Readmission in Patients with Chronic Kidney Disease undergoing PCI

2025\_June\_NRD\_A5

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## Preamble:

* **Reference Studies:**
  + [Nowrouzi et al., 2022](https://www.sciencedirect.com/science/article/pii/S2666273622003503#:~:text=By%20Kaplan%E2%80%93Meier%20analysis%2C%20freedom,18%25)
* **Study Objective:**
* To identify patient- and hospital-level predictors of 30-day all-cause hospital readmission among adults patients undergoing percutaneous coronary intervention and has been diagnosed with 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 association with in-hospital mortality.
* **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:
  + Patients aged ≥ 18 years
  + Undergoing percutaneous coronary intervention as the primary procedure.
  + Primary or secondary diagnosis of chronic kidney disease.
    - CKD was categorized as following:
      * No CKD
      * CKD Stage 1-3
      * CKD Stage 3-4
      * ESRD
  + 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
  + Trauma-related hospitalizations were excluded only from the readmission pool to avoid injury-related returns
* **Outcomes of Interest:**
  + Primary Outcome:
    - All-cause 30-day readmission
  + Secondary Outcomes (index admission):
    - In-hospital mortality (DIED)
    - Length of stay (LOS, in days)
    - Total hospitalization charges (TOTCHG), inflation-adjusted to 2017 USD
    - Discharge disposition
  + Readmission Characteristics:
    - In-hospital mortality
    - Length of stay (LOS, in days)
    - Total hospitalization charges (inflation-adjusted to 2017 USD)
* **Outcome Definitions:**
  + Readmission:
    - Defined using HCUP NRD’s methodology. Readmissions were identified only among patients with qualifying index events.
    - Trauma-related hospitalizations were excluded only from the readmission pool to avoid unrelated admissions.
  + Mortality:
    - In-hospital death recorded during index or readmission (DIED = 1)
  + LOS:
    - Reported in days; modeled as count outcome
  + Charge:
    - Derived from HCUP’s TOTCHG variable and adjusted to 2017 dollars using Consumer Price Index (CPI) data
  + Discharge Disposition:
  + - Home/self-care  
      
    - Transfer to another short-term hospital  
      
    - Transfer to skilled nursing facility (SNF), intermediate, or other facility  
    - Left against medical advice  
      
    - Died in hospital  
      
    - Alive, destination unknown
* **Covariates and Variable Construction:**
  + Demographic & Socioeconomic Factors:
    - Age (continuous)
    - Sex (FEMALE; ref = Male)
    - Primary expected payer (Insurance; Medicare, Medicaid, Private, Other)
    - Income quartile based on ZIP code (ZIPINC\_QRTL)
  + Comorbidities and Clinical Covariates:
    - Diabetes
    - Hypertension
    - Congestive heart failure
    - Chronic pulmonary disease
    - Anemia
    - Liver disease
    - Obesity
    - Renal Failure
    - Cardiac Arrhythmia
    - History of undergoing PCI
    - History of undergoing CABG
    - History of myocardial infarction
    - Peripheral vascular disease
    - Pulmonary Circulation Disorders
    - Valvular disease
    - Hypothyroidism
    - Atrial fibrillation
    - Hyperlipidemia
    - Depression
    - Fluid and electrolyte imbalance
    - Cerebrovascular disease
    - Coagulopathy
  + Hospital Characteristics:
    - Hospital bed size (Small, Medium, Large)
    - Urban/rural teaching status (Metropolitan, teaching vs non-teaching, etc.)
  + Disposition and Severity:
    - Discharge disposition
    - Length of stay
* **Statistical Methods:**
  + Survey Design and Weighting:
    - All analyses accounted for NRD’s complex survey design using weights (DISCWT), strata (NRD\_STRATUM), and clustering (HOSP\_NRD). Survey-adjusted methods were implemented via survey and srvyr packages.
  + Descriptive Analyses:
    - Baseline characteristics were summarized across stage of CKD using survey-weighted means/proportions.
    - 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 logistic regression modeled predictors of 30-day readmission.
    - The model included demographic, clinical, hospital-level, and index-stay factors.
    - Results were exponentiated to yield odds ratios (ORs) with 95% confidence intervals.
  + Readmission Characteristics:
    - A sub-analysis among patients with 30-day readmissions summarized readmission hospitalization characteristics descriptively using weighted survey statistics.
* **Software:** All analyses were conducted in R Statistical Language (Version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria).

## Descriptive Analyses

### Baseline Characteristics

| **Characteristic** | **Overall** N = 804,036*1* | **No CKD** N = 682,997*1* | **CKD, Stage 1-3** N = 78,019*1* | **CKD, Stage 4-5** N = 14,723*1* | **ESRD** N = 28,297*1* | **p-value***2* |
| --- | --- | --- | --- | --- | --- | --- |
| Age (years) | 65 (12) | 64 (12) | 72 (11) | 72 (11) | 65 (12) | <0.001 |
| Sex |  |  |  |  |  | <0.001 |
| Male | 540,231 (67%) | 463,621 (68%) | 51,198 (66%) | 8,576 (58%) | 16,836 (59%) |  |
| Female | 263,805 (33%) | 219,376 (32%) | 26,821 (34%) | 6,147 (42%) | 11,461 (41%) |  |
| Primary Expected Payer |  |  |  |  |  | <0.001 |
| Private | 230,007 (29%) | 215,191 (32%) | 10,615 (14%) | 1,670 (11%) | 2,531 (9.0%) |  |
| Medicaid | 73,414 (9.1%) | 66,260 (9.7%) | 4,252 (5.5%) | 905 (6.2%) | 1,997 (7.1%) |  |
| Medicare | 434,480 (54%) | 339,835 (50%) | 59,960 (77%) | 11,686 (79%) | 22,998 (81%) |  |
| Other | 65,003 (8.1%) | 60,692 (8.9%) | 3,131 (4.0%) | 451 (3.1%) | 729 (2.6%) |  |
| Median Household Income Quartile |  |  |  |  |  | <0.001 |
| 0-25th percentile | 236,911 (30%) | 199,245 (30%) | 23,023 (30%) | 4,412 (30%) | 10,232 (37%) |  |
| 26th to 50th percentile | 222,803 (28%) | 189,621 (28%) | 21,498 (28%) | 4,170 (29%) | 7,514 (27%) |  |
| 51st to 75th percentile | 192,904 (24%) | 164,295 (24%) | 19,095 (25%) | 3,468 (24%) | 6,046 (22%) |  |
| 76th to 100th percentile | 139,084 (18%) | 119,180 (18%) | 13,350 (17%) | 2,490 (17%) | 4,065 (15%) |  |
| Hospital Bed Size |  |  |  |  |  | <0.001 |
| Small | 87,706 (11%) | 75,002 (11%) | 8,841 (11%) | 1,378 (9.4%) | 2,484 (8.8%) |  |
| Large | 492,853 (61%) | 418,172 (61%) | 47,211 (61%) | 9,115 (62%) | 18,355 (65%) |  |
| Medium | 223,478 (28%) | 189,823 (28%) | 21,967 (28%) | 4,230 (29%) | 7,458 (26%) |  |
| Hospital Location and Teaching Status |  |  |  |  |  | <0.001 |
| Metropolitan, non-teaching | 201,618 (25%) | 173,771 (25%) | 18,165 (23%) | 3,419 (23%) | 6,262 (22%) |  |
| Metropolitan, teaching | 558,083 (69%) | 470,765 (69%) | 55,708 (71%) | 10,609 (72%) | 21,002 (74%) |  |
| Non-metropolitan | 44,335 (5.5%) | 38,461 (5.6%) | 4,146 (5.3%) | 695 (4.7%) | 1,033 (3.7%) |  |
| Non home discharge | 82,002 (10%) | 58,285 (8.5%) | 13,482 (17%) | 3,427 (23%) | 6,807 (24%) | <0.001 |
| Number of comorbidities |  |  |  |  |  |  |
| No comorbidities | 37,691 (4.7%) | 37,691 (5.5%) | 0 (0%) | 0 (0%) | 0 (0%) |  |
| One comorbidity | 230,204 (29%) | 230,204 (34%) | 0 (0%) | 0 (0%) | 0 (0%) |  |
| Two or more comorbidities | 536,141 (67%) | 415,102 (61%) | 78,019 (100%) | 14,723 (100%) | 28,297 (100%) |  |
| Congestive heart failure | 284,612 (35%) | 210,196 (31%) | 44,745 (57%) | 10,332 (70%) | 19,340 (68%) | <0.001 |
| Chronic pulmonary disease | 159,926 (20%) | 128,406 (19%) | 20,759 (27%) | 3,922 (27%) | 6,839 (24%) | <0.001 |
| Liver disease | 25,532 (3.2%) | 19,980 (2.9%) | 3,195 (4.1%) | 620 (4.2%) | 1,737 (6.1%) | <0.001 |
| Obesity | 163,777 (20%) | 134,748 (20%) | 19,540 (25%) | 3,603 (24%) | 5,885 (21%) | <0.001 |
| Hypertension | 649,653 (81%) | 534,045 (78%) | 73,936 (95%) | 14,083 (96%) | 27,590 (98%) | <0.001 |
| Diabetes | 321,166 (40%) | 243,780 (36%) | 46,049 (59%) | 9,959 (68%) | 21,378 (76%) | <0.001 |
| Anemia | 130,095 (16%) | 75,960 (11%) | 24,911 (32%) | 8,031 (55%) | 21,193 (75%) | <0.001 |
| Previous PCI | 167,395 (21%) | 136,249 (20%) | 20,396 (26%) | 3,601 (24%) | 7,148 (25%) | <0.001 |
| Previous CABG | 80,421 (10%) | 60,780 (8.9%) | 13,011 (17%) | 2,335 (16%) | 4,296 (15%) | <0.001 |
| Prior myocardial infarction | 144,603 (18%) | 116,840 (17%) | 17,876 (23%) | 3,438 (23%) | 6,449 (23%) | <0.001 |
| Peripheral vascular disease | 102,449 (13%) | 74,228 (11%) | 17,781 (23%) | 3,502 (24%) | 6,938 (25%) | <0.001 |
| Pulmonary circulation disorders | 39,752 (4.9%) | 25,735 (3.8%) | 8,090 (10%) | 1,890 (13%) | 4,038 (14%) | <0.001 |
| Valvular disease | 99,613 (12%) | 73,980 (11%) | 16,293 (21%) | 3,250 (22%) | 6,089 (22%) | <0.001 |
| Hypothyroidism | 88,348 (11%) | 68,581 (10%) | 12,977 (17%) | 2,632 (18%) | 4,158 (15%) | <0.001 |
| Atrial fibrillation | 127,506 (16%) | 95,637 (14%) | 20,701 (27%) | 4,035 (27%) | 7,132 (25%) | <0.001 |
| Hyperlipidemia | 579,131 (72%) | 489,433 (72%) | 60,364 (77%) | 10,720 (73%) | 18,614 (66%) | <0.001 |
| Depression | 73,045 (9.1%) | 59,199 (8.7%) | 9,103 (12%) | 1,517 (10%) | 3,226 (11%) | <0.001 |
| Fluid and electrolyte imbalance | 157,087 (20%) | 113,045 (17%) | 23,672 (30%) | 6,632 (45%) | 13,738 (49%) | <0.001 |
| Cerebrovascular disease | 41,356 (5.1%) | 30,635 (4.5%) | 6,952 (8.9%) | 1,318 (9.0%) | 2,451 (8.7%) | <0.001 |
| Coagulopathy | 36,344 (4.5%) | 25,791 (3.8%) | 5,817 (7.5%) | 1,340 (9.1%) | 3,396 (12%) | <0.001 |
| *1*Mean (SD); n (%) | | | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment; NA | | | | | | |

### Outcomes of Index Hospitalizations

| **Characteristic** | **Overall** N = 804,036*1* | **No CKD** N = 682,997*1* | **CKD, Stage 1-3** N = 78,019*1* | **CKD, Stage 4-5** N = 14,723*1* | **ESRD** N = 28,297*1* | **p-value***2* |
| --- | --- | --- | --- | --- | --- | --- |
| 30-Day Readmission |  |  |  |  |  | <0.001 |
| Without Readmission | 731,409 (91%) | 629,737 (92%) | 67,236 (86%) | 12,049 (82%) | 22,386 (79%) |  |
| With 30-day readmission | 72,628 (9.0%) | 53,261 (7.8%) | 10,783 (14%) | 2,673 (18%) | 5,911 (21%) |  |
| In-Hospital Mortality | 24,239 (3.0%) | 18,149 (2.7%) | 3,044 (3.9%) | 1,015 (6.9%) | 2,030 (7.2%) | <0.001 |
| Length of Stay (days) | 3.0 (2.0, 4.0) | 2.0 (2.0, 4.0) | 4.0 (2.0, 7.0) | 6.0 (3.0, 11.0) | 5.0 (3.0, 10.0) | <0.001 |
| Inflation-Adjusted Total Charges ($) | 83,436 (57,922, 128,109) | 80,842 (56,621, 122,424) | 95,374 (64,059, 151,818) | 110,485 (71,785, 182,095) | 122,740 (78,908, 202,320) | <0.001 |
| Discharged to Non-Home Setting | 82,002 (10%) | 58,285 (8.5%) | 13,482 (17%) | 3,427 (23%) | 6,807 (24%) | <0.001 |
| *1*n (%); Median (Q1, Q3) | | | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | | | |

## Readmission Hospitalization Characteristics

### Readmission Rate:

Index hospitalizations resulted in:

1. Readmission (n): 72627
2. Readmission Rate (%): 9.03%
3. Readmission Rate (95% CI): 8.89% to 9.18%

### In-Hospital Mortality by Readmission Status:

### In-Hospital Mortality Among Readmitted Patients

Readmission hospitalizations resulted in:

1. Deaths (n): 2393
2. Death Rate (%): 3.28%
3. Death Rate (95% CI): 3.08% to 3.48%

### Resource Utilization During Readmission

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 3 (IQR: 2–5)
2. Median Total Charges (IQR): $33,446 (IQR: $17,758–$65,489)

## Multivariable Analyses

### 30-Day Readmission:

logit\_model <- svyglm ( Readmit ~ CKD\_type + AGE + FEMALE + Insurance + ZIPINC\_QRTL + HOSP\_BEDSIZE + HOSP\_UR\_TEACH + Non\_Home\_Discharge + Congestive\_HF + Chronic\_pulmonary\_disease + Liver\_disease + Obesity + Hypertension + Diabetes + Anemia + PreviousPCI + PreviousCABG + PriorMI + PVD + Pulmonary\_Circ\_Disorders + Valvular\_disease + Hypothyroidism + AtrialFibrillation + Hyperlipidemia + Depression + Electrolyte\_imbalance + Cerebrovascular\_Disease + Coagulopathy, design = index\_design, family = quasibinomial )

tbl\_regression(logit\_model, exponentiate = TRUE, label = reg\_var\_labels)