

Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eTable 1: International Classification of Disease, Ninth Revision, Clinical Modification Codes Used to Define Heart Failure, Acute Myocardial Infarction, and Pneumonia Cohorts.

| Cohort name | Constituent ICD-9-CM codes |
|-----------------------------|--|
| Heart failure | 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.xx |
| Acute myocardial infarction | 410.xx excluding those with 410.x2 (AMI, subsequent episode of care) |
| Pneumonia | 480.x, 481, 482.xx, 483.x, 485, 486, 487.0, and 488.11 |

ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification

eTable 2: Modified Condition Category Constituents.

| Modified condition category number and name | Constituent CMS condition category codes | Additional ICD-9-CM diagnostic codes |
|--|--|--|
| 1 - Heart failure | 80 | |
| 2 - Acute myocardial infarction | 81 | |
| 3 - Unstable angina and other acute ischemic heart disease | 82 | |
| 4 - Chronic angina and coronary artery disease | 83, 84 | |
| 5 - Valvular/rheumatic heart disease | 86 | |
| 6 - Other cardiac disease including congenital heart and hypertensive disease | 85, 87, 88, 94, 89, 90, 91 | |
| 7 - Arrhythmias and conduction disorders | 92, 93 | |
| 8 - Pleural effusion/pneumothorax | 114 | |
| 9 - Chest pain | N/a (constituent ICD-9-CM codes on right) | 788.50, 788.59 |
| 10 - Syncope | N/a (constituent ICD-9-CM codes on right) | 780.2 |
| 11 - Acute stroke/transient ischemic attack | 95, 96, 97 | |
| 12 - Pulmonary embolism/deep venous thrombosis | N/a (constituent ICD-9-CM codes on right) | 415.1, 415.11, 415.19, 453.4, 453.40, 453.41, 453.42, 453.8, 453.81, 453.82, 453.83, 453.84, 453.85, 453.86, 453.87, 453.89, 453.9 |
| 13 - Other peripheral vascular disease | 104, 105, 106 (excluded ICD-9-CM codes on right) | Exclude 415.1, 415.11, 415.19, 453.4, 453.40, 453.41, 453.42, 453.8, 453.81, 453.82, 453.83, 453.84, 453.85, 453.86, 453.87, 453.89, 453.9 |
| 14 - Cardio-respiratory failure | 77, 78, 79 | |
| 15 - Chronic obstructive pulmonary disease/asthma | 108, 110 | |
| 16 - Pneumonia including aspiration pneumonitis | 111, 112, 113 | |
| 17 - Septicemia/shock | 2 | |
| 18 - Urinary tract infection and urinary system complaints | 135 | |
| 19 - Cellulitis | 152 | |
| 20 - Clostridium difficile-associated infection | N/a (constituent ICD-9-CM codes on right) | 8.45 |
| 21 - Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 131, 23 | |
| 22 - Anemia | 47 | |
| 23 - Gastrointestinal hemorrhage | N/a (constituent ICD-9-CM codes on right) | 531.0, 531.00, 531.01, 531.2, 531.20, 531.21, 531.40, 531.41, 531.6, 531.60, 531.61, 532.0, 532.00, 532.01, 532.2, 532.20, 532.21, 532.4, 532.40, 532.41, 532.6, 532.60, 532.61, 533.0, 533.00, 533.01, 533.2, 533.20, 533.21, 533.4, 533.40, 533.41, 533.6, 533.60, 533.61, 534.0, 534.00, 534.01, 534.2, 534.20, 534.21, 534.4, 534.40, 534.41, 534.6, 534.60, 534.61, 535.01, 535.11, 535.41, 535.51, 535.61, 562.02, 562.12, 569.3, 578, 578.0, 578.1, 578.9 |
| 24 - Diabetes and its complications | 15, 16, 17, 18, 19, 20 | |
| 25 - Fibrosis of lung and other chronic lung disorders | 109 | |
| 26 - Hip fracture | 158 | |
| 27 - Complications of care | 163, 164, 165 | |
| 28 - Other lung disorders including acute, congenital, and unspecified lung abnormalities | 115 (additional ICD-9-CM codes on right) | 788.0, 788.00, 788.01, 788.02, 788.05, 788.06, 788.9 |
| 29 - Primary cancer of the trachea, bronchus, lung, and pleura | N/a (constituent ICD-9-CM codes on right) | 162.9, 162.3, 162.5, 162.9, 162.2, 162.4 |
| 30 - Other admitting diagnoses | See below | See below |

| | | |
|---|--|---|
| Constituents of modified condition category 30 - other admitting diagnoses | 1, 3, 4, 5, 6 | |
| Other infections | 7, 8, 9, 10, 11, 12, 13, 14 | |
| Cancer | 21, 22, 24 | |
| Endocrine/metabolic | 25, 26, 27, 28, 29 | |
| Liver disease | 30, 31, 32, 33, 34, 35, 36 (Excluded ICD-9- CM codes on right) | Exclude 531.0, 531.00, 531.01, 531.2, 531.20, 531.21, 531.40, 531.41, 531.6, 531.60, 531.61, 532.0, 532.00, 532.01, 532.2, 532.20, 532.21, 532.4, 532.40, 532.41, 532.6, 532.60, 532.61, 533.0, 533.00, 533.01, 533.2, 533.20, 533.21, 533.4, 533.40, 533.41, 533.6, 533.60, 533.61, 534.0, 534.00, 534.01, 534.2, 534.20, 534.21, 534.4, 534.40, 534.41, 534.6, 534.60, 534.61, 535.01, 535.11, 535.41, 535.51, 535.61, 562.02, 562.12, 569.3, 578, 578.0, 578.1, 578.9 |
| Digestive (Gastrointestinal) | | |
| Musculoskeletal | 37, 38, 39, 40, 41, 42, 43 | |
| Other hematologic | 44, 45, 46 | |
| Cognitive | 48, 49, 50 | |
| Substance abuse | 51, 52, 53 | |
| Psychiatric | 54, 55, 56, 57, 58, 59, 60 | |
| Development disorders | 61, 62, 63, 64, 65, 66 | |
| Spinal cord | 67, 68, 69 | |
| Neuromuscular | 70, 71, 72, 73, 74, 75, 76 | |
| Non-acute cerebrovascular disease | 98, 99, 100, 101, 102, 103 | |
| Other pulmonary | 107 | |
| Ophthalmologic | 116, 117, 118, 119, 120, 121, 122, 123, 124 | |
| Ear, nose, and throat | 125, 126, 127 | |
| Other renal | 128, 129, 130, 132 | |
| Genitourinary | 133, 134, 136, 137, 138, 139, 140 | |
| Obstetric | 141, 142, 143, 144, 145, 146, 147 | |
| Other dermatologic | 150, 151, 153 | |
| Injury excluding hip fracture | 154, 155, 156, 157, 159, 160, 161, 162 (Excluded ICD-9-CM codes on right) | Exclude 162.9, 162.3, 162.5, 162.8, 162.2, 162.4 |
| Symptoms (major and minor) excluding respiratory | 166, 167 (Excluded ICD-9-CM codes on right) | Exclude 780.2, 786.0, 786.00, 786.01, 786.02, 786.05, 786.06, 786.50, 786.59, 786.9, 780.2 |
| Neonatal | 168, 169, 170, 171, 172 | |
| Organ transplant | 173, 174, 175 | |
| Miscellaneous surgical and non-surgical procedures | 176, 177, 178, 179, 180, 181, 182 | |
| Durable medical equipment | 185, 186, 187, 188, 189 | |
| Other | 183, 184 | |
| Skin ulcer including decubitus ulcer | 148, 149 | |
| Complications of care | 163, 164, 165 | |

CMS: Centers for Medicare & Medicaid Services; ICD-9-CM: International Classification of Diseases, Ninth Revision, Clinical Modification

eTable 3: Modified Condition Categories for Cardiovascular Diagnoses.

Modified condition category codes for cardiovascular diagnoses

- 1 - Heart failure
 - 2 - Acute myocardial infarction
 - 3 - Unstable angina and other acute ischemic heart disease
 - 4 - Chronic angina and coronary artery disease
 - 5 - Valvular/rheumatic heart disease
 - 6 - Other cardiac disease including congenital heart and hypertensive disease
 - 7 - Arrhythmias and conduction disorders
 - 9 - Chest pain
 - 10 - Syncope
 - 11 - Acute stroke/transient ischemic attack
 - 12 - Pulmonary embolism/deep venous thrombosis
 - 13 - Other peripheral vascular disease
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eTable 4: Modified Condition Categories for Pulmonary Diagnoses.

Modified condition category codes for pulmonary diagnoses

- 8 - Pleural effusion/pneumothorax
 - 14 - Cardio-respiratory failure
 - 15 - Chronic obstructive pulmonary disease/asthma
 - 18 - Pneumonia including aspiration pneumonitis
 - 25 - Fibrosis of lung and other chronic lung disorders
 - 28 - Other lung disorders including acute, congenital, and unspecified lung abnormalities
 - 29 - Primary cancer of the trachea, bronchus, lung, and pleura
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eTable 5: Common Comorbidities among 30-Day Readmissions for Patients Hospitalized with Heart Failure, Acute Myocardial Infarction, or Pneumonia.

| Rank | 30-day readmissions after heart failure hospitalization (329,308) | | 30-day readmissions after acute myocardial infarction hospitalization (108,992) | | 30-day readmissions after pneumonia hospitalization (214,239) | |
|------|---|----------------------------|---|----------------------------|---|----------------------------|
| | Comorbidity name | Percentage of readmissions | Comorbidity name | Percentage of readmissions | Comorbidity name | Percentage of readmissions |
| 1 | Coronary atherosclerosis or angina | 76.73% | Congestive heart failure | 64.36% | Gastrointestinal disorders | 62.97% |
| 2 | Specified arrhythmias | 71.34% | Specified arrhythmias | 57.19% | Chronic obstructive pulmonary disease | 62.10% |
| 3 | Iron deficiency or other anemias | 59.67% | Diabetes or associated complications | 48.59% | Iron deficiency or other anemias | 57.73% |
| 4 | Other gastrointestinal disorders | 58.56% | Iron deficiency or other anemias | 46.87% | Coronary atherosclerosis or angina | 53.73% |
| 5 | Vascular or circulatory disease | 56.46% | Disorders of fluid, electrolyte, acid-base | 44.83% | Congestive heart failure | 52.77% |
| 6 | Diabetes or associated complications | 55.12% | Renal failure | 42.14% | Other lung disorders | 52.41% |
| 7 | Disorders of fluid, electrolyte, and acid-base | 53.70% | Valvular or rheumatic heart disease | 38.82% | Disorders of fluid, electrolyte, and acid-base | 52.09% |
| 8 | Renal failure | 52.78% | Chronic obstructive pulmonary disease | 38.23% | Specified arrhythmias | 50.30% |
| 9 | Chronic obstructive pulmonary disease | 52.45% | History of infection | 32.65% | Vascular or circulatory disease | 48.96% |
| 10 | Valvular or rheumatic heart disease | 51.80% | Pneumonia | 32.15% | History of infection | 43.76% |

eTable 6: Ranked 30-Day Readmission Diagnoses by Modified Condition Category for Patients Hospitalized with Heart Failure, Acute Myocardial Infarction, or Pneumonia.

| Rank | 30-day readmissions after heart failure hospitalization (329,308) | | 30-day readmissions after acute myocardial infarction hospitalization (108,992) | | 30-day readmissions after pneumonia hospitalization (214,239) | |
|------|---|----------------------------|---|----------------------------|---|----------------------------|
| | Diagnosis by mCC | Percentage of readmissions | Diagnosis by mCC | Percentage of readmissions | Diagnosis by mCC | Percentage of readmissions |
| 1 | Heart failure | 35.22% | Heart failure | 19.27% | Pneumonia including aspiration pneumonitis | 22.36% |
| 2 | Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 8.11% | Acute myocardial infarction | 9.95% | Heart failure | 8.53% |
| 3 | Pneumonia including aspiration pneumonitis | 4.98% | Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 5.28% | Chronic obstructive pulmonary disease/asthma | 7.51% |
| 4 | Arrhythmias and conduction disorders | 4.04% | Arrhythmias and conduction disorders | 4.95% | Septicemia/shock | 5.95% |
| 5 | Septicemia/shock | 3.55% | Pneumonia including aspiration pneumonitis | 4.89% | Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 5.27% |
| 6 | Cardio-respiratory failure | 3.50% | Chronic angina and coronary artery disease | 4.85% | Cardio-respiratory failure | 4.88% |
| 7 | Chronic obstructive pulmonary disease/asthma | 3.14% | Septicemia/shock | 3.96% | Arrhythmias and conduction disorders | 2.88% |
| 8 | Chronic angina and coronary artery disease | 2.36% | Complications of care | 3.86% | Clostridium difficile-associated infection | 2.54% |
| 9 | Acute myocardial infarction | 2.32% | Cardio-respiratory failure | 3.14% | Urinary tract infection and urinary system complaints | 2.06% |
| 10 | Complications of care | 2.18% | Gastrointestinal hemorrhage | 3.09% | Gastrointestinal hemorrhage | 1.94% |
| 11 | Other peripheral | 2.18% | Acute stroke/transient | 2.88% | Acute stroke/transient | 1.93% |

| | | | | | | |
|----|---|-------|---|-------|--|-------|
| 12 | vascular disease Gastrointestinal hemorrhage | 2.06% | ischemic attack Chest pain | 2.85% | ischemic attack Other peripheral vascular disease | 1.72% |
| 13 | Acute stroke/transient ischemic attack | 2.01% | Other peripheral vascular disease | 2.78% | Complications of care | 1.61% |
| 14 | Valvular/rheumatic heart disease | 1.82% | Chronic obstructive pulmonary disease/asthma | 2.01% | Pulmonary embolism/deep venous thrombosis | 1.60% |
| 15 | Urinary tract infection and urinary system complaints | 1.78% | Urinary tract infection and urinary system complaints | 1.85% | Acute myocardial infarction | 1.46% |
| 16 | Diabetes and its complications | 1.32% | Unstable angina and other acute ischemic heart disease | 1.63% | Primary cancer of the trachea, bronchus, lung, and pleura | 1.26% |
| 17 | Chest pain | 0.93% | Pulmonary embolism/deep venous thrombosis | 1.54% | Pleural effusion/pneumothorax | 1.24% |
| 18 | Hip fracture | 0.89% | Diabetes and its complications | 1.20% | Hip fracture | 1.23% |
| 19 | Clostridium difficile-associated infection | 0.88% | Anemia | 1.11% | Diabetes and its complications | 0.98% |
| 20 | Anemia | 0.88% | Other cardiac disease including congenital heart and hypertensive disease | 0.99% | Chronic angina and coronary artery disease | 0.94% |
| 21 | Cellulitis | 0.74% | Clostridium difficile-associated infection | 0.95% | Fibrosis of lung and other chronic lung disorders | 0.92% |
| 22 | Pulmonary embolism/deep venous thrombosis | 0.65% | Syncope | 0.91% | Anemia | 0.90% |
| 23 | Pleural effusion/pneumothorax | 0.64% | Valvular/rheumatic heart disease | 0.82% | Chest pain | 0.79% |
| 24 | Syncope | 0.62% | Hip fracture | 0.69% | Cellulitis | 0.71% |
| 25 | Other cardiac disease including congenital heart and hypertensive disease | 0.56% | Pleural effusion/pneumothorax | 0.64% | Other lung disorders including acute, congenital, and unspecified lung abnormalities | 0.58% |
| 26 | Other lung disorders including acute, congenital, and unspecified lung | 0.28% | Cellulitis | 0.53% | Syncope | 0.55% |

| | | | | | | |
|----|--|--------|--|--------|---|--------|
| 27 | abnormalities Fibrosis of lung and other chronic lung disorders | 0.26% | Other lung disorders including acute, congenital, and unspecified lung abnormalities | 0.27% | Other cardiac disease including congenital heart and hypertensive disease | 0.42% |
| 28 | Primary cancer of the trachea, bronchus, lung, and pleura | 0.18% | Primary cancer of the trachea, bronchus, lung, and pleura | 0.23% | Valvular/rheumatic heart disease | 0.39% |
| 29 | Unstable angina and other acute ischemic heart disease | 0.12% | Fibrosis of lung and other chronic lung disorders | 0.16% | Unstable angina and other acute ischemic heart disease | 0.09% |
| 30 | Other | 11.82% | Other | 12.70% | Other | 17.13% |

mCC: modified condition category

eTable 7: Association of Readmission Diagnoses by Modified Condition Category with Median Time to Readmission for Patients Hospitalized with Heart Failure, Acute Myocardial Infarction, or Pneumonia.

| Reason for index hospitalization | Top 5 readmission diagnoses by modified condition category | Median time to readmission in days (Q1-Q3 in days) |
|----------------------------------|---|--|
| Heart failure | Heart failure | 13 (6-21) |
| | Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 11 (6-19) |
| | Pneumonia including aspiration pneumonitis | 12 (6-20) |
| | Arrhythmias and conduction disorders | 12 (6-20) |
| | Septicemia/shock | 11 (5-19) |
| Acute myocardial infarction | All heart failure readmissions | 12 (6-20) |
| | Heart failure | 10 (4-18) |
| | Acute myocardial infarction | 9 (4-17) |
| | Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 11 (6-19) |
| | Arrhythmias and conduction disorders | 10 (4-18) |
| Pneumonia | Pneumonia including aspiration pneumonitis | 9 (4-18) |
| | All acute myocardial infarction readmissions | 10 (4-18) |
| | Pneumonia including aspiration pneumonitis | 11 (5-19) |
| | Heart failure | 12 (6-20) |
| | Chronic obstructive pulmonary disease/asthma | 14 (7-21) |
| | Septicemia/shock | 12 (6-20) |
| | Renal disorders including renal failure and fluid, electrolyte, and acid-base abnormalities | 11 (6-19) |
| All pneumonia readmissions | 12 (6-20) | |

eTable 8: Association of Patient Characteristics with the Comorbidity-adjusted Odds of Readmission for Common Readmission Diagnoses by Modified Condition Category for Patients Hospitalized with Heart Failure, Acute Myocardial Infarction, or Pneumonia.

| Reason for readmission by modified condition category | Odds ratio by patient age in years (95% CI) | | | Odds ratio by patient sex (95% CI) | | Odds ratio by patient race (95% CI) | | |
|---|---|-------------------|-------------------|------------------------------------|-------------------|-------------------------------------|-------------------|-------------------|
| | 65-74 | 75-84 | ≥85 | Male | Female | White | Black | Other |
| Heart failure cohort | | | | | | | | |
| Heart failure | 1 | 0.99 (0.97, 1.01) | 1.07 (1.05, 1.10) | 1 | 0.98 (0.95, 0.98) | 1 | 1.22 (1.19, 1.25) | 1.07 (1.03, 1.11) |
| Renal disorders | 1 | 1.04 (1.00, 1.07) | 1.06 (1.03, 1.10) | 1 | 1.01 (0.98, 1.04) | 1 | 1.05 (1.01, 1.09) | 1.01 (0.95, 1.07) |
| Pneumonia | 1 | 1.21 (1.16, 1.27) | 1.59 (1.51, 1.68) | 1 | 0.81 (0.78, 0.84) | 1 | 0.74 (0.70, 0.79) | 0.92 (0.85, 0.99) |
| Arrhythmias and conduction disorders | 1 | 0.93 (0.89, 0.97) | 0.77 (0.73, 0.81) | 1 | 1.15 (1.11, 1.20) | 1 | 0.78 (0.74, 0.83) | 0.81 (0.74, 0.89) |
| Septicemia/shock | 1 | 1.16 (1.10, 1.22) | 1.26 (1.20, 1.34) | 1 | 0.91 (0.87, 0.94) | 1 | 1.00 (0.95, 1.06) | 1.22 (1.13, 1.33) |
| Cardiovascular diagnoses | 1 | 0.96 (0.94, 0.97) | 0.95 (0.93, 0.97) | 1 | 0.99 (0.97, 1.00) | 1 | 1.15 (1.12, 1.17) | 1.03 (0.99, 1.06) |
| Acute myocardial infarction cohort | | | | | | | | |
| Heart failure | 1 | 1.18 (1.14, 1.23) | 1.44 (1.38, 1.50) | 1 | 1.07 (1.04, 1.10) | 1 | 0.99 (0.94, 1.05) | 1.05 (0.98, 1.13) |
| Acute myocardial infarction | 1 | 1.04 (0.99, 1.09) | 1.51 (1.43, 1.60) | 1 | 0.90 (0.87, 0.94) | 1 | 1.03 (0.98, 1.10) | 1.03 (0.94, 1.14) |
| Renal disorders | 1 | 1.15 (1.07, 1.23) | 1.18 (1.09, 1.27) | 1 | 0.98 (0.91, 1.01) | 1 | 1.39 (1.28, 1.51) | 1.10 (0.97, 1.25) |
| Arrhythmias and conduction disorders | 1 | 0.95 (0.89, 1.02) | 0.83 (0.77, 0.90) | 1 | 0.90 (0.85, 0.95) | 1 | 0.58 (0.51, 0.65) | 0.84 (0.73, 0.96) |
| Pneumonia | 1 | 1.21 (1.12, 1.30) | 1.58 (1.44, 1.68) | 1 | 0.69 (0.65, 0.73) | 1 | 0.91 (0.82, 1.01) | 0.97 (0.84, 1.11) |