol developed specifically for elderly patients. Eligible patients were ≥ 70 years old with conditions falling into selected medical and surgical cardiac diagnostic-related groups (DRGs). During the initial 2-week period after discharge, 3 patients (4%) in the medical intervention group were readmitted, compared with 11 patients (16%) in the control group ($p = .02$). For the intervals from 2 to 6 weeks and from 6 to 12 weeks after discharge, the percentage of patients readmitted was similar for the intervention and control groups. Cumulatively, 10% of patients in the medical intervention group were readmitted during the first 6 weeks after discharge compared with 23% of control patients ([95% CI for the difference, -25% to -1%], $p = .04$). Twelve weeks after discharge, 22% of the intervention group had been rehospitalized compared with 33% of the control group ([95% CI for the difference, -26% to 4%], $p = .15$). The number of elderly patients rehospitalized in the medical control group was > 3 times higher than that of the intervention group during the first 2 weeks after	Naylor M, Brooten D, Jones R, Lavizzo-Mourey R, Mezey M, Pauly M. Comprehensive discharge planning for the hospitalized elderly. A randomized clinical trial. <i>Ann Intern Med.</i> 1994;120(12):999–1006.

	discharge. Six weeks after the initial hospital discharge, the readmission rate for the medical intervention group was 10%, well below nationally reported figures for comparable medical DRGs, suggesting that the intervention was most effective in delaying or preventing rehospitalizations during the first 6 weeks after the initial hospital discharge.	
Randomized controlled trial	Investigators studied 239 patients with heart failure at 6 sites to evaluate the effectiveness of a transitional care intervention delivered by advanced practice nurses (APN). The intervention consisted of a 3-month APN-directed discharge planning and home follow-up protocol. Study participants were ≥ 65 years old. Time to first readmission or death was longer in intervention patients $\log \text{rank}^2 = 5.0$, $p = .026$; Cox regression incidence density ratio = 1.65, [95% CI 1.13 to 2.40]. At 52 weeks, patients in the intervention group had fewer readmissions (104 vs. 162, $p = .047$).	Naylor MD, Brooten DA, Campbell RL, Maislin G, McCauley KM, Schwartz JS. Transitional care of older adults hospitalized with heart failure: a randomized, controlled trial. <i>J Am Geriatr Soc</i>. 2004;52(5):675–684.
Randomized controlled trial	Investigators studied 282 patients with CHF at a single hospital site to evaluate the effectiveness of a nurse-directed, multidisciplinary intervention on readmission rates within 90 days of hospital discharge. The intervention consisted of comprehensive education for the patient and family, a prescribed diet, social-service consultation and planning for an early discharge, a review of medications, and intensive follow-up. Eligible patients were ≥ 70 years old, had a confirmed diagnosis of CHF, and had at least one of the following risk factors for early readmission: prior history of heart failure, four or more hospitalizations for any reason in the preceding five years, or CHF precipitated by either an acute myocardial infarction or uncontrolled hypertension. Fifty-nine patients in the control group (42.1%) had at least one readmission during follow-up, as compared with 41 patients in the treatment group (28.9%; absolute reduction, 13.2%; [95% CI, 2.1% to 24.3%], $p = .03$). Multiple readmissions were more frequent in the control group (16.4%, vs. 6.3% in the treatment group; 95% CI for the difference, 2.8% to 17.4%; $p = .01$), such that the total number of readmissions during follow-up was reduced by 44.4% ($p = .02$).	Rich MW, Beckham V, Wittenberg C, Leven CL, Freedland KE, Carney RM. A multidisciplinary intervention to prevent the readmission of elderly patients with congestive heart failure. <i>N Engl J Med</i>. 1995;333(18):1190–1195.
Prospective cohort study	Investigators conducted a prospective cohort study of parents surveyed using the care transitions measure,	Berry JG, Ziniel SI, Freeman L, Kaplan

	a survey that assesses components of discharge care to describe parent perceptions of their child's hospital discharge and assess the relationship between perceptions and hospital readmission. 348 parents were surveyed, comprising a 5% random sample of parents or legal guardians of 11,910 hospitalized patients who were discharged from the hospital between March and October of 2010. Twenty-eight children (8.1%) experienced a readmission. Children had a lower readmission rate (4.4 vs. 11.3%, $p = .004$) and lower adjusted readmission likelihood (OR 0.2 [95% CI 0.1 to 0.6]) when their parents strongly agreed ($n = 206$) with the statement, 'I felt that my child was healthy enough to leave the hospital' from the index admission. Parent perception of their child's health at discharge was associated with the risk of a subsequent, unplanned readmission.	W, Antonelli R, Gay J, Coleman EA, Porter S, Goldmann D. Hospital readmission and parent perceptions of their child's hospital discharge. <i>Int J Qual Health Care</i>. 2013;25(5):573–581.
Retrospective cohort study	Investigators conducted a retrospective cohort study using the 2008 CMS Hospital Quality Alliance dataset linked to the 2007 American Hospital Association annual survey to examine the relationships among hospital characteristics, discharge processes, and readmission. The study cohort consisted of enrollees in Medicare fee-for-service who had been readmitted within 30 days for congestive heart failure or pneumonia. The study found a weak correlation ($r = 0.05$, $p < .001$) between performance on the two discharge measures: 1) the adequacy of documentation in the medical chart that discharge instructions were provided to patients with CHF and 2) patient-reported experiences with discharge planning. Larger hospitals performed better on the chart-based measure, while smaller hospitals and those with higher nurse-staffing levels performed better on the patient-reported measure. The study found no association between performance on the chart-based measure and readmission rates among patients with CHF (readmission rates among hospitals performing in the highest quartile vs. the lowest quartile, 23.7% vs. 23.5%; $p = .54$) and only a very modest association between performance on the patient-reported measure and readmission rates for CHF (readmission rates among hospitals performing in the highest quartile vs. the lowest quartile, 22.4%	Jha AK, Orav EJ, Epstein AM. Public reporting of discharge planning and rates of readmissions. <i>N Engl J Med</i>. 2009;361(27):2637–2645.

	vs. 24.7%; $p < .001$) and pneumonia (17.5% vs. 19.5%, $p < .001$).	
Retrospective cohort study	Investigators evaluated 48,538 patients who chose to participate in a telephonic intervention compared with patients who could not be reached by phone or declined to participate. Study participants were adult members of Medicare Advantage who had an acute inpatient hospitalization followed by discharge to home. Of the 48,538 Medicare members who received the intervention, 4,504 (9.3%) were readmitted to the hospital within 30 days, as compared with 5,598 controls (11.5%, $p < .0001$). There was a direct correlation between the timing of the intervention and the rate of readmission: the closer the intervention to the date of discharge, the greater the reduction in number of readmissions.	Costantino ME, Frey B, Hall B, Painter P. The influence of a postdischarge intervention on reducing hospital readmissions in a Medicare population. <i>Popul Heal Manag.</i> 2013.
Retrospective cohort study	Investigators studied a state-wide intervention that provided transitional care to Medicaid beneficiaries after they had been discharged from the hospital. The study cohort consisted of 13,476 Medicaid beneficiaries of any age who had multiple or catastrophic chronic conditions and had been discharged alive from an in-state general hospital with a qualifying DRG code during July 2010–June 2011 and enrolled in a Community Care of North Carolina primary care medical home at the time of discharge or within thirty days of discharge. Patients in the intervention group received comprehensive medication management, face-to-face self-management education for patients and families, and timely outpatient follow-up with a medical home that has been fully informed about the hospitalization and any clinical or social issues that complicate the patient's care. Patients who received the intervention were 20% less likely to experience a readmission during the subsequent year and experienced a significantly longer time between their initial discharge and their first readmission when compared with clinically similar patients who received routine care. In addition, transitional care patients were significantly less likely than others to have second and third readmissions.	Jackson CT, Trygstad TK, Dewalt DA, Dubard CA. Transitional care cut hospital readmissions for North Carolina Medicaid patients with complex chronic conditions. <i>Health Aff (Millwood)</i>. 2013;32(8):1407–1415.
Retrospective cohort study	Investigators studied 818 patients at a single hospital to evaluate the effect of acute care for elders (ACE) units on readmission as compared with usual care.	Flood KL, MacLennan PA, McGrew D, Green D, Dodd C,

	ACE units use an interdisciplinary team model to provide hospital care, in contrast to a multidisciplinary model used by the usual care unit in which providers from all disciplines deliver care but practice predominantly independently. Eligible patients were ≥ 70 years old, met inpatient admission criteria, and had either spent their entire hospitalization in the acute care for elders (ACE) unit or the usual care unit. Patients in the ACE unit experienced fewer readmissions within 30 days of discharge than those in the usual care unit (7.9% vs. 12.8%; $p = .02$).	Brown CJ. Effects of an acute care for elders unit on costs and 30-day readmissions. <i>JAMA Intern Med.</i> 2013;1–7.
Retrospective cohort study	Investigators studied 30,272 patients enrolled in a chronic disease management program who had a hospital admission for any reason during 2008. Those who received a telephone call within 14 days of discharge and were not readmitted prior to that call comprised the intervention group. All other enrollees formed the comparison group. Study participants were adult members of a large commercial health plan with Medicare Advantage. Receipt of a discharge call was associated with reduced rates of readmission: intervention group members were 23.1% less likely than the comparison group to be readmitted within 30 days of hospital discharge ($p = .043$).	Harrison PL, Hara PA, Pope JE, Young MC, Rula EY. The impact of postdischarge telephonic follow-up on hospital readmissions. <i>Popul Heal Manag.</i> 2011;14(1):27–32.
Retrospective cohort study	Investigators studied the effect of a post-discharge follow-up visit on readmission in patients with sickle cell disease (SCD). Study participants consisted of adults and children enrolled in Wisconsin Medicaid between January 2003 and December 2007. Classification of SCD was based on disease specific ICD-9-CM codes. Patients also had to have an inpatient hospitalization with a discharge diagnosis of SCD or two outpatient visits at least 30 days apart with a diagnosis of SCD. Patients who had post-discharge follow-up within 30 days of hospital discharge were readmitted less often than those who did not. Fifteen (9.87%) of the 152 patients with at least 1 outpatient visit (within 30 days or prior to a rehospitalization) were rehospitalized compared with 55 (21.5%) of the 256 without an outpatient visit ($p < .01$).	Leschke J, Panepinto JA, Nimmer M, Hoffmann RG, Yan K, Brousseau DC. Outpatient follow-up and rehospitalizations for sickle cell disease patients. <i>Pediatr Blood Cancer.</i> 2012;58(3):406–409.
Survey study	Investigators performed a cross-sectional study using a Web-based survey of hospitals to examine their	Bradley EH, Curry L, Horwitz LI, Sipsma H,

	reported use of specific hospital strategies intended to reduce readmissions for patients with heart failure. Eligible hospitals were enrolled in either the Hospital to Home National Quality Improvement Initiative or the State Action on Avoidable Rehospitalizations Initiative. Of the 658 eligible hospitals, 599 completed the survey. After adjusting for hospital teaching status, geographic location, and number of staffed beds, the investigators found that the following strategies were associated with lower 30-day hospital readmission rates: 1) partnering with community physicians or physician groups to reduce readmission; 2) partnering with local hospitals to reduce readmissions; 3) having nurses responsible for medication reconciliation; 4) arranging follow-up appointments before discharge; 5) having a process in place to send all discharge paper or electronic summaries directly to the patient's primary physician; and 6) assigning staff to follow up on test results that return after the patient is discharged. Hospitals that implemented more strategies had significantly lower 30-day readmission rates than those that only implemented one strategy.	Wang Y, Walsh MN, Goldmann D, White N, Piña IL, Krumholz HM. Hospital strategies associated with 30-day readmission rates for patients with heart failure. <i>Circ Cardiovasc Qual Outcomes</i>. 2013;6(4):444–450.
Readmission and Quality of Disease Management		
Case-control study	Investigators assessed the relationship between readmission risk and quality of inpatient care via chart review using condition-specific criteria for the admission work-up, evaluation and treatment, and discharge readiness. Study participants were adult male patients with diabetes, heart failure, or obstructive lung disease at 12 Veterans Administration (VA) hospitals in the southern United States between October 1, 1987 and September 30, 1989. Lower quality of care was associated with a higher risk of unplanned readmission within 14 days. Roughly 1 in 7 unplanned early readmissions in patients with diabetes, 1 in 5 in patients with heart failure, and 1 in 12 in patients with obstructive lung disease were attributable to substandard inpatient care after other variables were taken into account.	Ashton CM, Kuykendall DH, Johnson ML, Wray NP, Wu L. The association between the quality of inpatient care and early readmission. <i>Ann Intern Med</i>. 1995;122(6):415–421.
Prospective pre-post observational study	Investigators developed an asthma care process model (CPM) with the primary goal of standardizing asthma care and improving quality and examined its effect on readmission. The model incorporated the 3 Children's Asthma Care measures (CAC-1, -2, and -	Fassl BA, Nkoy FL, Stone BL, Srivastava R, Simon TD, Uchida DA, Koopmeiners K, Greene T, Cook LJ,

	3) recommended by the Joint Commission to improve the quality of pediatric inpatient asthma care. The measures required the following elements: 1) use of beta-agonists; 2) use of systemic corticosteroids; 3) provision of a home management plan that includes documentation of a follow-up appointment, environmental or other trigger control, a written action plan, and reliever and controller medications. Study participants were 1,865 children between the ages of 2 and 17 years old at a freestanding children's hospital. Increased compliance with the CAC measures was associated with a sustained decrease in readmissions. Six-month asthma readmission rates declined from an average of 17% to 12% ($p < .01$) post-implementation.	Maloney CG. The Joint Commission Children's Asthma Care quality measures and asthma readmissions. <i>Pediatrics</i>. 2012;130(3):482–491.
Retrospective cohort study	Using data from the 2009-2010 IMS LifeLink dataset, investigators studied the relationship between quality of care processes and readmission. Study participants were 30,139 commercially-insured patients with diabetes who were ≥ 19 years old. Patients who received at least one LDL test (OR 0.918, [95% CI 0.852 to 0.989], $p < .025$ and a ≥ 90-day supply of statins (OR 0.91, [95% CI 0.85 to 0.97], $p < .01$) had lower readmission rates than those who did not receive such care.	Chen JY, Ma Q, Chen H, Yermilov I. New bundled world: quality of care and readmission in diabetes patients. <i>J Diabetes Sci Technol</i>. 2012;6(3):563–571.
Retrospective cohort study	Investigators used the Premier Perspective database, which consisted of 312 hospitals and contained standard hospital discharge data, plus a date-stamped record of all materials and medications charged for during the hospitalization to evaluate the relationship between adherence to recommendations for surgical care and various clinical outcomes. Adherence to evidence-based processes of surgical care was measured in terms of use of appropriate peri-operative antibiotic prophylaxis, beta-blockade, and venous thromboembolism prophylaxis. The patient outcomes evaluated were mortality, length of stay (LOS), discharge disposition, surgical complications, readmissions, and reoperations within 30 days of discharge. Eligible patients were ≥ 18 years old, admitted between October 1, 2003 and September 30, 2005, and underwent primary hip or knee arthroscopy. Lack of adherence to surgical processes of care was	Bozic KJ, Maselli J, Pekow PS, Lindenauer PK, Vail TP, Auerbach AD. The influence of procedure volumes and standardization of care on quality and efficiency in total joint replacement surgery. <i>J Bone Joint Surg Am</i>. 2010;92(16):2643–2652.

	associated with increased risk of readmission (OR 1.25 [95% CI 1.13 to 1.37]) for 2 or 3 missed processes, compared with no missed processes).	
Retrospective cohort study	Investigators analyzed the Department of Veterans Affairs Patient Treatment File and medical records to assess the relationship between appropriateness of readmission and previous hospital stay using the InterQual admission and discharge standards, which are based on clinical indicators, service requirements, and discharge readiness. Of the 694 adult medical and surgical patients who were readmitted to a VA Medical Center within two weeks of discharge during the fiscal year 1984, 445 met eligibility criteria (available medical records and information on previous admission) for analysis. Forty-six percent (207/445) of the patients readmitted within 2 weeks of prior hospitalization had an inappropriate readmission, and 40% (178/445) had an inappropriate previous admission. Four percent (13/311) of readmitted patients had an inappropriate admission, discharge, and readmission. Appropriateness of the previous admission, previous discharge, and readmission were significantly associated.	Ludke RL, MacDowell NM, Booth BM, Hunter SA. Appropriateness of admissions and discharges among readmitted patients. <i>Health Serv Res.</i> 1990;25(3):501–525.
Retrospective cohort study	Investigators conducted a retrospective cohort study using the 2009 Medicare Inpatient dataset, the 2010 Medicare Provider Analysis and Review File, and the American Hospital Association annual survey on hospital characteristics to determine whether readmissions rates after major surgery vary across hospitals and whether these rates at a given hospital are related to other markers of surgical care quality. The study cohort consisted of 479,471 Medicare beneficiaries who had undergone any of the following surgical procedures in 2009: coronary-artery bypass grafting (CABG), pulmonary lobectomy, endovascular repair of abdominal aortic aneurysm, colectomy, and hip replacement. Hospitals with high surgical volume and low surgical mortality have lower rates of surgical readmission than other hospitals. Hospitals in the highest quartile for surgical volume had a significantly lower composite readmission rate than hospitals in the lowest quartile (12.7% vs. 16.8%, $p < .001$), and hospitals with the lowest surgical mortality rates had a significantly lower readmission rate than hospitals with the highest mortality rates (13.3% vs. 14.2%, $p < .001$).	Tsai TC, Joynt KE, Orav EJ, Gawande AA, Jha AK. Variation in Surgical-Readmission Rates and Quality of Hospital Care. <i>N Engl J Med.</i> 2013;369(12):1134–1142.