



THOMSON REUTERS

HEALTHCARE

# RISK-ADJUSTED MORTALITY INDEX METHODOLOGY

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# INTRODUCTION

## THE THOMSON REUTERS RISK-ADJUSTED MORTALITY INDEX (RAMI)

The Thomson Reuters Risk-Adjusted Mortality Index (RAMI) uses a method developed to compute the risk of death for hospital patients on the basis of clinical and hospital characteristic data.

The model was developed explicitly to take advantage of large amounts of administrative hospital inpatient data. Rather than to fit a large number of models on numerous clinically homogeneous patient groups, we elected to incorporate clinically-specific risk terms into each of four separate models:

1. Medical , age  $\geq$  65
2. Medical, age  $<$  65
3. Surgical , age  $\geq$  65
4. Surgical, age  $<$  65

These risk terms are based on the most granular level of clinical specificity available in the uniform billing (UB) data: the ICD-9-CM diagnosis and procedure codes. In addition, explicit interaction terms between principal and secondary diagnoses and between principal diagnosis and procedure were included to improve predictive accuracy. Note that specific sets of ICD-9-CM codes are explicitly NOT adjusted for in the model as they may be intervening variables, and therefore not appropriate adjusters for mortality risk (see Appendices A and B).

A priority in designing this model was to include all risk characteristics that were believed to represent patient risk on admission; these would include admission source and type. A limitation of this model is the current inability to determine consistently which ICD-9-CM-defined conditions were present on admission (POA) versus those that arose after the patient was admitted. However, this limitation should be mitigated to a large extent when POA information is more uniformly available in UB discharge data. Research is underway to incorporate the capability for using POA information in future RAMI models.

We designed RAMI to screen for potential opportunities to remedy higher than expected mortality rates. It has not been characterized as a methodology that is capable of providing a definitive answer regarding exceptionally high or low mortality rates. As the principal objective was for RAMI to be used as a tool for hospitals to advance quality improvement efforts, it was designed to facilitate peer-to-peer hospital comparisons. This design feature recognizes that hospitals differ on size, teaching status, and urban/rural community setting, and that such differences may introduce systematic bias that is not addressed completely through the use of patient-level information alone. However, RAMI is designed so that facility-level adjustments may be disabled if desired.

## DOCUMENT ORGANIZATION

**Methodology Overview** describes the theoretical and statistical development of the methodology.

**Methodology Exclusion** describes cases that are excluded from being assigned a RAMI mortality index.

**Model Specification** describes the creation of indicator variables and the actual underlying mathematical calculation involved in generating a RAMI mortality index.

**Model Performance** illustrates the appropriateness and validity of the mortality model.

## METHODOLOGY OVERVIEW

Thomson Reuters's Risk-Adjusted Mortality Index uses data from our Projected Inpatient Database (PIDB)—the largest all-payer inpatient database available in the marketplace.

### PROJECTED INPATIENT DATABASE

The database consists of case-level hospital discharge data, including:

- Hospital identification
- Patient demographics (for example, age and sex)
- A wide array of clinical information, such as length of stay, clinical grouping (DRG or RDRG), ICD-9-CM principal and secondary diagnoses, ICD-9-CM procedures, and disposition status.

Thomson Reuters obtains hospital characteristics (for example, number of beds and U.S. census division) by linking hospital identification numbers to American Hospital Association and Medicare cost report data. This exclusive database combines data from both public and proprietary state data as well as individual and group hospital contracts. It contains approximately 21 million all-payer discharges annually, obtained from approximately 2,500 hospitals, representing more than 50 percent of all discharges from acute care hospitals. For the normative database, neonates, cases transferred to other short-term hospitals, and cases with stays of less than one day are excluded.

### PATIENT-LEVEL DATA

Our method for normative comparisons uses patient-level data to effectively control for case mix and severity differences. The methodology evaluates ICD-9-CM diagnosis and procedure codes to adjust for severity within clinical case mix groupings. Patients are compared with other patients that have similar characteristics (i.e., age, sex, principal diagnosis, procedures performed, and comorbid conditions) to produce expected (normative) comparisons. This methodology ensures that facilities are compared with other facilities that have similar characteristics. We have tested this methodology extensively and shown that it produces valid normative comparisons using readily available administrative data, thus requiring no additional data collection.

## METHODOLOGY EXCLUSIONS

### FACILITY EXCLUSIONS

The following types of hospitals or facilities are excluded from the mortality model:

- Long-term care facilities (typical Medicare discharge length of stay greater than 25 days)
- Cancer specialty hospitals
- Psychiatric, substance abuse, and rehabilitation specialty hospitals
- Federally owned or controlled facilities
- Hospitals that are missing identified characteristics or have fewer than six beds

### PATIENT EXCLUSIONS

The Thomson Reuters Risk-Adjusted Mortality Index excludes neonates, cases transferred to other short-term hospitals, and cases with stays of less than one day. Certain other conditions preclude assigning an accurate mortality index. These exclusions are generally the result of invalid or missing information. The RAMI methodology does not assign a mortality risk to records that meet these conditions. Appendix C: RAMI Exclusion Codes describes the exclusion codes.

## MODEL SPECIFICATION

ICD-9-CM-specific rates of mortality are calculated from the normative data. The rates are calculated separately for four model groups: age younger than 65 and surgical DRG, age younger than 65 and medical DRG, age 65 and older and surgical DRG, and age 65 and older and medical DRG. We use a standard logistic regression model to estimate the risk of death for each patient. The risk is calculated by weighting the patient records of the client hospital by the logistic regression coefficients associated with the corresponding terms in the model and the intercept term. This produces the expected probability of death for each patient based on the experience of the norm for patients with similar characteristics (age, sex, diagnoses, procedures, diagnosis and procedure interactions, and admission source and type) at similar institutions (bed size, census division, teaching status, urban or rural community setting, and specialty type). After assigning the predicted probability of death for each patient, the patient-level data can then be aggregated across a variety of groupings (for example, hospital, service, DRG, RDRG, and so forth).

The assignment module first maps the input diagnosis and procedure codes from any federal fiscal year to the most recent available federal fiscal year. It then uses the Centers for Medicare & Medicaid Services' DRG Grouper to evaluate a current fiscal year DRG. The Thomson Reuters Risk-Adjusted Mortality algorithm then uses these values.

The Thomson Reuters Risk-Adjusted Mortality algorithm relies on the following regression model:

$$\begin{aligned} x = & \\ & \text{intercept} + \\ & \begin{array}{ll} \text{(age less than 65)} & \text{(age greater than or equal to 65)} \\ \text{age1ramicf} * \text{age1} + & \text{age9ramicf} * \text{age9} + \\ \text{age2ramicf} * \text{age2} + & \text{age10ramicf} * \text{age10} + \\ \text{age3ramicf} * \text{age3} + & \text{age11ramicf} * \text{age11} + \\ \text{age4ramicf} * \text{age4} + & \text{age12ramicf} * \text{age12} + \\ \text{age5ramicf} * \text{age5} + & \\ \text{age6ramicf} * \text{age6} + & \\ \text{age7ramicf} * \text{age7} + & \end{array} \\ & \\ & \text{(for all age groups)} \\ & \text{sexnewcf} * \text{sexnew} + \\ & \text{admfacfcf} * \text{admfacfcf} + \\ & \text{admfsnfcf} * \text{admfsnfcf} + \\ & \text{eradmcf} * \text{eradm} + \\ & \text{riskdx1cf} * \text{riskdx1} + \\ & \text{riskpxcf} * \text{riskpx} + \\ & \text{riskdx2cf} * \text{riskdx2} + \\ & \text{dx1dx2intcf} * \text{dx1dx2int} + \\ & \text{dx1pxintcf} * \text{dx1pxint} + \\ & \text{beds1cf} * \text{beds1} + \\ & \text{beds2cf} * \text{beds2} + \\ & \text{beds3cf} * \text{beds3} + \\ & \text{beds4cf} * \text{beds4} + \\ & \text{teachcf} * \text{teach} + \\ & \text{urbanfcf} * \text{urban} + \end{aligned}$$



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 cahcf \* cah +  
 childcf \* child +  
 womenscf \* women +  
 psyrehbcf \* psyrehb +  
 cardiaccf \* cardiac +  
 orthocf \* ortho +  
 othsurgcf \* othsurg +  
 othspeccf \* othspec +  
 specunasgcf \* specunasgn

From this equation, the “preliminary” expected mortality probability is obtained:

$$\text{Probability} = \frac{1}{1 + e^{-x}}$$

This value is then put through the post-modeling adjustment process, which uses the Clinical Classification Software (CCS) from the Agency for Healthcare Research and Quality (AHRQ). The process involves assigning a CCS category based on the principal diagnosis (CCSDX) for a patient discharge. The CCSDX has an associated adjustment factor, which is then applied to the patient’s “preliminary” expected mortality probability. The adjustment factor is derived using nationally representative inpatient data and calculating a ratio of observed mortality to expected mortality. That is adjusted by a z-score if it is an outlier.

The computed probability represents the risk of death for a single discharge. By summing this probability for all of a hospital’s discharges for a given period, one may obtain the number of expected deaths over that period.

For low-risk patients, Diseases and Disorders of the Eye (MDC 2), Pregnancy (MDC 14), Mental Disorders (MDC 19), and Alcohol/Drug Use (MDC 20), the overall risk of death for each age group is calculated for the expected values instead of the modeled risk of death.

The intercept and the variables whose names end in cf are regression coefficients that we compute for every fiscal year. The indicator variables are assigned according to the following rules.

## MODEL SPECIFICATION TABLES

### AGE REFERENCE GROUP FOR AGE LESS THAN 65 IS 29 DAYS TO 1 YEAR

Indicator Variable	Rule
age1rami	1 if age 1-4, else zero
age2rami	1 if age 5-14, else zero
age3rami	1 if age 15-24, else zero
age4rami	1 if age 25-34, else zero
age5rami	1 if age 35-44, else zero
age6rami	1 if age 45-54, else zero
age7rami	1 if age 55-64, else zero

#### AGE REFERENCE GROUP FOR AGE 65 OR GREATER IS 65-69

Indicator Variable	Rule
age9rami	1 if age 70-74, else zero
age10rami	1 if age 75-79, else zero
age11rami	1 if age 80-84, else zero
age12rami	1 if age 85 or older, else zero

Indicator Variable	Rule
sex	1 if female, zero if male
admfac	1 if admitted from another acute care facility, else zero
admfnsf	1 if admitted from a skilled nursing facility, else zero
eradm	1 if admitted through the Emergency Department, else zero

Indicator Variable	Rule
riskdx1	Principal diagnosis risk, see below
riskpx	Any procedure risk, see below
riskdx2	Secondary diagnosis risk, see below
dx1dx2int	Principal diagnosis and secondary diagnosis interaction risk, see below
dx1pxint	Principal diagnosis and any procedure interaction risk, see below

#### DIVISION REFERENCE GROUP IS HOSPITAL IN CT, MA, ME, NH, RI, VT (NEW ENGLAND)

Indicator Variable	Rule
div2	1 if hospital in NJ, NY, PA
div3	1 if hospital in DC, DE, FL, GA, MD, NC, SC, VA, WV
div4	1 if hospital in IL, IN, MI, OH, WI
div5	1 if hospital in AL, KY, MS, TN
div6	1 if hospital in IA, KS, MN, MO, ND, NE, SD
div7	1 if hospital in AR, LA, OK, TX
div8	1 if hospital in AZ, CO, ID, MT, NM, NV, UT, WY
div9	1 if hospital in AK, CA, HI, OR, WA

#### BEDS REFERENCE GROUP IS HOSPITAL BED COUNT LESS THAN 100

Indicator Variable	Rule
beds1	1 if hospital has 100-199 beds, else zero
beds2	1 if hospital has 200-299 beds, else zero
beds3	1 if hospital has 300-499 beds, else zero
beds4	1 if hospital has 500 or more beds, else zero

REFERENCE GROUP IS SHORT TERM GENERAL NON FEDERAL HOSPITAL (STGNF)

Indicator Variable	Rule
teach	1 if teaching hospital, else zero
urban	1 if hospital located in an urban area, else zero
cah	1 if hospital is a Critical Access Hospital, else zero
child	1 if is a Children's specialty hospital, else zero
women	1 if is a Woman's specialty hospital, else zero
psyrehb	1 if is a Psych, rehab or substance abuse specialty hospital else zero
cardiac	1 if is a Cardiac specialty hospital, else zero
ortho	1 if is a Orthopedic specialty hospital, else zero
othsurg	1 if is an Other Surgery specialty hospital, else zero
othspec	1 if ia an Other specialty hospital, else zero
specunasgn	1 if is not a STGNF but the specialty cannot be assigned, else zero

The variables riskdx1, riskpx, riskdx2, dx1dx2int, and dx1pxint are obtained from Thomson Reuters' normative databases and represent the risk of death for a patient having a particular diagnosis or procedure, or the interaction of diagnosis and procedure codes. The value for riskdx1 is obtained from a table containing these risks for the principal diagnosis. The value for riskdx2 is the risk factor for the secondary diagnosis with the greatest risk of mortality; the value of riskpx is the risk factor for any procedure with the greatest risk of mortality. The dx1dx2int and dx1pxint are the maximum risk associated with a principal diagnosis and secondary diagnosis, or any procedure combination.

In addition to the riskdx and riskpx variables as defined above, there are some ICD-9-CM diagnoses and procedure codes that have their death rate set to zero. The table in Appendix A: Zero Risk of Death ICD-9-CM Diagnosis Codes contains a comprehensive list of the diagnosis codes. Appendix B: Zero Risk of Death ICD-9-CM Procedure Codes contains a comprehensive list of the procedure codes.

## MODEL PERFORMANCE

The percent of cases classified correctly is measured by sensitivity, specificity, and percent correct, each factor taking a slightly different perspective:

- Sensitivity measures the percent of patients correctly classified among those that experience the outcome.
- Specificity refers to the percent of patients correctly classified among those that did not experience the outcome.
- Percent correct describes the percent of patients whose predicted outcome matches their actual experience, regardless of whether they experienced the outcome.

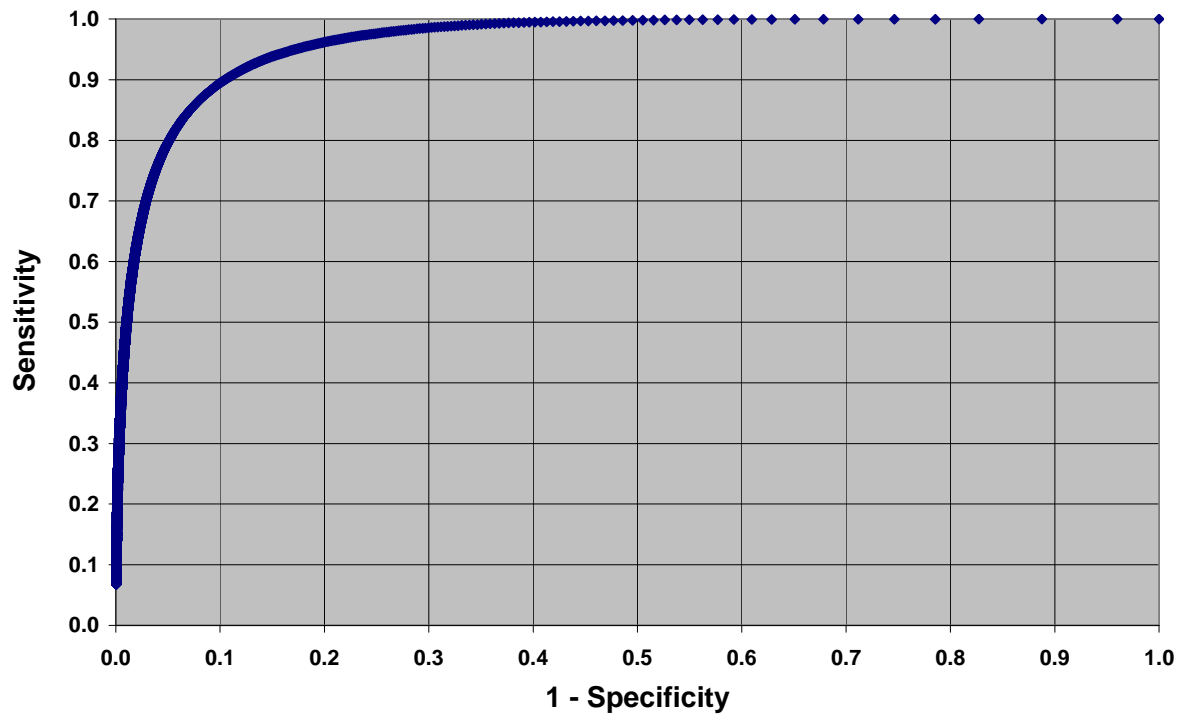
All three of these summary statistics use the observed outcome rate as the threshold, or cutoff value, for assigning the predicted outcome.

## THE C-STATISTIC

The c-statistic has gained popularity as an important model discrimination statistic. Suppose all possible pairs are made such that one patient experiences a death and the other does not. The c-statistic can be defined as the proportion of pairs where the probability of death is higher for the patient who dies than for one who did not. The c-statistic can also be defined as the area under a receiver operating characteristic (ROC) curve, where the maximum area equals one. The c-statistic is directly related to the model's sensitivity and specificity.

Model	Rate	C-statistic	Percent Correct	Sensitivity	Specificity
Medical , age > = 65	4.67%	0.913	85.1	76.7	89.3
Medical, age < 65	1.02%	0.977	94.3	90.9	94.7
Surgical , age >= 65	2.66%	0.963	91.6	87.5	92.7
Surgical, age < 65	0.78%	0.985	95.7	94.4	95.8

ROC Graph of RAMI for In-Hospital Death



## APPENDIX A: ICD-9-CM DIAGNOSIS CODES WHERE RISK OF DEATH IS SET TO ZERO

Code	Description
2513	Post surgical hypoinsulinemia
3240	Intracranial abscess
3241	Intraspinal abscess
3249	Intracranial and intraspinal abscess of unspecified site
3491	Nervous system complications from surgically implanted device
38330	Postmastoidectomy complication, unspecified
41511	Iatrogenic pulmonary embolism and infarction
45821	hypotension of hemodialysis
5121	Iatrogenic pneumothorax
64662	Infections of genitourinary tract in pregnancy; delivered, with mention of postpartum complication
66510	Rupture of uterus during labor; unspecified as to episode of care or not applicable
66511	Rupture of uterus during labor; delivered, with or without mention of antepartum condition
66800	Pulmonary complications of the administration of anesthetic or other sedation in labor and delivery; unspecified as to episode of care or not applicable.
66801	Pulmonary complications of the administration of anesthetic or other sedation in labor and delivery; delivered, with or without mention of antepartum condition.
66802	Pulmonary complications of the administration of anesthetic or other sedation in labor and delivery; delivered, with mention of postpartum complication.
66803	Pulmonary complications of the administration of anesthetic or other sedation in labor and delivery; antepartum condition or complication.
66810	Cardiac complications of the administration of anesthetic or other sedation in labor and delivery; unspecified as to episode of care or not applicable.
66811	Cardiac complications of the administration of anesthetic or other sedation in labor and delivery; delivered, with or without mention of antepartum condition.
66812	Cardiac complications of the administration of anesthetic or other sedation in labor and delivery; delivered, with mention of postpartum complication.
66813	Cardiac complications of the administration of anesthetic or other sedation in labor and delivery; antepartum condition or complication.
66820	CNS complications of the administration of anesthetic or other sedation in labor and delivery; unspecified as to episode of care or not applicable.
66821	CNS complications of the administration of anesthetic or other sedation in labor and delivery; delivered, with or without mention of antepartum condition.
66822	CNS complications of the administration of anesthetic or other sedation in labor and delivery; delivered, with mention of postpartum complication.
66823	CNS complications of the administration of anesthetic or other sedation in labor and delivery; antepartum condition or complication.
66880	Other complications of anesthesia or other sedation in labor and delivery; unspecified as to episode of care or not applicable.
66881	Other complications of anesthesia or other sedation in labor and delivery; delivered, with or without mention of antepartum condition.
66882	Other complications of anesthesia or other sedation in labor and delivery; delivered, with mention of postpartum complication.

Code	Description
66883	Other complications of anesthesia or other sedation in labor and delivery; antepartum condition or complication.
66890	Unspecified complication of anesthesia or other sedation in labor and delivery; unspecified as to episode of care or not applicable.
66891	Unspecified complication of anesthesia or other sedation in labor and delivery; delivered, with or without mention of antepartum condition.
66892	Unspecified complication of anesthesia or other sedation in labor and delivery; delivered, with mention of postpartum complication.
66893	Unspecified complication of anesthesia or other sedation in labor and delivery; antepartum condition or complication.
66912	Shock during or following labor and delivery; delivered, with mention of postpartum complication.
66932	Acute renal failure following labor and delivery; delivered, with mention of postpartum complication.
67002	Major puerperal infection; delivered, with mention of postpartum complication.
67142	Deep vein thrombosis, postpartum; delivered, with mention of postpartum complication.
67322	Obstetrical blood-clot embolism; delivered, with mention of postpartum complication.
67332	Obstetrical pyemic and septic embolism; delivered, with mention of postpartum complication.
67412	Disruption of cesarean wound; delivered, with mention of postpartum complication.
67422	Disruption of perineal wound; delivered, with mention of postpartum complication.
99700	Nervous system complications, unspecified
99701	Central nervous system complication
99702	Iatrogenic cerebrovascular infarction or hemorrhage
99709	Other nervous system complications
9971	Cardiac complications
9972	Peripheral vascular complications
9973	Respiratory complications
9974	Digestive system complications
9975	Urinary complications
99799	Other complications affecting specified body systems, NEC
9980	Postoperative shock
9981	Hemorrhage or hematoma complicating a procedure (no longer valid)
99811	Hemorrhage complicating a procedure
99812	Hematoma complicating a procedure
99813	Seroma complicating a procedure
9982	Accidental puncture or laceration during a procedure
99831	Disruption of internal operation wound
99832	Disruption of external operation wound
9984	Foreign body accidentally left during a procedure
9985	Postoperative infection (no longer valid)
99851	Infected postoperative seroma
99859	Other postoperative infection
9987	Acute reaction to foreign substance accidentally left during a procedure
99883	Non-healing surgical wound
99889	Other specified complications of procedures, NEC
9989	Unspecified complication of procedure, NEC
9991	Air embolism following infusion, perfusion, or transfusion
9992	Other vascular complications following infusion, perfusion, or transfusion
9993	Other infection following infusion, injection, transfusion, or vaccination
9994	Anaphylactic shock due to serum

Code	Description
9995	Other serum reaction
9996	ABO incompatibility reaction
9997	Rh incompatibility reaction
9998	Other transfusion reaction



## APPENDIX B: ICD-9-CM PROCEDURE CODES WHERE RISK OF DEATH IS SET TO ZERO

Code	Description
0123	Reopening of craniotomy site
0302	Reopening of laminectomy site
0475	Revision of previous repair of cranial and peripheral nerves
0602	Reopening of wound of thyroid field
1152	Repair of postoperative wound dehiscence of cornea
1266	Postoperative revision of scleral fistulization procedure
3403	Reopening of recent thoracotomy site
3941	Control of hemorrhage following vascular surgery
5412	Reopening of recent laparotomy site
5461	Reclosure of postoperative disruption of abdominal wall
6094	Control of postoperative hemorrhage of prostate
7562	Repair of current obstetric laceration of rectum and sphincter ani
7591	Evacuation of obstetrical incisional hematoma of perineum

## APPENDIX C: RAMI EXCLUSION CODES

### STANDARD EXCLUSION CODES

Code	Code Description
0000	Not Excluded
1001	Unable to Get Hospital Characteristics
1002	Invalid Division Code
1003	Invalid Teaching Indicator
1004	Invalid Urban Indicator
1006	Government Federal Hospital
1007	Bed Size < 6
1011	Invalid Specialty Type
1501	Invalid Sex Code
1503	Invalid Age (not in 0 - 124)
2001	Discharge Date Non-Numeric
2002	Discharge Date Earlier Than 1993
2003	Invalid Discharge Month Field
2004	Invalid Discharge Day Field
2501	Discharge To Other Short Term Facility
2502	Invalid Or Unknown Disposition
3502	Invalid Length Of Stay > 365 Days
4004	DRG 469,470 Invalid Principal Diagnosis Or Ungroupable
4503	RDRG 4700, Ungroupable
4504	Invalid RDRG Severity (RGN[4])
5010	Age > 50 and Diagnosis is 277.0-277.01
5011	Age < 20 and Diagnosis is 290.4-290.43
5013	Age < 35 and Diagnosis is 366.1-366.19, 366.9
5014	Age < 10 or > 55 and Diagnosis is 626-626.5
5015	Age < 13 and Diagnosis is 627-627.9
5016	Age < 10 or > 55 and Diagnosis is 630-676.94
5017	Age>1 and Diagnosis in (750.5, 760-7760.70, 760.72-760.74, 760.77-779.9)
5504	(Male or 55 < Age < 10) and Procedure is 662x, 663x, 6662 or 6663
5505	(Male or 55 < Age < 10) and Procedure is 6901, 6902, 6951, 6952 or 72-7599

## RAMI EXCLUSION CODES

Code	Description
1013	Spec_type =4 (Psych, Substance Abuse, Rehab)
1014	Spec_type =8 (Cancer)
1015	Spec_type=B (Long Term Acute Care (LTAC))
1513	Age < 29 Days or > 124 Years
3013	Encounter for palliative care
4012	DRG 468 Extensive OR Procedure Unrelated To Principal Diagnosis
4013	DRG 477 Nonextensive OR Procedure Unrelated To Principal Diagnosis
4015	DRG Not Surgical Or Medical
5001	No Diagnosis Codes
5601	Principal Diagnosis Has No Death Rate
5602	Secondary Diagnosis Has No Death Rate
5605	Procedure Has No Entry On Rate Table

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