Predictors, Outcomes, and Primary Causes of 30-Day Readmission Following Acute Kidney Injury in Cardiogenic Shock: Insights from the Nationwide Readmissions Database

RCOP NRD A18

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## Preamble:

* **Reference Studies:**
  + [Singh et al., 2021](https://pmc.ncbi.nlm.nih.gov/articles/PMC8396972/)
  + [Tarvasmakhi et al., 2018](https://onlinelibrary.wiley.com/doi/full/10.1002/ejhf.958)
* **Study Objective:**
* To evaluate the risk of 30-day all-cause hospital readmission in patients with Acute kidney injury (AKI) and Cardiogenic shock (CS) . The study also characterizes index hospitalization outcomes and readmission stay features. A secondary objective is to identify risk factors associated with 30-day readmission in this high-risk population using a logistic regression model.
* **Data Source:**
* This retrospective cohort study used data from the 2016–2017 Nationwide Readmissions Database (NRD), developed by the Healthcare Cost and Utilization Project (HCUP). The NRD is a nationally representative, all-payer database of U.S. hospitalizations that allows linkage of patients across hospital stays within a calendar year. Survey weights, stratification, and clustering variables support complex sampling design for national estimates.
* **Cohort Definition:**
* Index admissions were selected based on the following inclusion criteria:
  + Adults aged ≥18 years
  + All diagnoses of CS and AKI , identified using ICD-10-CM codes for CS (isCS pattern, including R57) and AKI (isAKI pattern, including N170, N171, N172, N178, N179)
  + 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
* Readmissions were defined as:
  + Any non-trauma hospitalization within 30 days of discharge
* **Outcomes of Interest:**
  + Primary Outcome:
    - 30-day all-cause readmission (Yes/No), flagged using NRD linkage variables
  + Secondary Outcomes (index admission):
    - In-hospital mortality (DIED)
    - Length of stay (LOS, continuous in days and also categorized as ≤4 vs >4 days)
    - Total hospitalization charges (TOTCHG), inflation-adjusted to 2017 USD
    - Non-home discharge
  + Outcomes during readmission:
    - 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
  + Non-Home Discharge:
    - Defined as any disposition other than home/self-care, specifically:
      * 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)
    - ZIP-based median income quartile (ZIPINC\_QRTL)
    - Weekend admission (AWEEKEND)
  + Clinical Comorbidities:
    - Elixhauser comorbidity variables:
      * Diabetes
      * Peripheral vascular disease
      * Chronic pulmonary disease
      * Hypertension
      * Congestive heart failure
      * Alcohol abuse
      * Obesity
      * Anemia
      * Liver disease
  + Additional clinical risk factors (non-Elixhauser)
    - Smoking
    - Previous stroke or transient ischemic attack
    - Atrial fibrillation
    - Acute myocardial infarction
  + 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 (categorized as above)
* **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 stratified based on whether the patients were readmitted or not during index admissions.
    - P-values from design-based statistical tests (Rao–Scott adjusted chi-square for categorical variables; design-based Kruskal–Wallis test for continuous variables).
  + Multivariable Analysis:
    - A survey-weighted logistic regression modeled predictors of 30-day readmission.
    - The model included demographic, clinical, hospital-level, and index-stay factors.
    - Reference levels were explicitly set (e.g., Male, LOS ≤4 days).
    - 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 = 136,748*1* | **Without Readmission** N = 123,078*1* | **With 30-Day Readmission** N = 13,671*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 67 (15) | 67 (15) | 65 (14) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 87,808 (64%) | 78,720 (64%) | 9,088 (66%) |  |
| Female | 48,940 (36%) | 44,358 (36%) | 4,582 (34%) |  |
| Primary Expected Payer |  |  |  | <0.001 |
| Private | 23,688 (17%) | 21,614 (18%) | 2,074 (15%) |  |
| Medicaid | 15,985 (12%) | 13,837 (11%) | 2,148 (16%) |  |
| Medicare | 88,478 (65%) | 79,671 (65%) | 8,807 (65%) |  |
| Other | 8,355 (6.1%) | 7,741 (6.3%) | 614 (4.5%) |  |
| Median Household Income Quartile |  |  |  | <0.001 |
| 0-25th percentile | 42,137 (31%) | 37,595 (31%) | 4,542 (34%) |  |
| 26th to 50th percentile | 36,804 (27%) | 33,183 (27%) | 3,621 (27%) |  |
| 51st to 75th percentile | 31,718 (24%) | 28,561 (24%) | 3,157 (23%) |  |
| 76th to 100th percentile | 24,118 (18%) | 21,947 (18%) | 2,172 (16%) |  |
| Admission Day |  |  |  | 0.067 |
| Monday-Friday | 101,612 (74%) | 91,328 (74%) | 10,284 (75%) |  |
| Saturday-Sunday | 35,137 (26%) | 31,750 (26%) | 3,386 (25%) |  |
| Hospital Bed Size |  |  |  | 0.053 |
| Small | 12,801 (9.4%) | 11,518 (9.4%) | 1,283 (9.4%) |  |
| Large | 92,993 (68%) | 83,514 (68%) | 9,479 (69%) |  |
| Medium | 30,954 (23%) | 28,046 (23%) | 2,909 (21%) |  |
| Hospital Location and Teaching Status |  |  |  | <0.001 |
| Metropolitan, non-teaching | 24,745 (18%) | 22,479 (18%) | 2,266 (17%) |  |
| Metropolitan, teaching | 107,302 (78%) | 96,299 (78%) | 11,003 (80%) |  |
| Non-metropolitan | 4,701 (3.4%) | 4,299 (3.5%) | 402 (2.9%) |  |
| Anemia | 20,479 (15%) | 17,792 (14%) | 2,687 (20%) | <0.001 |
| Congestive Heart Failure | 106,637 (78%) | 94,753 (77%) | 11,884 (87%) | <0.001 |
| Chronic Pulmonary Disease | 38,545 (28%) | 34,164 (28%) | 4,381 (32%) | <0.001 |
| Liver disease | 38,815 (28%) | 35,553 (29%) | 3,261 (24%) | <0.001 |
| Atrial fibrillation | 61,332 (45%) | 54,673 (44%) | 6,659 (49%) | <0.001 |
| Diabetes | 55,783 (41%) | 49,420 (40%) | 6,363 (47%) | <0.001 |
| Smoking | 17,140 (13%) | 15,124 (12%) | 2,016 (15%) | <0.001 |
| Peripheral Vascular Disease | 31,265 (23%) | 27,367 (22%) | 3,898 (29%) | <0.001 |
| Hypertension | 41,291 (30%) | 37,717 (31%) | 3,574 (26%) | <0.001 |
| Prior Stroke or TIA | 12,867 (9.4%) | 11,405 (9.3%) | 1,463 (11%) | <0.001 |
| Alcohol Abuse | 7,917 (5.8%) | 7,032 (5.7%) | 885 (6.5%) | 0.018 |
| Acute Myocardial Infarction | 25,801 (19%) | 23,408 (19%) | 2,393 (18%) | 0.018 |
| Obesity | 24,781 (18%) | 22,088 (18%) | 2,693 (20%) | 0.006 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### Outcomes of Index Hospitalization

| **Characteristic** | **Overall** N = 136,748*1* | **Without Readmission** N = 123,078*1* | **With 30-Day Readmission** N = 13,671*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| In-Hospital Mortality | 56,972 (42%) | 56,972 (46%) | 0 (0%) | <0.001 |
| Length of Stay (days) | 10 (4, 18) | 9 (4, 17) | 14 (8, 23) | <0.001 |
| Inflation-Adjusted Total Charges ($) | 145,810 (68,968, 307,667) | 142,535 (66,933, 302,833) | 176,502 (88,643, 348,549) | <0.001 |
| Discharged to Non-Home Setting | 91,369 (67%) | 85,481 (69%) | 5,889 (43%) | <0.001 |
| *1*n (%); Median (Q1, Q3) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | |

## Multivariable Analyses

### Risk Factors for 30-Day Readmission

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Age (years) | 1.0 | 0.99, 1.00 | <0.001 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.01 | 0.95, 1.07 | 0.8 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 1.49 | 1.34, 1.65 | <0.001 |
| Medicare | 1.36 | 1.25, 1.48 | <0.001 |
| Other | 0.88 | 0.74, 1.03 | 0.12 |
| Median Household Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.94 | 0.87, 1.01 | 0.11 |
| 51st to 75th percentile | 0.97 | 0.90, 1.05 | 0.4 |
| 76th to 100th percentile | 0.89 | 0.82, 0.97 | 0.009 |
| Admission Day |  |  |  |
| Monday-Friday | — | — |  |
| Saturday-Sunday | 0.97 | 0.91, 1.03 | 0.3 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.93 | 0.83, 1.04 | 0.2 |
| Medium | 0.93 | 0.83, 1.05 | 0.3 |
| Hospital Location and Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 1.02 | 0.95, 1.10 | 0.6 |
| Non-metropolitan | 0.91 | 0.76, 1.09 | 0.3 |
| Non\_Home\_Discharge |  |  |  |
| No | — | — |  |
| Yes | 0.35 | 0.33, 0.38 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 1.30 | 1.21, 1.40 | <0.001 |
| Congestive Heart Failure |  |  |  |
| No | — | — |  |
| Yes | 1.57 | 1.44, 1.70 | <0.001 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.14 | 1.08, 1.21 | <0.001 |
| Chronic Pulmonary Disease |  |  |  |
| No | — | — |  |
| Yes | 1.15 | 1.08, 1.22 | <0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 0.86 | 0.81, 0.92 | <0.001 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.24 | 1.17, 1.32 | <0.001 |
| Smoking |  |  |  |
| No | — | — |  |
| Yes | 1.12 | 1.02, 1.22 | 0.014 |
| Peripheral Vascular Disease |  |  |  |
| No | — | — |  |
| Yes | 1.19 | 1.11, 1.26 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 0.87 | 0.82, 0.93 | <0.001 |
| Prior Stroke or TIA |  |  |  |
| No | — | — |  |
| Yes | 1.12 | 1.02, 1.23 | 0.023 |
| Alcohol Abuse |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 0.98, 1.25 | 0.10 |
| Acute Myocardial Infarction |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.94, 1.11 | 0.6 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.96 | 0.88, 1.05 | 0.4 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

used (Mb) gc trigger (Mb) max used (Mb)  
Ncells 38434275 2052.7 105220756 5619.4 105220756 5619.4  
Vcells 657112060 5013.4 1026256031 7829.8 1026255924 7829.8

### Top 10 causes for readmissions

Table 1: Top Causes of Readmission

| Diagnosis Code | ICD-10 Description | Proportion |
| --- | --- | --- |
| I130 | Hypertensive heart and chronic kidney disease | 34.0% |
| I5023 | Heart failure | 14.5% |
| A419 | Sepsis, unspecified organism | 10.7% |
| I5043 | Heart failure, other type | 5.8% |
| J9601 | Acute respiratory failure | 3.1% |
| I110 | Hypertensive heart disease | 2.9% |
| I63519 | Cerebral infarction | 1.8% |
| I472 | Paroxysmal tachycardia | 1.8% |
| I2699 | Pulmonary embolism | 1.7% |
| J690 | Aspiration pneumonitis | 1.7% |

### LOS and Cost by Readmission Status:

Readmission Hospitalizations resulted in

1. Median Length of Stay (IQR), days: 5 (IQR: 3–9)
2. Median Total Charges (IQR): $41,252 (IQR: $21,473–$89,479)

### In-Hospital Mortality Among Readmitted Patients

Readmission hospitalizations resulted in:

1. Deaths (n): 1378
2. Death Rate (%): 10.09%
3. Death Rate (95% CI): 9.32% to 10.86%