**The Hospital Frailty Risk Score and its association with in-hospital mortality, cost, length of stay and discharge location in patients with heart failure**

Short running title: Frailty and outcomes in heart failure

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**Abstract**

**Background:** Little is known about frailty amongst patients hospitalized with heart failure (HF) on a national level.

**Methods:** We conducted a retrospective cohort study of patients admitted to hospital for HF in the United States. We examined how low, intermediate and high risk of frailty as defined by the Hospital Frailty Risk Score has changed over time and how it is related to inpatient mortality, length of stay, cost and discharge location.

**Results:** We included 11,626,400 inpatient episodes for HF. The proportions of patients that had low risk, intermediate and high risk of frailty were 80.0% (n=9,300,873), 19.9% (n=2,314,001) and 0.1% (n=11,526). Intermediate or high risk of frailty increased from 9.9% in 2004 to 31.7% in 2014. Length of stay in hospital was greater in the high compared to low risk groups (11.3 days vs 4.6 days, respectively). The cost of admission was also greater in the high risk group ($23,084±39,681) compared to the low risk group ($9,103±12,768). Intermediate and high risk of frailty groups were associated with increased in odds of mortality (OR 2.38 95% CI 2.22-2.34, p<0.001 and OR 3.05 95%CI 2.57-3.62, p<0.001, respectively) and discharge to nursing facilities (intermediate risk OR 1.52 95%CI 1.50-1.54, p<0.001 and high risk OR 1.60 95%CI 1.35-1.90, p<0.001).

**Conclusions:** Frailty is significant and increasing in a national cohort of patients with HF in the United States. Patients at higher risk of frailty have increased in-hospital mortality, length of stay and inpatient costs, and a greater proportion are discharged to nursing home.

**Keywords:** heart failure; frailty; mortality; cost

**Introduction**

Frailty is defined as a clinically recognizable state of increased vulnerability resulting from a decline in reserve and function across multiple physiological systems.[1] It overlaps considerably with age[2] and multi-morbidity.[3] Frailty is common in patients with heart failure, ranging from 15-74%.[4]

Frailty in chronic heart failure is associated with higher mortality and hospitalization[5] and a worse quality of life.[6] Frailty can make the diagnosis and treatment of heart failure challenging as symptoms of weakness, fatigue, sarcopenia and breathlessness encountered in frailty mirror those observed in heart failure.[7] The identification of frailty in people with heart failure is important as a comprehensive approach with interventions to manage domains such as mobility, strength, balance, motor processing cognition, nutrition, endurance and physical activity may provide benefit to frail patients with heart failure.[8] While many studies have evaluated the prognostic impact of frailty in heart failure, the literature is limited to small studies, with the largest recent review of frailty in heart failure consisting of 758 patients.[9] Furthermore, there is a lack of a gold standard for assessing frailty in a heart failure population.[10]

The Hospital Frailty Risk Score (HFRS), a score utilising International Statistical Classification of Diseases and Related Health Problems (ICD) codes, was developed to identify patients at low, intermediate and high risk of frailty.[11] It was derived from data in over 1 million elderly patients in the United Kingdom and is based on electronic health records and was validated against the Fried and Rockwood frailty scales.[11] To date, frailty has not been assessed in people with heart failure on a national level in any setting and little is known about frailty in an acute heart failure cohort. Furthermore, little is known about the association between HFRS and in-hospital mortality, length of stay, cost and discharge location in patients admitted with heart failure.

In this study, we examine the HFRS in a national acute care hospital cohort admitted with heart failure in the United States. We examine temporal trends in the risk of frailty as defined by the HFRS, and associations between risk of frailty and inpatient mortality, length of stay, cost and discharge location.

**Methods**

We conducted a retrospective cohort study of patients admitted to hospital in the United States using data from the National Inpatient Sample (NIS). This dataset is the largest all-payer inpatient health care database, which was created by the Agency for Healthcare Research and Quality’s (AHRQ) Healthcare Cost and Utilization Project (HCUP). Data for the years 2004 to 2014, which were used for the current analysis, contains information from 7 to 8 million hospital discharges per year.[12] The NIS dataset contains patient demographic variables, AHRQ comorbidity measures, hospital variables, ICD-9 diagnostic codes (15 between 2004 and 2008, 25 between 2009 and 2013 and 30 in 2014) and 15 procedure codes.

All individuals aged 18 years or over with a primary diagnosis of heart failure between January 2004 and December 2014 were included. Heart failure was defined by the ICD-9 codes 40201 40211 40291 40401 40403 40411 40413 40413 40491 40493 428\*.

Frailty was defined by the Hospital Frailty Score as previously described.[11] While the score was previously derived from ICD-10 codes, only ICD-9 codes were available in the 2004 to 2014 NIS dataset. Our mapping of the codes from ICD-10 to ICD-9, along with the weights applied for each variable, are shown in Supplementary Table 1. For each of the elements in the score there was a weighting derived by Gilbert et al and the score was derived by summing all the individual weighted elements. We used the cutoffs for the low (<5), intermediate (5-10) and high (>15) risk of frailty as they were defined in the original derivation of the Hospital Frailty Score.[11]

We collected data on patient demographics, which included age, sex, ethnicity, and median household income defined by ZIP code, as well as details regarding the admission (weekend or weekday). We used the Agency for Healthcare Research and Quality (AHRQ) comorbidity measures, defined by the Elixhauser comorbidity software;[13] they included hypertension, diabetes, obesity, congestive heart failure, peripheral vascular disease, chronic lung disease, liver disease, peptic ulcer disease, and cancer. We used ICD-9 diagnostic codes to define smoking (V1582, 3051), hypercholesterolemia (2720/2724), coronary artery disease (41400/41407), previous myocardial infarction (412), previous percutaneous coronary intervention (PCI) (V4582), previous coronary artery bypass graft surgery (CABG) (V4581), atrial fibrillation (42731), previous stroke (V1254 438\*), dementia (290\* 2941\* 2942\* 2948 3310/3312 33182 797), cardiogenic shock (78551) cardiac arrest (4275), ventilation (9601 9602 9603 9604 9605 967\*), LV assist device/IABP (376\* 9744), vasopressor use (0017), coronary angiogram (8855 3722 3723 8854 8853 8856), PCI, CABG (361\* 362 3631 3632 369\*), pacemaker or ICD insertion (3780 3781 3782 3783 0050 3794 3796), CRT device (0050 0051 0053 0054) and heart transplant (3751). Leukemia was defined by Clinical Classification Software (CCS) code 39. We collected characteristics including urban versus rural designation and number of beds per hospital. We used the Charlson Comorbidity Index, derived according to previous published methodology, as a measure of comorbidity.[14]

Statistical analysis was performed on Stata 14 (College Station, TX, USA). A flow diagram was used to illustrate patient inclusion and patients with missing data for age, sex and in-hospital death were excluded. Discharge weights were applied to individual records to obtain national estimates. We examined trends in frailty risk over time in the overall cohort as well as the subgroups according to age (≤75 years or >75 years), sex and race (White, Black and other). Further trends in mortality rate over time were explored according to frailty risk. Descriptive statistics were presented according to frailty risk group. The breakdown of the prevalence of variables within the Hospital Frailty Risk score with >1% prevalence was examined in a table. Multiple logistic regression with adjustments were used to identify factors associated with frailty. The independent odds of in-hospital mortality were explored with multiple logistic regression for the full cohort and the cohort excluding high risk patients with cardiogenic shock, cardiac arrest, ventilation, LV assist device or IABP or vasopressor use. Additional multiple logistic regressions were used to determine the independent association between frailty and discharge to nursing facilities, use of ICD and CRT.

**Results**

A total of 11,626,400 inpatient episodes for heart failure were included in the analysis (Supplementary Figure 1). The proportion of patients that had low risk, intermediate and high risk of frailty was 80.0% (n=9,300,873), 19.9% (n=2,314,001) and 0.1% (n=11,526). The proportion of patients with intermediate risk of frailty increased from 9.9% in 2004 to 31.7% in 2014 (Figure 1). Over the same period patients at high risk of frailty increased from 0.03% to 0.21%. Supplementary Figure 2 shows the trends in any frailty according to age, sex and race. At all time-points, there was a significantly greater prevalence of patients with intermediate or high frailty in those >75 years old (compared to patients age ≤75 years) and a higher prevalence of frailty among females compared to males. Patients who were Caucasian had a greater prevalence of frailty compared to black patients or those of other ethnicities. The variables in the hospital frailty score with greater than 1% prevalence are shown in Supplementary Table 2. We examined the changes in age, highly weighted variables (weight >3) in the Hospital Frailty Risk score and highly prevalent variables (>10%) in Supplementary Table 3. In general, the highly prevalent variables in general increased in prevalence over time.

The characteristics, comorbidities, management and outcomes of heart failure patients according to frailty status are shown in Table 1. Increasing frailty status was associated with an increasing mean age of patients, that increased from 72 years, 76 years and 81 years for the low risk, intermediate risk and high risk of frailty respectively. The proportion of female patients increased with increasing frailty risk (49.9%, 53.4% and 55.9% for low, intermediate and high risk). Patients at high risk of frailty had the greatest proportion of Medicare recipients (88.3%) and lowest proportion of patients with private insurance (6.4%). There was a higher prevalence of previous stroke with increasing frailty which was 6.1%, 11.4% and 17.2% for low risk, intermediate risk and high risk of frailty. A similar increase was observed comparing low, intermediate and high risk of frailty groups for peripheral vascular disease (10.1%, 13.7% and 15.4%, respectively).

The evaluation of factors associated with intermediate or high risk of frailty is shown in Supplementary Table 4. It appears that in more recent years there was a greater odds of patients with frailty (OR 4.87 95%CI 4.73-5.01, p<0.001 comparing 2014 to 2004). Previous heart failure (OR 2.00 95%CI 1.92-2.08, p<0.001), liver disease (OR 1.76 95%CI 1.72-1.81, p<0.001), cardiogenic shock (OR 2.58 95%CI 2.48-2.68, p<0.001), receipt of ventilation (OR 3.91 95%CI 3.82-4.00, p<0.001) and vasopressor use (OR 2.05 95%CI 1.94-2.16, p<0.001) were the factors most strongly associated with frailty.

In-hospital mortality rate increased with greater frailty from 2.2% in the low risk group to 12.7% in the high risk group. Length of stay in hospital was more than double for the high risk compared to low risk group (11.3 days vs 4.6 days, respectively). The cost of admission was also more than double in the high risk group ($23,084±39,681) compared to the low risk group ($9,103±12,768).

The trends in in-hospital mortality according to frailty are shown in Figure 2. There was a clear decline in mortality between 2004 and 2014 in the low risk of frailty (3.05% to 1.51%) and intermediate risk of frailty groups (12.05% to 5.94%). While there was a decline in the high risk of frailty group from 2004 to 2014, the progressive decline was less apparent as the rate of mortality fluctuated across the years.

Overall increased frailty was associated with increased odds of in-hospital mortality (Table 2). Compared to low risk of frailty, intermediate and high risk of frailty were associated with a 2-fold increase in odds of mortality (OR 2.38 95% CI 2.22-2.34, p<0.001 for intermediate risk and OR 3.05 95%CI 2.57-3.62, p<0.001 for high risk). Excluding high risk patients with shock, cardiac arrest, ventilation, LV assist device or IABP or vasopressor use the odds for high compared to low risk of frailty increased 5-fold (OR 4.90 95%CI 3.96-6.08, p<0.001).

After exclusion of patients that died in-hospital and patients that were transferred to another hospital, the rate of patients admitted to nursing facilities after discharge was 25.0% which was 22.9% in the group with low risk of frailty, 36.1% in the group with intermediate risk of frailty and 44.1% in the group with high risk of frailty. After adjustments, compared to low risk of frailty, intermediate risk was associated with 1.5-fold increase in odds of discharge to nursing facilities (OR 1.52 95%CI 1.50-1.54, p<0.001) and high risk was associated with 1.6-fold increase in odds of discharge to nursing facilities (OR 1.60 95%CI 1.35-1.90, p<0.001). Any frailty was associated with a reduction in use of ICD (OR 0.52 95%CI 0.50-0.54, p<0.001) and CRT (OR 0.39 95%CI 0.37-0.40, p<0.001).

**Discussion**

Our study of frailty using a validated risk score has several key findings. First, frailty is common amongst the HF population, with one in five hospital patients admitted with a principle diagnosis of HF have intermediate or high risk of frailty. Second, rates of frailty have increased dramatically over time from 1 in 10 patients in 2004 to 1 in 3 patients at intermediate or high risk of frailty in 2014. Third, while there is a declining trend in in-hospital mortality in the low and moderate risk of frailty group, mortality in the high risk of frailty group mortality rate remains greater than 10%. Fourth, frailty is independently associated with in-hospital mortality and is further associated with increased length of stay, greater cost and discharge to nursing home. Furthermore, frail patients are also less likely to receive evidence-based device therapy such as ICD and CRT devices. These results indicate that considering frailty is important among hospitalized patients with heart failure as these patients have worse survival and are a greater burden to health services and measures to improve outcomes in this high-risk group are needed.

The prevalence and impact of frailty depends on the measure used, the population assessed and its impact on outcomes depends on the timing of follow up. In the emergency department setting, the Frailty-AHF study, which took place in 3 Spanish centres, found that frailty as defined by the Fried criteria was present in 36.3% of the 465 patients age ≥65 years that attended for heart failure without severe functional dependence or dementia.[15] After adjustments for potential confounders this study reported an increase in risk of 30-day mortality (HR 2.5 95%CI 1.0-6.0, p=0.047). In the inpatient setting using the same frailty criteria, the Frail-HF study reported that 76% of patients were classified as frail among 450 non-dependent patients age ≥70 years who were hospitalized with heart failure.[16] In this cohort, there was a 2-fold increase in all-cause mortality (HR 2.13-1.07-4.23). In the community settings using a modified version of the definition used by the Cardiovascular Health Study, a study of 223 heart failure patients found that 21% were frail and 48% were of intermediate frailty. [17] Over a duration of 2.4 years of follow up, there was a 2-fold increase in risk of death among frail compared to non-frail patients.[17] Unlike the studies highlighted, the current study is a national study with a much larger sample size and a different but validated measure for frailty. Our estimate of frailty is more modest (20%) but interestingly the increase in risk of in-hospital mortality is similar to the 2-fold increase in mortality reported by multiple studies with different follow up times.

One of the challenges of assessing frailty is that there is no gold standard assessment.[18] Two approaches have been used to define frailty which includes a deficit model which consists of adding together an individual’s number of impairments and conditions to create a frailty index and a second approach to define a frailty phenotype consisting of 5 possible components (weight loss, exhaustion, weakness, slowness and reduced physical activity) as markers of an underlying physiologic state of multi-systems and energy dysregulation.[19] The Hospital Frailty Risk Score fits into the deficit model, which has the advantage that it is entirely based on ICD codes and it is validated against the Fried and Rockwood scales. Its major drawback is that in the absence of automated computation it is potentially challenging for clinicians to calculate.

While we demonstrate that frailty is common and associated with reduced survival, greater burden to health services and loss of independence, the changes in clinical practice once a patient is identified as high risk of frailty is less clear. There is evidence that frailty may be potentially preventable or treated with specific modalities such as exercise, protein-calorie supplementation, vitamin D and reduction of polypharmacy.[19] In the context of heart failure, it is likely that those patients identified as high risk of frailty need individualized or tailored care to improve quality of life and independence using hospital and community support programs. Even in those frail patients limited by symptoms of advanced heart failure, it is important to adopt a patient-centred approach with education, collaborative decision making, and discussing goals of care.

In the current study, the proportion of patients with high risk of frailty was extremely low (0.1%). While we do not know the exact reason for this, there are few possible explanations. The population which was used to derive the score were hospitalized patients who were age 75 years or older and were non-elective. In the current study, just under half (48.3%) of patients were of age less than 75 years. In addition, the heart failure cohort is non-selective so there were patients with heart failure admissions that were classified as elective (8.8%). In addition, the heart failure cohort is different from the general non-selective elderly population admitted to hospital in terms of prevalence of potential factors contributing frailty risk. Furthermore, while we believe the ICD-9 codes are robust, there may be differences in coding practices on a local level comparing United States (current study) and United Kingdom (derivation study) which may account for a degree of differences in the proportion of frail patients.

One of the key findings of the current study is an increase in the prevalence of frailty through the years of the study. While the exact reason for this is not clear, as the hospital frailty score is based on clinical diagnostic codes, it may relate to the increase in comorbidities in the heart failure population. We observed that overall the average Charlson comorbidity score increased from 1.5 in 2004 to 2.5 in 2014. In addition, the type of comorbidities has changed over time. For example, the most common variable contributing to frailty was chronic kidney disease and it increased from 2.7% in 2004 to 46.9% in 2014 and similar increases were observed for disorders of fluid, electrolyte and acid base balance and acute kidney failure. Finally, improved survival of patients with heart failure will provision of evidence based pharmacotherapy and device based therapies means that patients with heart failure are more likely to survive to develop a frailty phenotype in the future.

We observed a declining trend in in-hospital mortality among heart failure patients which was apparent in the low and intermediate risk groups but not in the high risk group. We believe that trend towards lower mortality over time may reflect better inpatient care in recent years, including broader use of device based therapies and more aggressive medical management of heart failure which could have greater impact on the low and intermediate risk population who are managed more proactively with the best evidence based therapy. This is in contrast to the high risk of frailty population, which may have dementia or other disabilities so patients are managed more conservatively or with palliation and so may have not benefited from provision of advances in evidence based therapies. This is supported by the observation that comorbidity burden among this highest risk group increased significantly which may be a driver of mortality or decisions not to treat aggressively. We observed increases in the comorbidity as defined by the mean Charlson comorbidity index in recent years in all frailty groups but the increase was more much pronounced in the high risk of frailty group (1.5 in 2004 to 2.2 in 2014 in low risk, 1.9 in 2004 to 3.2 in 2014 in intermediate risk and 3.5 in 2004 to 4.3 in 2014). This increase in comorbidity in the highest risk group may tip the balance between benefit and risk of harm from aggressive management, so that the clinicians choose to manage the patient more conservatively.

The current study has several limitations. First, the NIS is constructed without a patient identifier and the analysis is based on hospital episodes with heart failure. Consequently, patients may appear more than once and there is no way of knowing to what extent a patient is counted more than once. Second, only ICD-9 codes were available in this dataset so we had to map the codes from ICD-10 to ICD-9. While differences between coding versions for some conditions exist, there is evidence that ICD-9 and ICD-10 administrative data in recording clinical conditions is similar.[20] However, these codes have the limitation that they do not differentiate between heart failure with reduced and preserved ejection fraction. Third, for any observational data, there is the potential for residual confounding and we cannot prove causality in our associations between frailty and outcome. Fourth, we are unable to assess any of the other validated frailty measures in this cohort because the data to calculate these scores were not available. Another limitation is the potential for miscoding in this large nationally representative dataset. We observed low rates of patients with previous congestive heart failure and cannot exclude the possibility of coding errors. For example, it could be that there were inaccuracies in documentation of existing heart failure in patients with primary admission for heart failure. Finally, a key disadvantage of the current study is the lack of prescription data. This is particularly important as use of evidence-based therapies may contribute to differences in patients’ outcomes. In the community study by Martin-Sanchez et al[15] there was no difference in the use of any medications in acute episode treatment comparing the frail and non-frail groups. There was also no statistical difference in beta-blocker and angiotensin converting enzyme inhibitors reported by the community study by McNallan et al but they did report an increased prevalence of statin use in the more functionally deficit tertile.[17] The consideration of whether medications may differentially improve outcomes according to frailty status in heart failure patients may be a potential area for further research.

**Conclusions**

In conclusion, for the first time we have utilized the Hospital Frailty Risk Score to evaluate the risk of frailty in a national heart failure cohort in the United States and found that 1 in 5 patients are frail and rates are rising. Compared to low risk of frailty patients, patients that are frail have increased in-hospital mortality, length of stay, inpatient costs and a greater proportion are discharged to nursing home. These findings indicate that assessment of frailty in hospitalized patients is important as these patients have worse survival and specific modalities to minimize the impact of frailty such as exercise, protein-calorie supplementation, vitamin D and reduction of polypharmacy should be considered in high risk of frailty groups.

**Author statement**

All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

**Contributors**

CSK and MAM designed the study and concept. CSK performed the data analysis and CSK and MAM wrote the first draft of the manuscript. All authors contributed to the writing of the paper.

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**Figure Legend**

**Figure 1: Trends in frailty risk over time**

**Figure 2: Trends in mortality by frailty risk**

**Table 1: Characteristics of patients according to frailty risk**

**Table 2: Adjusted odds of in-hospital death by frailty group**

**Supplementary Figure 1: Flow diagram of patient inclusion**

**Supplementary Figure 2: Trends in frailty by age, sex and race**

**Supplementary Table 1: Frailty score ICD-10 and ICD-9 codes**

**Supplementary Table 2: Variables with greater than 1% prevalence in the Hospital Frailty Score**

**Supplementary Table 3: Changes in age and prevalent and highly weighted variables in the Hospital Frailty Risk score**

**Supplementary Table 4: Multiple logistic regression model to examine variables associated with any frailty**

**Figure 1: Trends in frailty risk over time**

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**Figure 2: Trends in mortality by frailty risk**

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**Table 1: Characteristics of patients according to frailty risk**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Low frailty risk (n=9,300,873) | Intermediate frailty risk (n=2,314,001) | High frailty risk (n=11,526) | p-value |
| Age (year) | 72±15 (n=9,300,873) | 76±13 (n=2,314,001) | 81±11 (n=11,526) | <0.001 |
| Female | 4,641,520 (49.9%) | 1,235,107 (53.4%) | 6,445 (55.9%) | <0.001 |
| Race | | | | <0.001 |
| White | 5,136,131 (66.8%) | 1,456,848 (71.2%) | 8,027 (74.3%) |  |
| Black | 159,0918 (20.7%) | 340,504 (16.7%) | 1,404 (13.0%) |  |
| Hispanic | 612,159 (8.0%) | 150,806 (7.4%) | 776 (7.2%) |  |
| Asian or Pacific Islander | 42,402 (1.7%) | 41,309 (2.0%) | 30 (2.6%) |  |
| Native American | 171,090 (0.6%) | 9,450 (0.5%) | 336 (0.3%) |  |
| Other | 2,060,387 (2.2%) | 46,435 (2.3%) | 2,916 (2.7%) |  |
| Weekend admission | 2,060,387 (22.2%) | 539,366 (23.3%) | 2,916 (25.3%) |  |
| Year | | | | <0.001 |
| 2004 | 972,942 (10.9%) | 106323 (4.7%) | 341 (3.0%) |  |
| 2005 | 927,095 (10.4%) | 111023 (4.9%) | 237 (2.1%) |  |
| 2006 | 1,005,068 (11.3%) | 140318 (6.2%) | 316 (2.8%) |  |
| 2007 | 903,139 (10.2%) | 162653 (7.2%) | 405 (3.6%) |  |
| 2008 | 839,583 (9.4%) | 178612 (7.9%) | 450 (3.9%) |  |
| 2009 | 776,047 (8.7%) | 221869 (9.8%) | 1,181 (10.4%) |  |
| 2010 | 724,215 (8.1%) | 231364 (10.2%) | 1,418 (12.4%) |  |
| 2011 | 739,799 (8.3%) | 263846 (11.7%) | 1,700 (14.9%) |  |
| 2012 | 679,599 (7.6%) | 257287 (11.4%) | 1,616 (14.2%) |  |
| 2013 | 669,284 (7.5%) | 276316 (12.2%) | 1,661 (14.6%) |  |
| 2014 | 665,172 (7.5%) | 308991 (13.7%) | 2,086 (18.3%) |  |
| Primary expected payer | | | | <0.001 |
| Medicare | 6,805,798 (73.3%) | 1,879,679 (81.3%) | 10,162 (88.3%) |  |
| Medicaid | 761,442 (8.2%) | 143,417 (6.2%) | 435 (3.8%) |  |
| Private insurance | 1,189,804 (12.8%) | 213,027 (9.2%) | 731 (6.4%) |  |
| Self-pay | 327,278 (3.5%) | 41,305 (1.8%) | 84 (0.7%) |  |
| No charge | 33,505 (0.4%) | 3,860 (0.2%) | 0 (0%) |  |
| Other | 167,190 (1.8%) | 29,611 (1.3%) | 94 (0.8%) |  |
| Quartile of household income based on ZIP code | | | | <0.001 |
| 0th-25th | 3,105,603 (34.1%) | 695,079 (30.6%) | 3,119 (27.5%) |  |
| 26th-50th | 2,428,430 (26.7%) | 589,660 (26.0%) | 2,699 (23.8%) |  |
| 51th-75th | 1,987,761 (21.9%) | 533,894 (23.5%) | 2,956 (26.1%) |  |
| 76th-100th | 1,573,926 (17.3%) | 452,738 (19.9%) | 2,565 (22.6%) |  |
| Smoking | 1,860,957 (20.0%) | 470,077 (20.3%) | 1,750 (15.2%) | <0.001 |
| Hypercholesterolemia | 3,267,247 (35.1%) | 838,832 (36.3%) | 4,003 (34.7%) | <0.001 |
| Hypertension | 5,912,950 (63.6%) | 1,500,015 (64.8%) | 7,483 (64.9%) | <0.001 |
| Diabetes | 3,991,413 (42.9%) | 1,011,409 (43.7%) | 4,285 (37.2%) | <0.001 |
| Obesity | 1,260,314 (13.6%) | 358,979 (15.5%) | 1,616 (14.0%) | <0.001 |
| Previous congestive heart failure | 45,061 (0.5%) | 40,766 (1.8%) | 420 (3.6%) | <0.001 |
| Coronary artery disease | 4,308,672 (46.3%) | 1,042,048 (45.0%) | 5,219 (45.3%) | <0.001 |
| Previous myocardial infarction | 1,168,472 (12.6%) | 270,474 (11.7%) | 1,176 (10.2%) | <0.001 |
| Previous PCI | 785,908 (8.5%) | 168,747 (7.3%) | 539 (4.7%) | <0.001 |
| Previous CABG | 1,411,332 (15.2%) | 294,109 (12.7%) | 1,082 (9.4%) | <0.001 |
| Atrial fibrillation | 3,225,864 (34.7%) | 948,684 (41.0%) | 5,684 (49.3%) | <0.001 |
| Valvular heart disease | 22,301 (0.2%) | 17,002 (0.7%) | 188 (1.6%) | <0.001 |
| Peripheral vascular disorders | 940,277 (10.1%) | 315,856 (13.7%) | 1,774 (15.4%) | <0.001 |
| Chronic lung disease | 3,318,970 (35.7%) | 909,480 (39.3%) | 4,181 (36.3%) | <0.001 |
| Hypothyroidism | 1,277,113 (13.7%) | 419,327 (18.1%) | 2,338 (20.3%) | <0.001 |
| Liver disease | 194,764 (2.1%) | 86,583 (3.7%) | 381 (3.3%) | <0.001 |
| Peptic ulcer disease | 2,852 (0.03%) | 989 (0.04%) | 5 (0.04%) | <0.001 |
| Cancer | 235,159 (2.5%) | 64,860 (2.8%) | 321 (2.8%) | <0.001 |
| Charlson Comorbidity Index | 1.9±1.5 (n=9,300,873) | 2.9±1.7 (n=2,314,001) | 4.1±1.8 (n=11,526) | <0.001 |
| Hospital bed size | | | | <0.001 |
| Small | 1,434,349 (15.5%) | 331,306 (14.4%) | 1,661 (14.5%) |  |
| Medium | 2,357,352 (25.4%) | 595,344 (25.9%) | 2,921 (25.4%) |  |
| Large | 5,476,616 (59.1%) | 1,376,230 (59.8%) | 6,900 (60.1%) |  |
| Teaching hospital | 2,880,847 (39.7%) | 585,440 (40.1%) | 2,363 (38.6%) | <0.001 |
| Urban hospital | 8,631,099 (94.1%) | 2,148,689 (94.1%) | 10,859 (95.0%) | 0.060 |
| Cardiogenic shock | 46,331 (0.5%) | 56,434 (2.4%) | 366 (3.2%) | <0.001 |
| Cardiac arrest | 35,937 (0.4%) | 32,991 (1.4%) | 222 (1.9%) | <0.001 |
| Ventilation | 126,152 (1.4%) | 145,013 (6.3%) | 1,315 (11.4%) | <0.001 |
| LV assist device or IABP | 23,600 (0.3%) | 18,885 (0.8%) | 99 (0.9%) | <0.001 |
| Vasopressor use | 19,226 (0.2%) | 20,497 (0.9%) | 138 (1.2%) | <0.001 |
| Coronary angiogram | 680,133 (7.3%) | 124,269 (5.3%) | 400 (3.5%) | <0.001 |
| PCI | 85,332 (2.3%) | 20,403 (1.7%) | 64 (0.9%) | <0.001 |
| CABG | 24,905 (0.3%) | 10,725 (0.5%) | 44 (0.4%) | <0.001 |
| Pacemaker or ICD insertion | 203,760 (2.2%) | 32,349 (1.4%) | 168 (1.5%) | <0.001 |
| CRT device | 219,398 (2.4%) | 20,378 (0.9%) | 59 (0.5%) | <0.001 |
| Heart transplant | 7,765 (0.06%) | 8,664 (0.15%) | 49 (0.13%) | <0.001 |
| In-hospital death | 208,623 (2.2%) | 173,353 (7.5%) | 1,463 (12.7%) | <0.001 |
| Length of stay during index (days) | 4.6±4.7 (n=9,300,542) | 7.9±8.3 (n=2,313,863) | 11.3±12.0 (n=11,526) | <0.001 |
| Cost of admission (USD) | 9,103±12,768 (n=8,186,165) | 15,604±25,889 (n=2128336) | 23,084±39,681 (n=10,864) | <0.001 |

P-values were determined from one-way analysis of variance for continuous variables and Chi2 test for categorical variables.

PCI=percutaneous coronary intervention, CABG=coronary artery bypass graft, LV=left ventricular, IABP=intra-aortic balloon pump, ICD=implantable cardioverter defibrillator, CRT=cardiac resynchronization therapy, USD=United States Dollar

**Table 2: Adjusted odds of in-hospital death by frailty group**

|  |  |  |
| --- | --- | --- |
| Group | Odds ratio (95%CI) | p-value |
| Full heart failure cohort  Low frailty risk  Intermediate frailty risk  High frailty risk | 1.00 (Ref)  2.28 (2.22-2.34)  3.05 (2.57-3.62) | -  <0.001  <0.001 |
| Heart failure cohort excluding high risk patients\*  Low frailty risk  Intermediate frailty risk  High frailty risk | 1.00 (Ref)  3.06 (2.96-3.16)  4.90 (3.96-6.08) | -  <0.001  <0.001 |

Adjusted for age, sex, race, weekend admission, year, primary expected payer, quartile of income, hypertension, hypercholesterolemia, obesity, diabetes, smoking, coronary artery disease, previous myocardial infarction, previous PCI, previous CABG, previous heart failure, atrial fibrillation, valvular heart disease, peripheral vascular disease, chronic lung disease, hypothyroidism, liver disease, peptic ulcer, cancer, hospital bed size, teaching hospital, urban hospital, shock, cardiac arrest, ventilation, left ventricular assist device or intra-aortic balloon pump, vasopressor, coronary angiogram, percutaneous coronary intervention, coronary artery bypass graft, pacemaker or implantable cardioverter defibrillator, cardiac resynchronization therapy and heart transplant.

\*Excluding patients with shock, cardiac arrest, ventilation, left ventricular assist device or intra-aortic balloon pump or vasopressor use

**Supplementary Figure 1: Flow diagram of patient inclusion**

Patients included in the analysis (n=11,626,400)

Frailty in cohort

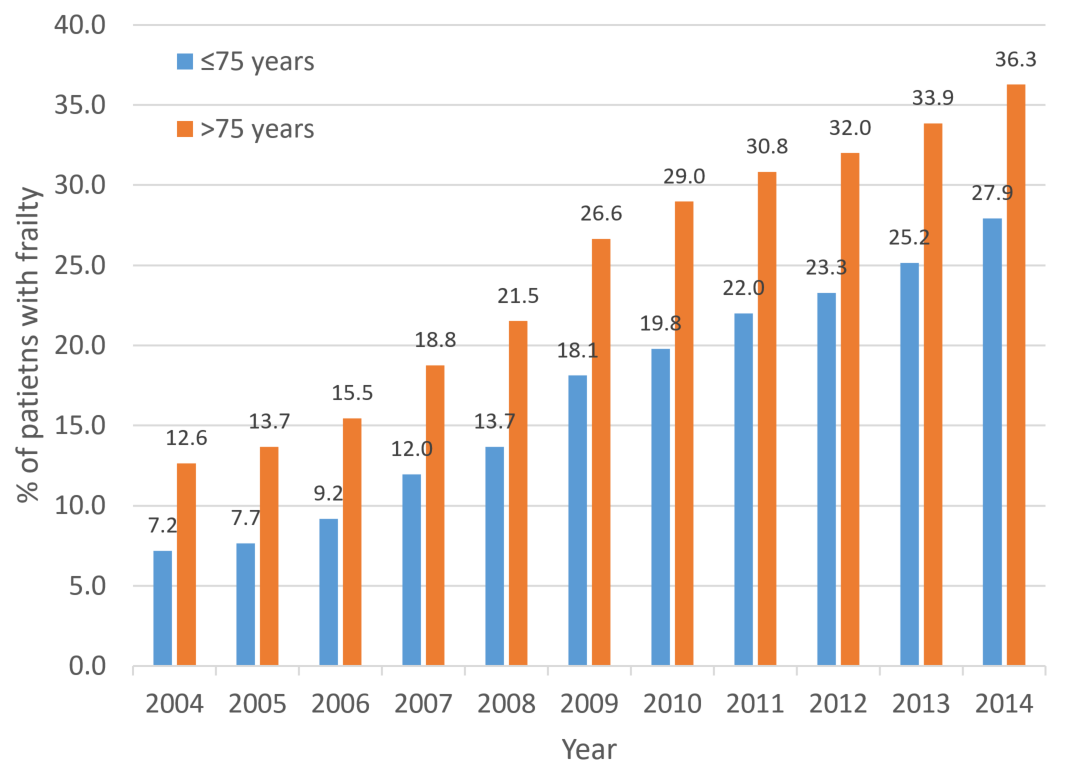
* Low Risk (<5) 80.0% (n=9,300,873)
* Intermediate Risk (5-15) 19.9% (n=2,314,001)
* High Risk (>15) 0.1% (n=11,526)

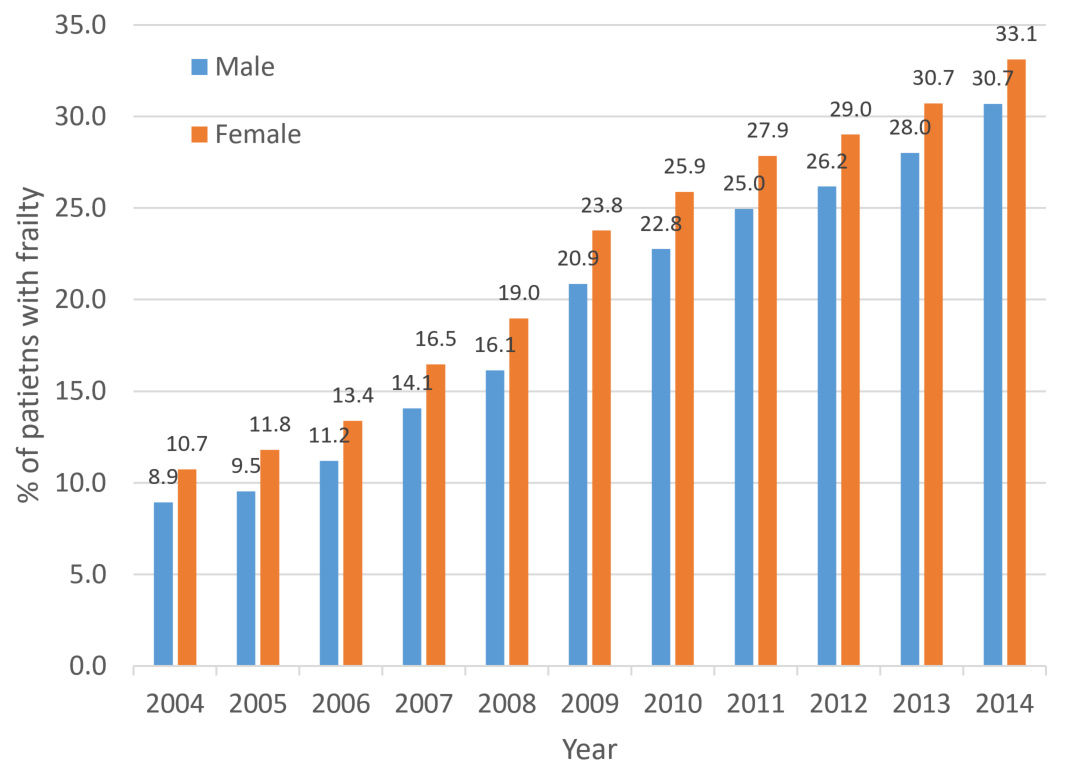
Patients excluded for missing data for:

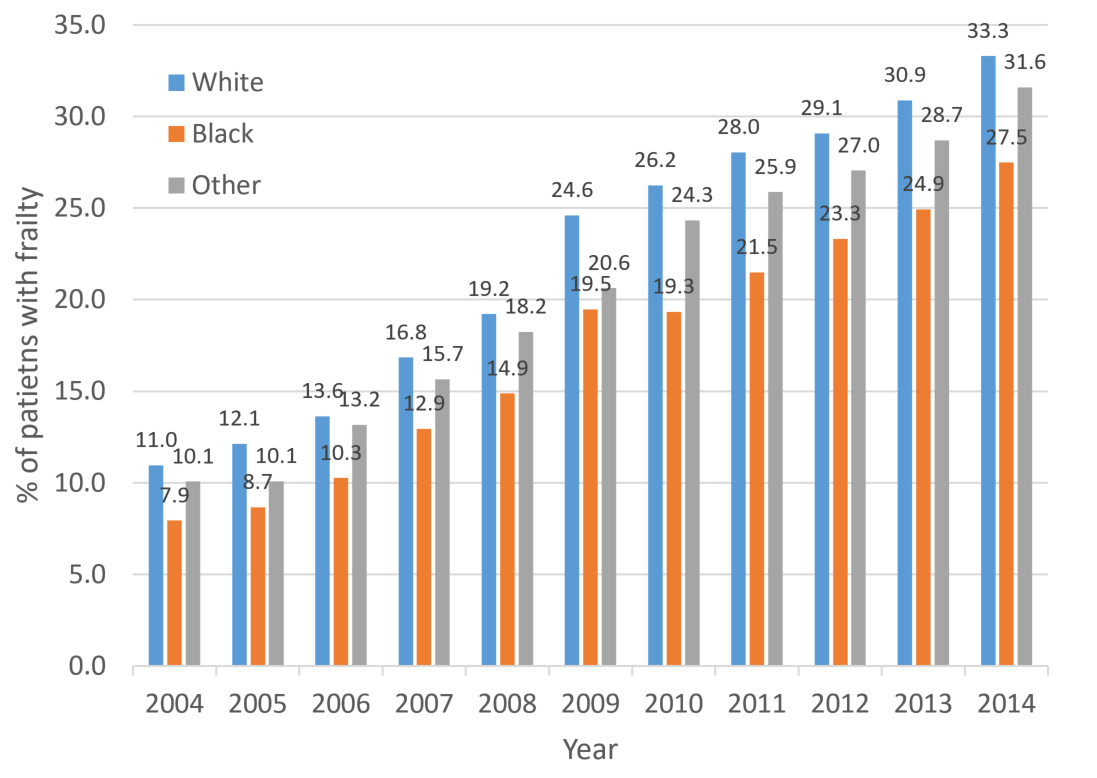
* Age (n=16,874)
* Sex (n=1,216)
* In-hospital death (n=5,545)

Patients in the National Inpatient Sample with heart failure between 2004 and 2014 (n=11,650,035)

**Supplementary Figure 2: Trends in frailty by age, sex and race**

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**Supplementary Table 1: Frailty score ICD-10 and ICD-9 codes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ICD-10 | ICD Description | Weight | ICD-9 | ICD-9 Description |
| F00 | Dementia in Alzheimer's disease | 7.1 | 331.0 AND 290\* OR  331.0 AND 294.2 | Alzheimer’s disease and dementia and dementia unspecified |
| G81 | Hemiplegia | 4.4 | 342\* | Hemiplegia and hemiparesis |
| G30 | Alzheimer's disease | 4 | 331.0 | Alzheimer's disease |
| I69 | Sequelae of cerebrovascular disease | 3.7 | 438.9 | Late effects of cerebrovascular disease |
| R29 | Other symptoms and signs involving the nervous and musculoskeletal systems (R29.6 Tendency to fall) | 3.6 | 781.9 | Other symptoms and signs involving the nervous and musculoskeletal systems (R29.6 Tendency to fall) |
| N39 | Other disorders of urinary system (including urinary tract infection and urinary incontinence) | 3.2 | 599.1\* 599.2\* 599.3\* 599.4\* 599.5\* 599.6\* 599.8\* 599.9\* | Other disorders of urethra and urinary tract |
| F05 | Delirium, not induced by alcohol and other psychoactive substances | 3.2 | 290.11 290.3 290.41 293.0 293.1 293.89 | Presenile dementia with delirium, senile dementia with delirium, vascular dementia with delirium, delirium not classified elsewhere, subacute delirium, other transient mental disorder |
| W19 | Unspecified fall | 3.2 | E888\* | Fall striking sharp object, fall striking object NEC, fall NEC, fall NOS |
| S00 | Superficial injury of head | 3.2 | 910.0 910.1 910.8 910.9 | Abrasion head, abrasion head-infected, superficial injury head NEC, superficial injury head NED-infected |
| R31 | Unspecified haematuria | 3 | 599.7\* | Haematuria |
| B96 | Other bacterial agents as the cause of diseases classified to other chapters (secondary code) | 2.9 | 041\* | Bacterial infections in conditions classified elsewhere and of unspecified site |
| R41 | Other symptoms and signs involving cognitive functions and awareness | 2.7 | 799.5\* | Signs and symptoms involving cognition |
| R26 | Abnormalities of gait and mobility | 2.6 | 781.2 | Abnormality of gait |
| I67 | Other cerebrovascular diseases | 2.6 | 437 | Other and ill-defined cerebrovascular disease |
| R56 | Convulsions, not elsewhere classified | 2.6 | 780.39 | Convulsions NEC |
| R40 | Somnolence, stupor and coma | 2.5 | 780.0\* | Alteration of consciousness |
| T83 | Complications of genitourinary prosthetic device, implants and grafts | 2.4 | 997.70 | Other complications due to unspecified device, implant, and graft |
| S06 | Intracranial injury | 2.4 | 850\* 851\* 852\* 853\* 854\* | Intracranial injury, excluding those with skull fracture |
| S42 | Fracture of shoulder and upper arm | 2.3 | 810 811 812 | Fracture of clavicle, fracture of scapula, fracture of humerus |
| E87 | Other disorders of fluid, electrolyte and acid-base balance | 2.3 | 276.0 276.1 276.2 276.3 276.5 276.6\* 276.7 276.8 276.9 | Disorders of fluid, electrolyte and acid-base balance |
| M25 | Other joint disorders, not elsewhere classified | 2.3 | 719.9\* | Unspecified disorder of joint |
| E86 | Volume depletion | 2.3 | 276\* | Volume depletion |
| R54 | Senility | 2.2 | 797 | Senility without mention of psychosis |
| Z50 | Care involving use of rehabilitation procedures | 2.1 | V57 | Care involving use of rehabilitation procedures |
| F03 | Unspecified dementia | 2.1 | 290.0\* 290.1\* 290.2\* 290.8\* 290.9\* 294.2 excluding Alzheimer’s disease (331.0) | Dementia, unspecified |
| W18 | Other fall on same level | 2.1 | E885 E886 | Fall on same level from slipping, tripping, or stumbling, fall on same level from collision, pushing, or shoving by or with other person |
| Z75 | Problems related to medical facilities and other health care | 2 | V63.2 V63.8 V63.9 | Person awaiting admission adequate facility elsewhere, reasons unavailability medical facilities, unspecified reason unavailability medical facilities |
| F01 | Vascular dementia | 2 | 290.4\* | Vascular dementia |
| S80 | Superficial injury of lower leg | 2 | 916\* | Superficial injury of hip, thigh, leg, and ankle |
| L03 | Cellulitis | 2 | 681\* 682\* | Cellulitis and abscesses of finger and toe, other cellulitis and abscess |
| H54 | Blindness and low vision | 1.9 | 369\* | Blindness and low vision |
| E53 | Deficiency of other B group vitamins | 1.9 | 266\* | Deficiency of B-complex components |
| Z60 | Problems related to social environment | 1.8 | V62.9 | Unspecified psychosocial circumstance |
| G20 | Parkinson's disease | 1.8 | 332\* | Parkinson's disease |
| R55 | Syncope and collapse | 1.8 | 780.2 | Syncope and collapse |
| S22 | Fracture of rib(s), sternum and thoracic spine | 1.8 | 807.0\* 807.1\* 807.2 807.3 807.4 805.2 805.4 | Closed fracture of rib(s), open fracture of rib(s), closed fracture of sternum, open fracture of sternum, flail chest, closed fracture of dorsal (thoracic) vertebra without mention of spinal cord injury, open fracture of dorsal (thoracic) vertebra without mention of spinal cord injury |
| K59 | Other functional intestinal disorders | 1.8 | 564.89 | Other functional disorders of intestine |
| N17 | Acute renal failure | 1.8 | 584 | Acute kidney failure |
| L89 | Decubitus ulcer | 1.7 | 707.0\* | Pressure ulcer |
| Z22 | Carrier of infectious disease | 1.7 | V02\* | Carrier or suspected carrier of infectious disease |
| B95 | Streptococcus and staphylococcus as the cause of diseases classified to other chapters | 1.7 | 041.0\* 041.1\* | Streptococcus infection in conditions classified elsewhere and of unspecified site, streptococcus, unspecified, staphylococcus infection in conditions classified elsewhere and of unspecified site, staphylococcus, unspecified. |
| L97 | Ulcer of lower limb, not elsewhere classified | 1.6 | 707.10 | Ulcer of lower limb, unspecified |
| R44 | Other symptoms and signs involving general sensations and perceptions | 1.6 | 781.1 782.0 | Disturbances, smell and taste, sensory disturbance skin |
| K26 | Duodenal ulcer | 1.6 | 532\* | Duodenal ulcer |
| I95 | Hypotension | 1.6 | 458\* | Hypotension |
| N19 | Unspecified renal failure | 1.6 | 586 | Renal failure, unspecified |
| A41 | Other septicaemia | 1.6 | 038.9 | Unspecified septicaemia |
| Z87 | Personal history of other disease and conditions | 1.5 | V12.60 V12.69 | Personal history of unspecified disease of respiratory system, personal history of other disease of respiratory system |
| J96 | Respiratory failure, not elsewhere classified | 1.5 | 518.81 518.84 518.51 518.83 | Acute respiratory failure, acute and chronic respiratory failure, acute respiratory failure following trauma and surgery, chronic respiratory failure |
| X59 | Exposure to unspecific factor | 1.5 | E928.9 | Unspecific accident |
| M19 | Other arthrosis | 1.5 | 715\* | Osteoarthrosis and allied disorders |
| G40 | Epilepsy | 1.4 | 345\* | Epilepsy and recurrent seizures |
| M81 | Osteoporosis without pathological fracture | 1.4 | 733.0\* | Osteoporosis |
| S72 | Fracture of femur | 1.4 | 820\* 821\* | Fracture of neck of femur, fracture of other and unspecified parts of femur |
| S32 | Fracture of lumbar spine and pelvis | 1.4 | 805.4 805.5 808\* | Closed fracture of lumbar vertebra without mention of spinal cord injury, open fracture of lumbar vertebra without mention of spinal cord injury, fracture of pelvis |
| E16 | Other disorders of pancreatic internal secretion | 1.4 | 251\* | Other disorders of pancreatic internal secretion |
| R94 | Abnormal results of function studies | 1.4 | 794\* | Nonspecific abnormal results of function studies |
| N18 | Chronic renal failure | 1.4 | 585\* | Chronic kidney disease |
| R33 | Retention of urine | 1.3 | 788.2\* | Retention of urine |
| R69 | Unknown and unspecified causes of morbidity | 1.3 | 799.9 | Other unknown and unspecified cause of morbidity and mortality |
| N28 | Other disorders of kidney and ureters, not elsewhere classified | 1.3 | 593\* | Other disorders of kidney and ureter |
| R32 | Unspecified urinary incontinence | 1.2 | 788.30 | Urinary incontinence, unspecified |
| G31 | Other degenerative disease of the nervous system, not elsewhere classified | 1.2 | 331.11 331.19 331.2 330.8 330.8 331.82 331.83 331.6 331.89 331.9 | Pick's disease, other frontotemporal dementia, senile degeneration of the brain, other specified cerebral degenerations in childhood, dementia with Lewy bodies, mild cognitive impairment, corticobasal degeneration, other cerebral degeneration, cerebral degeneration unspecified |
| Y95 | Nosocomial condition | 1.2 | 136.9 | Unspecified infectious and parasitic diseases |
| S09 | Other and unspecified injuries of head | 1.2 | 959.01 | Head injury, unspecified |
| R45 | Symptoms and signs involving emotional state | 1.2 | 308.0 | Predominant disturbance of emotions |
| G45 | Transient cerebral ischaemic attacks and related syndromes | 1.2 | 435\* | Transient cerebral ischemia |
| Z74 | Problems related to care-provider dependency | 1.1 | V60.9 | Unspecified housing or economic circumstance |
| M79 | Other soft tissue disorder, not elsewhere classified | 1.1 | 729.99 | Soft tissue disorder NEC |
| W06 | Fall involving bed | 1.1 | E884.4 | Fall from bed |
| S01 | Open wound of head | 1.1 | 870\*/873\* | Open wound of ocular adnexa, open wound of eyeball, open wound of ear, other open wound of head |
| A04 | Other bacterial intestinal infections | 1.1 | 008.49 | Bacterial enteritis NEC |
| A09 | Diarrhoea and gastroenteritis of presumed infectious origin | 1.1 | 009.3 | Diarrhoea of presumed infectious origin |
| J18 | Pneumonia, organism unspecified | 1.1 | 486\* | Pneumonia, organism unspecified |
| J69 | Pneumonitis due to solids and liquids | 1 | 507.0 | Pneumonitis due to inhalation of food or vomitus |
| R47 | Speech disturbances, not elsewhere classified | 1 | 784.59 | Other speech disturbance |
| E55 | Vitamin D deficiency | 1 | 268\* | Vitamin D deficiency |
| Z93 | Artificial opening status | 1 | V44 | Artificial opening status |
| R02 | Gangrene, not elsewhere classified | 1 | 785.4 | Gangrene |
| R63 | Symptoms and signs concerning food and fluid intake | 0.9 | 783.9 | Other symptoms concerning nutrition, metabolism, and development |
| H91 | Other hearing loss | 0.9 | 389.9 | Unspecified hearing loss |
| W10 | Fall on and from stairs and steps | 0.9 | E880.9 | Accidental fall on or from other stairs or steps |
| W01 | Fall on same level from slipping, tripping and stumbling | 0.9 | E885 | Fall on same level from slipping, tripping and stumbling |
| E05 | Thyrotoxicosis (hyperthyroidism) | 0.9 | 242\* | Thyrotoxicosis with or without goitre |
| M41 | Scoliosis | 0.9 | 737.3\* | Kyphoscoliosis and scoliosis |
| R13 | Dysphagia | 0.8 | 787.2\* | Dysphagia |
| Z99 | Dependence on enabling machines and devices | 0.8 | V46 | Other dependence on machines and devices |
| U80 | Agent resistant to penicillin and related antibiotics | 0.8 | V09.1 | Infection with microorganisms resistant to cephalosporins and other B-lactam antibiotics |
| M80 | Osteoporosis with pathological fracture | 0.8 | 733.0\* AND 733.1 V13.51 | Pathological fracture, history of pathological fracture |
| K92 | Other diseases of digestive system | 0.8 | 570\*/579\* | Other disease of digestive system |
| I63 | Cerebral infarction | 0.8 | 434.91\* 434.11 434.01 V12.54 997.02 | Cerebral artery occlusion, unspecified with cerebral infarction, cerebral embolism with cerebral infarction, personal history of transient ischemic attack, and cerebral infarction without residual deficits, iatrogenic cerebrovascular infarction or haemorrhage |
| N20 | Calculus of kidney and ureter | 0.7 | 592\* | Calculus of kidney and ureter |
| F10 | Mental and behavioural disorders due to use of alcohol | 0.7 | 291\* 303\* | Alcohol-induced mental disorders, alcohol dependence syndrome |
| Y84 | Other medical procedures as the cause of abnormal reaction to the patient | 0.7 | E878 E879 | Surgical operation and other surgical procedures as the cause of abnormal reaction of patient or later complication without mention of misadventure at time of operation, cardiac catheterization as the cause of abnormal reaction to patient, or of later complication, without mention of misadventure at time of procedure |
| R00 | Abnormalities of heart beat | 0.7 | 785.1 | Palpitations |
| J22 | Unspecified acute lower respiratory infection | 0.7 | 465.9 | Acute upper respiratory infection NOS |
| Z73 | Problems related to life-management difficulty | 0.6 | V695 V4985 | Behavioural insomnia of childhood, dual sensory impairment |
| R79 | Other abnormal findings of blood chemistry | 0.6 | 790.6 | Abnormal blood chemistry NEC |
| Z91 | Personal history of risk factor, not elsewhere classified | 0.5 | V15\* | Other personal history presenting hazards to health |
| S51 | Open wound of forearm | 0.5 | 881.00 | Open wound of forearm |
| R32 | Depressive episode | 0.5 | 296.20/296.26 296.30/296.36 331 | Major depressive disorder, single episode, major depressive disorder, recurrent episode, depressive disorder, not elsewhere classified |
| M48 | Spinal stenosis (secondary code only) | 0.5 | 724.0\* 723.0 | Spinal stenosis, other than cervical, cervical spinal stenosis |
| E83 | Disorders of mineral metabolism | 0.4 | 275 | Disorders of mineral metabolism |
| M15 | Polyarthrosis | 0.4 | 7165\* | Unspecified polyarthropathy or polyarthritis |
| D64 | Other anaemias | 0.4 | 285.8 285.9 | Anaemia NEC, Anaemia NOS |
| L08 | Other local infections of skin and subcutaneous tissue | 0.4 | 686 | Other local infections of skin and subcutaneous tissue |
| R11 | Nausea and vomiting | 0.3 | 787.0\* | Nausea and vomiting |
| K52 | Other noninfective gastroenteritis and colitis | 0.3 | 558\* | Other and unspecified noninfectious gastroenteritis and colitis |
| R50 | Fever of unknown origin | 0.1 | 780.60 | Fever NOS |

NEC=not elsewhere specified, NOS=not otherwise specified

**Supplementary Table 2: Variables with greater than 1% prevalence in the Hospital Frailty Score**

|  |  |  |
| --- | --- | --- |
| Variable | n | % |
| Chronic kidney disease | 746757 | 31.7 |
| Disorders of fluid, electrolyte and acid-base balance | 569250 | 24.2 |
| Other personal history presenting hazards to health | 443693 | 18.9 |
| Acute kidney failure | 384338 | 16.3 |
| Anemia, not elsewhere specified | 311302 | 13.2 |
| Pneumonia, organism unspecified | 262530 | 11.2 |
| Respiratory failure | 251986 | 10.7 |
| Osteoarthrosis and allied disorders | 190030 | 8.1 |
| Other disorders of kidney and ureter | 150353 | 6.4 |
| Other disease of digestive system | 119489 | 5.1 |
| Hypotension | 107876 | 4.6 |
| Bacterial infections in conditions classified elsewhere and of unspecified site | 88460 | 3.8 |
| Cellulitis | 82636 | 3.5 |
| Pathological fracture or history of pathological fracture | 82419 | 3.5 |
| Osteoporosis | 82181 | 3.5 |
| Volume depletion | 63574 | 2.7 |
| Pressure ulcer | 51463 | 2.2 |
| Alzheimer’s disease | 41064 | 1.7 |
| Hematuria | 32304 | 1.4 |
| Retention of urine | 31435 | 1.3 |
| Staphylococcus or streptococcus infection of unspecified site | 30955 | 1.3 |
| Dysphagia | 29382 | 1.2 |
| Calculus of kidney and ureters | 25650 | 1.1 |
| Alcohol-induced mental disorders including alcohol dependence syndrome | 25650 | 1.1 |
| Epilepsy and recurrent seizures | 25249 | 1.1 |
| Parkinson’s disease | 23738 | 1.0 |
| Unspecified hearing loss | 23080 | 1.0 |
| Blindness or low vision | 22854 | 1.0 |

**Supplementary Table 3: Changes in age and prevalent and highly weighted variables in the Hospital Frailty Risk score**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Weight | Prevalence | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| Mean age | - | - | 72.6±14.1 | 73.0±14.2 | 72.4±14.5 | 72.3±14.6 | 72.6±14.5 | 72.5±14.6 | 72.6±14.7 | 72.9±14.6 | 72.5±14.2 | 72.2±14.2 | 72.0±14.2 |
| Dementia in Alzheimer’s disease | 7.1 | 0.04% | 0.05% | 0.03% | 0.03% | 0.04% | 0.04% | 0.04% | 0.04% | 0.04% | 0.05% | 0.04% | 0.04% |
| Hemiplegia | 4.4 | 0.14% | 0.10% | 0.11% | 0.09% | 0.10% | 0.14% | 0.16% | 0.17% | 0.17% | 0.16% | 0.17% | 0.19% |
| Alzheimer’s disease | 4.0 | 1.75% | 1.73% | 1.66% | 1.70% | 1.81% | 1.95% | 1.97% | 1.92% | 1.89% | 1.69% | 1.56% | 1.38% |
| Sequelae of cerebrovascular disease | 3.7 | 0.07% | 0.13% | 0.10% | 0.07% | 0.09% | 0.07% | 0.06% | 0.05% | 0.05% | 0.05% | 0.05% | 0.04% |
| Other symptoms and signs involving the nervous and musculoskeletal systems | 3.6 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Other disorders of the urinary system | 3.2 | 0.20% | 0.14% | 0.14% | 0.13% | 0.18% | 0.19% | 0.20% | 0.21% | 0.23% | 0.23% | 0.24% | 0.29% |
| Delirium, not induced by alcohol and other psychoactive substances | 3.2 | 0.48% | 0.32% | 0.32% | 0.29% | 0.33% | 0.56% | 0.56% | 0.59% | 0.60% | 0.57% | 0.63% | 0.57% |
| Unspecified fall | 3.2 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Superficial injury of head | 3.2 | 0.03% | 0.02% | 0.02% | 0.02% | 0.02% | 0.02% | 0.03% | 0.03% | 0.03% | 0.04% | 0.03% | 0.03% |
| Unspecified haematuria | 3.0 | 1.39% | 1.62% | 1.62% | 1.52% | 1.52% | 1.13% | 1.20% | 1.24% | 1.26% | 1.29% | 1.33% | 1.43% |
| Chronic kidney disease | 1.4 | 32.18% | 2.68% | 7.88% | 21.34% | 33.41% | 34.58% | 39.06% | 41.49% | 43.42% | 44.78% | 45.34% | 46.92% |
| Disorders of fluid, electrolyte and acid-base balance | 2.3 | 24.40% | 18.19% | 19.05% | 19.39% | 20.70% | 22.43% | 24.92% | 26.32% | 27.94% | 29.16% | 30.59% | 32.34% |
| Other personal history presenting hazards to health | 0.5 | 10.13% | 11.16% | 12.83% | 14.15% | 15.30% | 19.64% | 21.92% | 23.84% | 25.73% | 27.84% | 32.49% | 19.22% |
| Acute kidney failure | 1.8 | 16.42% | 7.60% | 8.51% | 9.29% | 11.55% | 14.89% | 17.98% | 19.81% | 20.45% | 22.28% | 24.62% | 27.27% |
| Anemia, not elsewhere specified | 0.4 | 13.34% | 12.13% | 11.83% | 11.82% | 11.91% | 12.46% | 14.15% | 14.35% | 14.66% | 15.01% | 14.53% | 14.63% |
| Pneumonia, organism unspecified | 1.5 | 6.86% | 7.96% | 10.24% | 11.34% | 12.06% | 12.46% | 12.80% | 13.02% | 12.64% | 12.88% | 12.43% | 11.26% |
| Respiratory failure | 1.4 | 10.78% | 6.28% | 5.17% | 4.45% | 5.08% | 6.64% | 9.87% | 11.36% | 14.80% | 16.44% | 19.17% | 22.33% |

**Supplementary Table 4: Multiple logistic regression model to examine variables associated with any frailty**

|  |  |  |
| --- | --- | --- |
| Variable | Odds ratio (95%CI) | p-value |
| Age (year) | 1.02 (1.02-1.02) | <0.001 |
| Female | 1.00 (0.99-1.01) | 0.79 |
| Race vs White |  |  |
| Black | 0.91 (0.90-0.92) | <0.001 |
| Hispanic | 0.96 (0.94-0.98) | <0.001 |
| Asian or Pacific Islander | 1.07 (1.04-1.11) | <0.001 |
| Native American | 0.91 (0.84-0.99) | 0.02 |
| Other | 0.98 (0.95-1.01) | 0.25 |
| Weekend admission | 1.07 (1.06-1.09) | <0.001 |
| Year vs 2004 |  |  |
| 2005 | 1.14 (1.10-1.18) | <0.001 |
| 2006 | 1.44 (1.40-1.49) | <0.001 |
| 2007 | 1.80 (1.75-1.86) | <0.001 |
| 2008 | 2.12 (2.06-2.19) | <0.001 |
| 2009 | 3.03 (2.94-3.12) | <0.001 |
| 2010 | 3.36 (2.27-3.46) | <0.001 |
| 2011 | 3.60 (3.50-3.71) | <0.001 |
| 2012 | 3.86 (3.76-3.98) | <0.001 |
| 2013 | 4.18 (4.06-4.30) | <0.001 |
| 2014 | 4.87 (4.73-5.01) | <0.001 |
| Primary expected payer vs Medicare |  |  |
| Medicaid | 1.02 (1.00-1.05) | 0.05 |
| Private insurance | 0.85 (0.83-0.86) | <0.001 |
| Self-pay | 0.77 (0.74-0.80) | <0.001 |
| No charge | 0.73 (0.65-0.81) | <0.001 |
| Other | 0.83 (0.80-0.87) | <0.001 |
| Quartile of income vs 0th-25th |  |  |
| 26th-50th | 1.01 (1.00-1.03) | 0.12 |
| 51th-75th | 1.07 (1.05-1.08) | <0.001 |
| 76th-100th | 1.07 (1.05-1.08) | <0.001 |
| Smoking | 0.96 (0.94-0.97) | <0.001 |
| Hypercholesterolemia | 0.89 (0.88-0.90) | <0.001 |
| Hypertension | 0.95 (0.94-0.96) | <0.001 |
| Diabetes | 1.13 (1.12-1.15) | <0.001 |
| Obesity | 1.27 (1.25-1.29) | <0.001 |
| Previous congestive heart failure | 2.00 (1.92-2.08) | <0.001 |
| Coronary artery disease | 0.96 (0.95-0.97) | <0.001 |
| Previous myocardial infarction | 0.95 (0.93-0.96) | <0.001 |
| Previous PCI | 0.77 (0.75-0.78) | <0.001 |
| Previous CABG | 0.78 (0.76-0.79) | <0.001 |
| Atrial fibrillation | 1.08 (1.07-1.10) | <0.001 |
| Valvular heart disease | 1.39 (1.31-1.48) | <0.001 |
| Peripheral vascular disorders | 1.27 (1.03-1.63) | <0.001 |
| Chronic lung disease | 1.19 (1.17-1.20) | <0.001 |
| Hypothyroidism | 1.16 (1.14-1.17) | <0.001 |
| Liver disease | 1.76 (1.72-1.81) | <0.001 |
| Peptic ulcer disease | 1.30 (1.03-1.63) | 0.020 |
| Cancer | 0.94 (0.91-0.97) | <0.001 |
| Hospital bed size vs small |  |  |
| Medium | 1.04 (1.02-1.06) | <0.001 |
| Large | 1.07 (1.05-1.09) | <0.001 |
| Teaching hospital | 0.98 (0.97-0.99) | 0.001 |
| Urban hospital | 1.17 (1.14-1.20) | <0.001 |
| Cardiogenic shock | 2.58 (2.48-2.68) | <0.001 |
| Cardiac arrest | 1.17 (1.12-1.23) | <0.001 |
| Ventilation | 3.91 (3.82-4.00) | <0.001 |
| LV assist device or IABP | 1.30 (1.22-1.38) | <0.001 |
| Vasopressor use | 2.05 (1.94-2.16) | <0.001 |
| Coronary angiogram | 0.54 (0.53-0.55) | <0.001 |
| PCI | 1.21 (1.16-1.26) | <0.001 |
| CABG | 1.57 (1.47-1.68) | <0.001 |
| Pacemaker or ICD insertion | 0.66 (0.64-0.68) | <0.001 |
| CRT device | 0.39 (0.38-0.41) | <0.001 |
| Heart transplant | 1.50 (1.33-1.69) | <0.001 |

PCI=percutaneous coronary intervention, CABG=coronary artery bypass graft, LV=left ventricular, IABP=intra-aortic balloon pump, ICD=implantable cardioverter defibrillator, CRT=cardiac resynchronization therapy