30-day Readmissions in Patients With Heart Failure and Chronic Kidney Disease: Insights From the 2016–2017 Nationwide Readmissions Database

Analysis for NRD June A16

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## Preamble:

* **Reference Studies:**
  + [Nowrouzi et al., 2022](https://www.jtcvsopen.org/article/S2666-2736(22)00350-3/fulltext)
  + [Minhas et al., 2023](https://www.ajconline.org/article/S0002-9149(23)00359-4/fulltext)
* **Study Objective:**
* To identify patient- and hospital-level predictors of 30-day all-cause hospital readmission among adults hospitalized with heart failure and chronic kidney disease using a nationally representative dataset. This study also evaluates the clinical and economic burden of readmission in this high-risk population, including its associations with in-hospital mortality, length of stay (LOS), and hospital charges.
* **Data Source:**
* A retrospective cohort study using the 2016–2017 Nationwide Readmissions Database (NRD), developed by the Healthcare Cost and Utilization Project (HCUP). The NRD enables tracking of individual patients across hospitalizations within a given year via synthetic identifiers, capturing discharges from U.S. community hospitals and supporting survey-weighted national estimates through complex sampling design.
* **Cohort Definition:**
* Index hospitalizations were included if they met all of the following criteria:
  + Adults aged ≥18 years
  + Principal diagnosis of Heart failure (HF), identified using ICD-10-CM codes for HF (isHF pattern, including I501, I5021, I5023, I5031, I5033, I5041, I5043 )
  + Evidence of Chronic Kidney Disease (CKD), derived from secondary diagnosis fields using ICD-10-CM patterns N181, N182, N183, N1830, N1831, N1832, N184, N185, N186, N189
  + Non-elective admission
  + Index discharge by the end of November to allow for a complete 30-day follow-up period
  + Complete data on LOS and NRD\_DAYSTOEVENT, required to compute discharge dates
* **Outcomes of Interest:**
  + Primary Outcome:
    - Binary indicator of 30-day readmission (Yes/No)
  + Secondary Outcomes:
    - In-hospital mortality (binary)
    - Length of stay (LOS, in days)
    - Total hospitalization charges (inflation-adjusted to 2017 USD)
* **Outcome Definitions:**
  + Readmission:
    - Defined using NRD’s linkage variables. Readmissions were identified only among patients with qualifying index events.
    - Trauma-related hospitalizations were excluded only from the readmission pool to avoid planned or injury-related returns unrelated to HF hospitalizations.
  + Mortality:
    - In-hospital death recorded during index or readmission (DIED = 1)
  + LOS:
    - Reported in days; modeled as count outcome
  + Cost:
    - Derived from HCUP’s TOTCHG variable and adjusted to 2017 dollars using Consumer Price Index (CPI) data
* **Covariates and Variable Construction:**
  + Demographic & Socioeconomic Factors:
    - Sex (FEMALE; ref = Male)
    - Primary expected payer (Insurance; Medicare, Medicaid, Private, Other)
    - ZIP-based median income quartile (ZIPINC\_QRTL)
    - Weekend admission (AWEEKEND)
  + CKD Stages:
    - CKD Stage 1: N181
    - CKD Stage 2: N182
    - CKD Stage 3: N183, N1830, N1831, N1832
    - CKD Stage 4: N184
    - CKD Stage 5: N185
    - ESRD: N186
  + Clinical Characteristics:
    - Standard comorbidities (from Elixhauser Index), using binary indicators:
    - Peripheral vascular disease
    - Chronic pulmonary disease
    - Diabetes mellitus
    - Hypertension
    - Renal failure
    - Obesity
    - Alcohol abuse
  + Additional clinical risk factors (non-Elixhauser)
    - Smoking
    - HIV
    - Previous Myocardial Infarction
    - Atrial fibrillation
    - Hyperlipidemia
    - Previous stroke
  + Acute complications identified via ICD-10 code matching:
    - Acute Kidney Injury (AKI)
    - Cardiogenic Shock (CS)
  + Hospital Characteristics:
    - Hospital bed size (Small, Medium, Large)
    - Urban/rural teaching status (Metropolitan, teaching vs non-teaching, etc.)
  + Disposition and Severity:
    - Non-home discharge (e.g., SNF, hospice, other facilities, or death)
    - Length of stay (continuous variable)
* **Statistical Methods:**
  + Survey Design and Weighting:
    - All analyses incorporated NRD’s complex sampling design using discharge weights (DISCWT), strata (NRD\_STRATUM), and clustering (HOSP\_NRD) via the survey and srvyr packages.
  + Descriptive Statistics:
    - Weighted baseline characteristics of index hospitalizations were summarized and stratified by 30-day readmission status to compare patients who were readmitted versus those who were not.
    - Stratification was performed using a derived binary variable, which categorized patients as:
      * With 30-day readmission
      * Without readmission
    - P-values from design-based statistical tests (Rao–Scott adjusted chi-square for categorical variables; design-based Kruskal–Wallis test for continuous variables).
  + Multivariable Regression:
    - A survey-weighted Cox proportional hazards model estimated predictors of 30-day readmission.
    - The model included demographic, clinical, hospital-level, and index-stay factors.
    - Reference levels were explicitly set (e.g., Male, CKD Stage).
    - Results were exponentiated to yield hazard ratios (HRs) with 95% confidence intervals.
* **Software:**  
  All analyses were conducted in R Statistical Language (Version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria).

## Descriptive Statistics:

### Readmission Rate:

Index hospitalizations resulted in:

1. Readmission (n): 75370
2. Readmission Rate (%): 20.92%
3. Readmission Rate (95% CI): 20.65% to 21.19%

### In-Hospital Mortality by Readmission Status:

Index hospitalizations resulted in:

1. Deaths (n): 12453
2. Death Rate (%): 3.46%
3. Death Rate (95% CI): 3.34% to 3.58%

Readmission hospitalizations resulted in:

1. Deaths (n): 5233
2. Death Rate (%): 6.97%
3. Death Rate (95% CI): 6.67% to 7.27%

### Resource Utilization During Index Admission

Index hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 4 (IQR: 3–7)
2. Median Total Charges (IQR): $29,531 (IQR: $17,147–$54,195)

### Resource Utilization During Readmission

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 4 (IQR: 3–7)
2. Median Total Charges (IQR): $32,448 (IQR: $17,854–$62,786)

## Baseline table:

| **Characteristic** | **Without Readmission** N = 284,887*1* | **With 30-day readmission** N = 75,371*1* | **p-value***2* | **Overall** N = 360,258*1* |
| --- | --- | --- | --- | --- |
| Age (years) | 74 (13) | 72 (14) | <0.001 | 74 (13) |
| Sex |  |  | 0.5 |  |
| Male | 156,645 (55%) | 41,591 (55%) |  | 198,236 (55%) |
| Female | 128,242 (45%) | 33,780 (45%) |  | 162,022 (45%) |
| Median Income Quartile |  |  | <0.001 |  |
| 0-25th percentile | 88,329 (31%) | 26,324 (35%) |  | 114,653 (32%) |
| 26th to 50th percentile | 75,312 (27%) | 19,693 (26%) |  | 95,005 (27%) |
| 51st to 75th percentile | 68,574 (24%) | 16,755 (23%) |  | 85,329 (24%) |
| 76th to 100th percentile | 48,981 (17%) | 11,612 (16%) |  | 60,594 (17%) |
| Admission day |  |  | 0.007 |  |
| Monday-Friday | 216,948 (76%) | 56,855 (75%) |  | 273,803 (76%) |
| Saturday-Sunday | 67,939 (24%) | 18,516 (25%) |  | 86,454 (24%) |
| Hospital Bed Size |  |  | 0.088 |  |
| Small | 50,781 (18%) | 12,908 (17%) |  | 63,689 (18%) |
| Large | 154,518 (54%) | 41,220 (55%) |  | 195,738 (54%) |
| Medium | 79,588 (28%) | 21,243 (28%) |  | 100,831 (28%) |
| Teaching Status |  |  | 0.7 |  |
| Metropolitan, non-teaching | 77,301 (27%) | 20,352 (27%) |  | 97,653 (27%) |
| Metropolitan, teaching | 177,862 (62%) | 47,269 (63%) |  | 225,131 (62%) |
| Non-metropolitan | 29,724 (10%) | 7,749 (10%) |  | 37,474 (10%) |
| Non-home discharge | 77,567 (27%) | 18,812 (25%) | <0.001 | 96,379 (27%) |
| Diabetes mellitus | 153,387 (54%) | 43,145 (57%) | <0.001 | 196,533 (55%) |
| Smoking | 22,577 (7.9%) | 7,683 (10%) | <0.001 | 30,261 (8.4%) |
| Peripheral vascular disease | 72,817 (26%) | 21,416 (28%) | <0.001 | 94,233 (26%) |
| Hypertension | 8,592 (3.0%) | 2,336 (3.1%) | 0.4 | 10,928 (3.0%) |
| Hyperlipidemia | 156,045 (55%) | 40,662 (54%) | 0.014 | 196,707 (55%) |
| Prior stroke or Transient ischemic attack | 40,015 (14%) | 11,006 (15%) | 0.017 | 51,021 (14%) |
| CKD stage |  |  | <0.001 |  |
| CKD, Stage 1 | 1,109 (0.5%) | 223 (0.4%) |  | 1,332 (0.5%) |
| CKD, Stage 2 | 12,684 (5.5%) | 3,084 (5.1%) |  | 15,768 (5.4%) |
| CKD, Stage 3 | 136,636 (59%) | 34,019 (56%) |  | 170,655 (59%) |
| CKD, Stage 4 | 46,547 (20%) | 12,885 (21%) |  | 59,432 (20%) |
| CKD, Stage 5 | 4,591 (2.0%) | 1,240 (2.0%) |  | 5,831 (2.0%) |
| ESRD | 28,096 (12%) | 9,505 (16%) |  | 37,601 (13%) |
| Alcohol abuse | 6,038 (2.1%) | 1,899 (2.5%) | <0.001 | 7,937 (2.2%) |
| HIV infection | 1,043 (0.4%) | 547 (0.7%) | <0.001 | 1,590 (0.4%) |
| Previous myocardial infarction | 47,762 (17%) | 13,180 (17%) | 0.004 | 60,943 (17%) |
| Atrial fibrillation | 138,482 (49%) | 35,909 (48%) | 0.005 | 174,391 (48%) |
| Obesity | 65,690 (23%) | 17,579 (23%) | 0.3 | 83,269 (23%) |
| Chronic pulmonary disease | 113,846 (40%) | 33,876 (45%) | <0.001 | 147,721 (41%) |
| Liver disease | 13,074 (4.6%) | 4,182 (5.5%) | <0.001 | 17,256 (4.8%) |
| Cardiogenic shock | 7,422 (2.6%) | 1,382 (1.8%) | <0.001 | 8,804 (2.4%) |
| Acute kidney injury | 121,860 (43%) | 32,430 (43%) | 0.4 | 154,290 (43%) |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

## Multivariable Analyses

### Multivariable Predictors of 30-Day Readmission

Stratified 1 - level Cluster Sampling design (with replacement)  
With (2990) clusters.  
subset(nrd\_design, IndexEvent == 1)  
Sampling variables:  
 - ids: HOSP\_NRD   
 - strata: NRD\_STRATUM   
 - weights: DISCWT

| **Characteristic** | **HR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Age (years) | 1.00 | 1.00, 1.00 | 0.9 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 1.02 | 0.99, 1.04 | 0.2 |
| Index Length of stay (days) | 1.00 | 1.00, 1.01 | 0.005 |
| Median Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 1.01 | 0.98, 1.04 | 0.5 |
| 51st to 75th percentile | 1.01 | 0.98, 1.04 | 0.6 |
| 76th to 100th percentile | 1.01 | 0.97, 1.05 | 0.6 |
| Admission day |  |  |  |
| Monday-Friday | — | — |  |
| Saturday-Sunday | 0.99 | 0.96, 1.02 | 0.4 |
| Hospital Bed Size |  |  |  |
| Large | — | — |  |
| Medium | 1.01 | 0.99, 1.04 | 0.3 |
| Small | 1.03 | 0.99, 1.06 | 0.14 |
| Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 1.00 | 0.97, 1.03 | >0.9 |
| Non-metropolitan | 1.00 | 0.95, 1.05 | >0.9 |
| Non-home discharge |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.99, 1.05 | 0.13 |
| Diabetes mellitus |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.98, 1.03 | 0.6 |
| Smoking |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.97, 1.05 | 0.7 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.98, 1.04 | 0.5 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.95, 1.09 | 0.7 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 1.00, 1.05 | 0.068 |
| Prior stroke or Transient ischemic attack |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.95, 1.02 | 0.4 |
| CKD stage |  |  |  |
| CKD, Stage 1 | — | — |  |
| CKD, Stage 2 | 1.02 | 0.86, 1.22 | 0.8 |
| CKD, Stage 3 | 1.02 | 0.86, 1.21 | 0.8 |
| CKD, Stage 4 | 1.00 | 0.84, 1.20 | >0.9 |
| CKD, Stage 5 | 0.95 | 0.79, 1.14 | 0.6 |
| ESRD | 1.09 | 0.91, 1.30 | 0.3 |
| Alcohol abuse |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.90, 1.06 | 0.6 |
| HIV infection |  |  |  |
| No | — | — |  |
| Yes | 0.88 | 0.77, 1.01 | 0.071 |
| Previous myocardial infarction |  |  |  |
| No | — | — |  |
| Yes | 0.97 | 0.94, 1.01 | 0.10 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.98, 1.03 | 0.6 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.95, 1.01 | 0.3 |
| Chronic pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 1.00 | 0.97, 1.02 | 0.8 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 1.00 | 0.95, 1.06 | 0.9 |
| Cardiogenic shock |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.92, 1.14 | 0.7 |
| Acute kidney injury |  |  |  |
| No | — | — |  |
| Yes | 1.04 | 1.01, 1.07 | 0.002 |
| Abbreviations: CI = Confidence Interval, HR = Hazard Ratio | | | |

## Top Causes of Readmissions

Top 10 causes of 30-day re-admissions among CKD patients who had an index hospitalization for heart failure.

Top 10 Diagnoses by Weighted Proportion

| Diagnosis | Proportion |
| --- | --- |
| I50 | 0.3354759 |
| I13 | 0.1148964 |
| A41 | 0.0588748 |
| N17 | 0.0511431 |
| J96 | 0.0416590 |
| I21 | 0.0209110 |
| J44 | 0.0203388 |
| J18 | 0.0202191 |
| I48 | 0.0193433 |
| E87 | 0.0163273 |