Thirty-Day Readmission Rates, Timing, Predictors, and Costs After Coronary Artery Bypass Graft Surgery in Obese Patients

RCOP NRD A28

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## Preamble:

* **Reference Studies:**
  + [Kim et al., 2018](https://www.ahajournals.org/doi/10.1161/JAHA.118.009863)
  + [Yeo et al., 2019](https://doi.org/10.1001/jamanetworkopen.2019.12208)
* **Study Objective:**
* To evaluate 30-day all-cause hospital readmissions following coronary artery bypass grafting (CABG) among patients with obesity, using a nationally representative sample of U.S. hospitalizations. Specifically, the study aims to:
  + Describe demographic, clinical, and hospital-level characteristics of patients undergoing CABG who are obese.
  + Quantify 30-day readmission rates and timing.
  + Compare in-hospital mortality and healthcare utilization between index and readmission hospitalizations.
  + Identify predictors of readmission in this surgical cohort.
* **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 hospitalizations were defined using the following criteria:
  + Adults aged ≥18 years
  + Diagnosed with obesity, identified by ICD-10-CM codes:
    - E6601, E6609, E661, E662, E668, E66811, E66812, E66813, E6689, E669, Z6830–Z6845
  + Underwent CABG, identified by ICD-10-PCS procedure codes
  + 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:
    - All-cause 30-day readmission (Yes/No), flagged using NRD linkage variables
  + Secondary Outcomes (index admission):
    - In-hospital mortality (DIED)
    - Length of stay (LOS, in days)
    - Total hospitalization charges (TOTCHG), inflation-adjusted to 2017 USD
    - Non-home discharge
  + 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
  + 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)
    - Income quartile based on ZIP code (ZIPINC\_QRTL)
    - Weekend vs weekday admission (AWEEKEND)
    - Elective vs non-elective admission
  + Clinical Variables:
    - Comorbidities from Elixhauser or diagnosis flags:
      * Diabetes
      * Renal failure
      * Congestive heart failure
      * Peripheral vascular disease
      * Chronic pulmonary disease
    - In-Hospital/Postoperative complications:
      * Infection
      * Bleeding
      * Acute kidney injury
      * Ischemic stroke
  + 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
* **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 by readmission status 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 Modeling:
    - A survey-weighted Cox proportional hazards model was fitted to assess predictors of 30-day readmission.
    - The model included demographic, clinical, hospital-level, and index-stay factors.
    - Hazard ratios (HRs) with 95% confidence intervals (CIs) were reported
  + 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).

## Baseline Characteristics

| **Characteristic** | **Overall** N = 109,925*1* | **Without Readmission** N = 100,781*1* | **With 30-day readmission** N = 9,144*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 64 (10) | 64 (10) | 65 (10) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 76,359 (69%) | 70,427 (70%) | 5,932 (65%) |  |
| Female | 33,566 (31%) | 30,354 (30%) | 3,211 (35%) |  |
| Primary Expected Payer |  |  |  | <0.001 |
| Private | 36,528 (33%) | 34,329 (34%) | 2,199 (24%) |  |
| Medicaid | 8,519 (7.8%) | 7,702 (7.7%) | 817 (8.9%) |  |
| Medicare | 58,513 (53%) | 52,852 (53%) | 5,661 (62%) |  |
| Other | 6,239 (5.7%) | 5,779 (5.7%) | 460 (5.0%) |  |
| Median Household Income Quartile |  |  |  | <0.001 |
| 0-25th percentile | 31,022 (29%) | 28,201 (28%) | 2,821 (31%) |  |
| 26th to 50th percentile | 32,269 (30%) | 29,525 (30%) | 2,744 (30%) |  |
| 51st to 75th percentile | 27,676 (26%) | 25,492 (26%) | 2,184 (24%) |  |
| 76th to 100th percentile | 17,315 (16%) | 16,038 (16%) | 1,276 (14%) |  |
| Admission Day |  |  |  | <0.001 |
| Monday-Friday | 96,597 (88%) | 88,706 (88%) | 7,890 (86%) |  |
| Saturday-Sunday | 13,328 (12%) | 12,075 (12%) | 1,253 (14%) |  |
| Admission Type |  |  |  | <0.001 |
| Elective | 51,371 (47%) | 47,470 (47%) | 3,901 (43%) |  |
| Non-elective | 58,101 (53%) | 52,887 (53%) | 5,214 (57%) |  |
| Hospital Bed Size |  |  |  | 0.004 |
| Small | 10,935 (9.9%) | 9,924 (9.8%) | 1,011 (11%) |  |
| Large | 72,175 (66%) | 66,043 (66%) | 6,133 (67%) |  |
| Medium | 26,815 (24%) | 24,815 (25%) | 2,000 (22%) |  |
| Hospital Location and Teaching Status |  |  |  | 0.4 |
| Metropolitan, non-teaching | 19,893 (18%) | 18,184 (18%) | 1,710 (19%) |  |
| Metropolitan, teaching | 86,657 (79%) | 79,526 (79%) | 7,131 (78%) |  |
| Non-metropolitan | 3,375 (3.1%) | 3,071 (3.0%) | 303 (3.3%) |  |
| Diabetes Mellitus | 67,731 (62%) | 61,695 (61%) | 6,035 (66%) | <0.001 |
| Chronic Kidney Disease / Renal Failure | 26,496 (24%) | 23,495 (23%) | 3,002 (33%) | <0.001 |
| Congestive Heart Failure | 42,154 (38%) | 37,691 (37%) | 4,463 (49%) | <0.001 |
| Chronic Pulmonary Disease | 27,639 (25%) | 24,616 (24%) | 3,023 (33%) | <0.001 |
| Peripheral Vascular Disease | 17,196 (16%) | 15,425 (15%) | 1,771 (19%) | <0.001 |
| Non\_Home\_Discharge | 25,883 (24%) | 22,805 (23%) | 3,078 (34%) | <0.001 |
| Postoperative Infection | 876 (0.8%) | 806 (0.8%) | 70 (0.8%) | 0.8 |
| Postoperative Bleeding | 2,553 (2.3%) | 2,337 (2.3%) | 216 (2.4%) | 0.9 |
| Acute Kidney Injury | 26,078 (24%) | 23,082 (23%) | 2,996 (33%) | <0.001 |
| Ischemic Stroke | 1,617 (1.5%) | 1,429 (1.4%) | 188 (2.1%) | 0.002 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

## Unadjusted Outcomes

### Outcomes of Index Hospitalizations

| **Characteristic** | **Overall** N = 109,925*1* | **Without Readmission** N = 100,781*1* | **With 30-day readmission** N = 9,144*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Length of Stay (days) | 8 (6, 12) | 8 (6, 12) | 10 (7, 16) | <0.001 |
| Inflation-Adjusted Total Charges ($) | 167,281 (115,709, 256,321) | 164,869 (114,407, 251,289) | 197,399 (134,243, 312,709) | <0.001 |
| Discharged to Non-Home Setting | 25,883 (24%) | 22,805 (23%) | 3,078 (34%) | <0.001 |
| *1*Median (Q1, Q3); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### 30-Day Readmission Timing

The median time to 30-day readmission following index hospitalization was 9 days (IQR: 4–17).

### In-Hospital Mortality by Readmission Status:

Index hospitalizations resulted in:

1. Deaths (n): 2538
2. Death Rate (%): 2.31%
3. Death Rate (95% CI): 2.14% to 2.48%

Readmission hospitalizations resulted in:

1. Deaths (n): 208
2. Death Rate (%): 2.3%
3. Death Rate (95% CI): 1.74% to 2.85%

### Resource Utilization for Readmission (LOS, Cost)

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 4 (IQR: 2–6)
2. Median Total Charges (IQR): $31,385 (IQR: $18,275–$59,171)

## Multivariable Analyses

### Multivariable Predictors of 30-Day Readmission

Stratified 1 - level Cluster Sampling design (with replacement)  
With (1077) 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, 1.01 | 0.3 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.03 | 0.97, 1.10 | 0.4 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 0.96 | 0.84, 1.09 | 0.5 |
| Medicare | 0.97 | 0.89, 1.07 | 0.6 |
| Other | 1.02 | 0.87, 1.18 | 0.8 |
| Median Household Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.99 | 0.91, 1.07 | 0.7 |
| 51st to 75th percentile | 0.96 | 0.87, 1.05 | 0.3 |
| 76th to 100th percentile | 0.93 | 0.84, 1.03 | 0.14 |
| Admission Day |  |  |  |
| Monday-Friday | — | — |  |
| Saturday-Sunday | 0.98 | 0.90, 1.08 | 0.7 |
| Admission Type |  |  |  |
| Elective | — | — |  |
| Non-elective | 1.04 | 0.97, 1.12 | 0.3 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.96 | 0.86, 1.08 | 0.5 |
| Medium | 0.93 | 0.83, 1.05 | 0.3 |
| Hospital Location and Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 1.01 | 0.94, 1.09 | 0.8 |
| Non-metropolitan | 1.05 | 0.87, 1.26 | 0.6 |
| Diabetes Mellitus |  |  |  |
| No | — | — |  |
| Yes | 0.99 | 0.92, 1.06 | 0.7 |
| Renal Failure |  |  |  |
| No | — | — |  |
| Yes | 0.99 | 0.93, 1.07 | 0.9 |
| Congestive Heart Failure |  |  |  |
| No | — | — |  |
| Yes | 0.97 | 0.91, 1.03 | 0.4 |
| Chronic Pulmonary Disease |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.95, 1.10 | 0.5 |
| Peripheral Vascular Disease |  |  |  |
| No | — | — |  |
| Yes | 0.97 | 0.89, 1.06 | 0.5 |
| Discharged to Non-Home Setting |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.87, 1.00 | 0.060 |
| Postoperative Infection |  |  |  |
| No | — | — |  |
| Yes | 0.67 | 0.51, 0.88 | 0.004 |
| Postoperative Bleeding |  |  |  |
| No | — | — |  |
| Yes | 1.33 | 1.11, 1.58 | 0.002 |
| Acute Kidney Injury |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.94, 1.10 | 0.7 |
| Ischemic Stroke |  |  |  |
| No | — | — |  |
| Yes | 0.81 | 0.65, 1.01 | 0.064 |
| Length of Stay (days) | 1.00 | 0.99, 1.00 | 0.046 |
| Abbreviations: CI = Confidence Interval, HR = Hazard Ratio | | | |