Comparative Analysis of Postoperative Complications and 30-Day Readmissions After CABG in Diabetic vs. Non-Diabetic Patients: A National Readmissions Database Study

RCOP NRD A20

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## Preamble:

* **Reference Studies:**
  + [MA et al., 2020](https://bmccardiovascdisord.biomedcentral.com/articles/10.1186/s12872-020-01447-8)
  + [HR Lehto et al., 2021](https://pmc.ncbi.nlm.nih.gov/articles/PMC10027652/)
* **Study Objective:**
* To evaluate the risk of 30-day all-cause hospital readmission in patients undergoing CABG, comparing those with diabetes and those without diabetes. 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
  + Patients undergoing CABG were identified by ICD-10-CM codes for CABG (isCABG pattern, including “0210083”, “0210088”, “0210089”, “021008C”, “021008F”, “021008W”, “0210093”, “0210098”, “0210099”, “021009C”, “021009F”, “021009W”, “02100A3”, “02100A8”, “02100A9”, “02100AC”, “02100AF”, “02100AW”, “02100J3”, “02100J8”, “02100J9”, “02100JC”, “02100JF”, “02100JW”, “02100K3”, “02100K8”, “02100K9”, “02100KC”, “02100KF”, “02100KW”, “02100Z3”, “02100Z8”, “02100Z9”, “02100ZC”, “02100ZF”, “0210444”, “0210483”, “0210488”, “0210489”, “021048C”, “021048F”, “021048W”, “0210493”, “0210498”, “0210499”, “021049C”, “021049F”, “021049W”, “02104A3”, “02104A8”, “02104A9”, “02104AC”, “02104AF”, “02104AW”, “02104D4”, “02104J3”, “02104J8”, “02104J9”, “02104JC”, “02104JF”, “02104JW”, “02104K3”, “02104K8”, “02104K9”, “02104KC”, “02104KF”, “02104KW”, “02104Z3”, “02104Z8”, “02104Z9”, “02104ZC”, “02104ZF”, “0211083”, “0211088”, “0211089”, “021108C”, “021108F”, “021108W”, “0211093”, “0211098”, “0211099”, “021109C”, “021109F”, “021109W”, “02110A3”, “02110A8”, “02110A9”, “02110AC”, “02110AF”, “02110AW”, “02110J3”, “02110J8”, “02110J9”, “02110JC”, “02110JF”, “02110JW”, “02110K3”, “02110K8”, “02110K9”, “02110KC”, “02110KF”, “02110KW”, “02110Z3”, “02110Z8”, “02110Z9”, “02110ZC”, “02110ZF”, “0211444”, “0211483”, “0211488”, “0211489”, “021148C”, “021148F”, “021148W”, “0211493”, “0211498”, “0211499”, “021149C”, “021149F”, “021149W”, “02114A3”, “02114A8”, “02114A9”, “02114AC”, “02114AF”, “02114AW”, “02114D4”, “02114J3”, “02114J8”, “02114J9”, “02114JC”, “02114JF”, “02114JW”, “02114K3”, “02114K8”, “02114K9”, “02114KC”, “02114KF”, “02114KW”, “02114Z3”, “02114Z8”, “02114Z9”, “02114ZC”, “02114ZF”, “0212083”, “0212088”, “0212089”, “021208C”, “021208F”, “021208W”, “0212093”, “0212098”, “0212099”, “021209C”, “021209F”, “021209W”, “02120A3”, “02120A8”, “02120A9”, “02120AC”, “02120AF”, “02120AW”, “02120J3”, “02120J8”, “02120J9”, “02120JC”, “02120JF”, “02120JW”, “02120K3”, “02120K8”, “02120K9”, “02120KC”, “02120KF”, “02120KW”, “02120Z3”, “02120Z8”, “02120Z9”, “02120ZC”, “02120ZF”, “0212444”, “0212483”, “0212488”, “0212489”, “021248C”, “021248F”, “021248W”, “0212493”, “0212498”, “0212499”, “021249C”, “021249F”, “021249W”, “02124A3”, “02124A8”, “02124A9”, “02124AC”, “02124AF”, “02124AW”, “02124D4”, “02124J3”, “02124J8”, “02124J9”, “02124JC”, “02124JF”, “02124JW”, “02124K3”, “02124K8”, “02124K9”, “02124KC”, “02124KF”, “02124KW”, “02124Z3”, “02124Z8”, “02124Z9”, “02124ZC”, “02124ZF”, “0213083”, “0213088”, “0213089”, “021308C”, “021308F”, “021308W”, “0213093”, “0213098”, “0213099”, “021309C”, “021309F”, “021309W”, “02130A3”, “02130A8”, “02130A9”, “02130AC”, “02130AF”, “02130AW”, “02130J3”, “02130J8”, “02130J9”, “02130JC”, “02130JF”, “02130JW”, “02130K3”, “02130K8”, “02130K9”, “02130KC”, “02130KF”, “02130KW”, “02130Z3”, “02130Z8”, “02130Z9”, “02130ZC”, “02130ZF”, “0213444”, “0213483”, “0213488”, “0213489”, “021348C”, “021348F”, “021348W”, “0213493”, “0213498”, “0213499”, “021349C”, “021349F”, “021349W”, “02134A3”, “02134A8”, “02134A9”, “02134AC”, “02134AF”, “02134AW”, “02134D4”, “02134J3”, “02134J8”, “02134J9”, “02134JC”, “02134JF”, “02134JW”, “02134K3”, “02134K8”, “02134K9”, “02134KC”, “02134KF”, “02134KW”, “02134Z3”, “02134Z8”, “02134Z9”, “02134ZC”, “02134ZF”)
  + Whether patients had diabetes or not:
  + 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
    - Acute myocardial infarction
    - Acute kidney injury
    - Stroke
  + 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:
      * Peripheral vascular disease
      * Congestive heart failure
      * Chronic pulmonary disease
      * Liver disease
      * Obesity
      * Alcohol abuse
      * Anemia
      * Hypertension
  + Additional clinical risk factors (non-Elixhauser)
    - Smoking
    - Atrial fibrillation
  + Acute complications and resource utilization identified via ICD-10 code matching:
    - Acute myocardial infarction
    - Acute kidney injury
    - 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 (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 the presence or absence of Diabetes in patients undergoing CABG 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 = 200,674*1* | **Patients without diabetes undergoing coronary artery bypass grafting** N = 103,715*1* | **Patients with diabetes undergoing coronary artery bypass grafting** N = 96,959*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 66 (11) | 66 (11) | 65 (10) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 146,516 (73%) | 78,938 (76%) | 67,578 (70%) |  |
| Female | 54,158 (27%) | 24,777 (24%) | 29,381 (30%) |  |
| Primary Expected Payer |  |  |  | <0.001 |
| Private | 56,530 (28%) | 30,868 (30%) | 25,662 (27%) |  |
| Medicaid | 17,494 (8.7%) | 8,025 (7.8%) | 9,469 (9.8%) |  |
| Medicare | 111,617 (56%) | 56,855 (55%) | 54,762 (57%) |  |
| Other | 14,689 (7.3%) | 7,784 (7.5%) | 6,906 (7.1%) |  |
| Median Household Income Quartile |  |  |  | <0.001 |
| 0-25th percentile | 57,571 (29%) | 28,069 (27%) | 29,502 (31%) |  |
| 26th to 50th percentile | 56,410 (29%) | 28,994 (28%) | 27,416 (29%) |  |
| 51st to 75th percentile | 48,968 (25%) | 25,863 (25%) | 23,105 (24%) |  |
| 76th to 100th percentile | 34,566 (18%) | 19,149 (19%) | 15,418 (16%) |  |
| Admission Day |  |  |  | 0.007 |
| Monday-Friday | 159,361 (79%) | 82,773 (80%) | 76,588 (79%) |  |
| Saturday-Sunday | 41,313 (21%) | 20,942 (20%) | 20,371 (21%) |  |
| Hospital Bed Size |  |  |  | 0.072 |
| Small | 16,238 (8.1%) | 8,466 (8.2%) | 7,772 (8.0%) |  |
| Large | 135,511 (68%) | 69,446 (67%) | 66,065 (68%) |  |
| Medium | 48,924 (24%) | 25,803 (25%) | 23,122 (24%) |  |
| Hospital Location and Teaching Status |  |  |  | 0.5 |
| Metropolitan, non-teaching | 37,012 (18%) | 19,310 (19%) | 17,702 (18%) |  |
| Metropolitan, teaching | 158,727 (79%) | 81,903 (79%) | 76,824 (79%) |  |
| Non-metropolitan | 4,935 (2.5%) | 2,502 (2.4%) | 2,433 (2.5%) |  |
| Smoking | 39,444 (20%) | 22,833 (22%) | 16,611 (17%) | <0.001 |
| Peripheral Vascular Disease | 34,566 (17%) | 17,869 (17%) | 16,696 (17%) | >0.9 |
| Hypertension | 133,049 (66%) | 70,713 (68%) | 62,335 (64%) | <0.001 |
| Atrial Fibrillation | 69,032 (34%) | 36,250 (35%) | 32,783 (34%) | 0.001 |
| Alcohol Use Disorder | 8,849 (4.4%) | 5,911 (5.7%) | 2,938 (3.0%) | <0.001 |
| Obesity | 57,356 (29%) | 20,988 (20%) | 36,367 (38%) | <0.001 |
| Chronic Pulmonary Disease | 49,424 (25%) | 25,454 (25%) | 23,970 (25%) | 0.6 |
| Liver Disease | 9,337 (4.7%) | 4,573 (4.4%) | 4,764 (4.9%) | <0.001 |
| Congestive Heart Failure | 84,513 (42%) | 38,174 (37%) | 46,339 (48%) | <0.001 |
| Anemia | 18,585 (9.3%) | 6,649 (6.4%) | 11,936 (12%) | <0.001 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### Outcomes of Index Hospitalization

| **Characteristic** | **Overall** N = 200,674*1* | **Patients without diabetes undergoing coronary artery bypass grafting** N = 103,715*1* | **Patients with diabetes undergoing coronary artery bypass grafting** N = 96,959*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| 30-Day Readmission | 18,559 (9.2%) | 8,522 (8.2%) | 10,037 (10%) | <0.001 |
| In-Hospital Mortality | 6,544 (3.3%) | 3,629 (3.5%) | 2,915 (3.0%) | <0.001 |
| Length of Stay (days) | 10 (7, 14) | 9 (7, 13) | 11 (8, 15) | <0.001 |
| Inflation-Adjusted Total Charges ($) | 192,057 (133,099, 302,238) | 183,437 (128,006, 286,698) | 201,764 (139,556, 318,059) | <0.001 |
| Discharged to Non-Home Setting | 50,792 (25%) | 23,654 (23%) | 27,138 (28%) | <0.001 |
| Acute myocardial infarction | 22,180 (11%) | 10,594 (10%) | 11,586 (12%) | <0.001 |
| Acute kidney injury | 50,957 (25%) | 21,765 (21%) | 29,192 (30%) | <0.001 |
| Stroke | 4,327 (2.2%) | 2,168 (2.1%) | 2,159 (2.2%) | 0.2 |
| *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** |
| --- | --- | --- | --- |
| CABG categories |  |  |  |
| Patients without diabetes undergoing coronary artery bypass grafting | — | — |  |
| Patients with diabetes undergoing coronary artery bypass grafting | 1.17 | 1.11, 1.23 | <0.001 |
| Age (years) | 1.00 | 1.00, 1.00 | 0.4 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.21 | 1.15, 1.28 | <0.001 |
| Primary Expected Payer |  |  |  |
| Private | — | — |  |
| Medicaid | 1.61 | 1.48, 1.75 | <0.001 |
| Medicare | 1.33 | 1.24, 1.43 | <0.001 |
| Other | 1.14 | 1.03, 1.26 | 0.012 |
| Median Household Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.91 | 0.86, 0.97 | 0.002 |
| 51st to 75th percentile | 0.91 | 0.86, 0.97 | 0.003 |
| 76th to 100th percentile | 0.86 | 0.80, 0.92 | <0.001 |
| Admission Day |  |  |  |
| Monday-Friday | — | — |  |
| Saturday-Sunday | 1.05 | 0.99, 1.11 | 0.078 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.99 | 0.90, 1.10 | >0.9 |
| Medium | 0.94 | 0.85, 1.05 | 0.3 |
| Hospital Location and Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 0.95 | 0.88, 1.01 | 0.11 |
| Non-metropolitan | 0.94 | 0.77, 1.14 | 0.5 |
| Non-Home Discharge |  |  |  |
| No | — | — |  |
| Yes | 1.29 | 1.22, 1.37 | <0.001 |
| Smoking |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.87, 1.00 | 0.060 |
| Peripheral Vascular Disease |  |  |  |
| No | — | — |  |
| Yes | 1.14 | 1.07, 1.21 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 0.86 | 0.81, 0.90 | <0.001 |
| Atrial Fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.22 | 1.16, 1.28 | <0.001 |
| Alcohol Use Disorder |  |  |  |
| No | — | — |  |
| Yes | 0.96 | 0.85, 1.09 | 0.6 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.90 | 0.86, 0.95 | <0.001 |
| Chronic Pulmonary Disease |  |  |  |
| No | — | — |  |
| Yes | 1.27 | 1.20, 1.34 | <0.001 |
| Liver Disease |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.85, 1.05 | 0.3 |
| Congestive Heart Failure |  |  |  |
| No | — | — |  |
| Yes | 1.31 | 1.25, 1.38 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 1.33 | 1.24, 1.42 | <0.001 |
| AMI |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.95, 1.11 | 0.5 |
| AKI |  |  |  |
| No | — | — |  |
| Yes | 1.16 | 1.10, 1.23 | <0.001 |
| Stroke |  |  |  |
| No | — | — |  |
| Yes | 1.05 | 0.93, 1.20 | 0.4 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

## Readmission Hospitalization Characteristics

### In-Hospital Mortality Among Readmitted Patients

Readmission hospitalizations resulted in:

1. Deaths (n): 574
2. Death Rate (%): 3.11%
3. Death Rate (95% CI): 2.72% to 3.5%

### Resource Utilization During Readmission

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 4 (IQR: 2–6)
2. Median Total Charges (IQR): $32,361 (IQR: $18,448–$62,170)