Contemporary 30-Day Readmissions Following ICD Implantation in Ischemic vs Non-Ischemic Cardiomyopathy

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## Preamble:

* **Reference Studies:**
  + [Gharbin et al., 2023](https://www.sciencedirect.com/science/article/abs/pii/S0146280623000269)
  + [Higgins et al., 2020](https://www.ajconline.org/article/S0002-9149(20)30769-4/fulltext)
  + [Sheth et al., 2025](https://www.benthamdirect.com/content/journals/ccr/10.2174/011573403X345244250217052010)
* **Study Objective:**
* To identify patient- and hospital-level predictors of 30-day all-cause hospital readmission among adults patients hospitalized with ischemic or non-ischemic cardiomyopathy undergoing ICD implantation 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
  + Principal diagnosis of ischemic cardiomyopathy (ICD code I255) or non-ischemic cardiomyopathy (ICD code I42) undergoing ICD implantation.
  + 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
    - 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)
  + Comorbidities and Clinical Covariates:
    - Diabetes
    - Hypertension
    - Cardiac Resynchronization Therapy
    - Family history of sudden cardiac death
    - Congestive heart failure
    - Chronic pulmonary disease
    - Anemia
    - Liver disease
    - Obesity
    - CKD
    - Atrial Fibrillation or Flutter
    - Ventricular Tachycardia
    - History of undergoing PCI
    - History of undergoing CABG
    - History of 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
* **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 ischemic vs. non-ischemic cardiomyopathy groups 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 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, hospital bed size).
    - Results were exponentiated to yield hazard ratios (HRs) 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 = 46,137*1* | **Ischemic Cardiomyopathy** N = 22,212*1* | **Non-Ischemic Cardiomyopathy** N = 23,925*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 64 (14) | 68 (11) | 60 (15) | <0.001 |
| Sex |  |  |  | <0.001 |
| Female | 12,180 (26%) | 4,257 (19%) | 7,923 (33%) |  |
| Male | 33,958 (74%) | 17,955 (81%) | 16,003 (67%) |  |
| Median Income Quartile |  |  |  | <0.001 |
| 0-25th percentile | 15,024 (33%) | 6,785 (31%) | 8,238 (35%) |  |
| 26th to 50th percentile | 12,011 (26%) | 6,098 (28%) | 5,913 (25%) |  |
| 51st to 75th percentile | 10,382 (23%) | 5,115 (23%) | 5,267 (22%) |  |
| 76th to 100th percentile | 8,086 (18%) | 3,916 (18%) | 4,171 (18%) |  |
| Hospital Bed Size |  |  |  | 0.068 |
| Large | 30,810 (67%) | 14,622 (66%) | 16,188 (68%) |  |
| Medium | 11,473 (25%) | 5,628 (25%) | 5,846 (24%) |  |
| Small | 3,854 (8.4%) | 1,962 (8.8%) | 1,892 (7.9%) |  |
| Teaching Status |  |  |  | 0.024 |
| Metropolitan, non-teaching | 9,112 (20%) | 4,564 (21%) | 4,548 (19%) |  |
| Metropolitan, teaching | 35,920 (78%) | 17,082 (77%) | 18,837 (79%) |  |
| Non-metropolitan | 1,106 (2.4%) | 566 (2.5%) | 540 (2.3%) |  |
| Non-home discharge | 6,118 (13%) | 3,368 (15%) | 2,750 (11%) | <0.001 |
| Length of stay (days) | 8 (9) | 8 (9) | 8 (10) | 0.075 |
| Number of comorbidities |  |  |  | <0.001 |
| No comorbidities | 658 (1.4%) | 0 (0%) | 658 (2.7%) |  |
| One comorbidity | 7,804 (17%) | 1,518 (6.8%) | 6,286 (26%) |  |
| Two or more comorbidities | 37,676 (82%) | 20,694 (93%) | 16,982 (71%) |  |
| Cardiac Resynchronization Therapy | 169 (0.4%) | 67 (0.3%) | 102 (0.4%) | 0.2 |
| Atrial Fibrillation or Flutter | 18,051 (39%) | 8,551 (38%) | 9,501 (40%) | 0.090 |
| Ventricular Tachycardia | 20,848 (45%) | 10,484 (47%) | 10,364 (43%) | <0.001 |
| Congestive heart failure | 44,717 (97%) | 22,212 (100%) | 22,505 (94%) | <0.001 |
| Chronic pulmonary disease | 12,224 (26%) | 6,332 (29%) | 5,892 (25%) | <0.001 |
| Liver disease | 2,881 (6.2%) | 1,106 (5.0%) | 1,775 (7.4%) | <0.001 |
| Obesity | 9,837 (21%) | 4,091 (18%) | 5,745 (24%) | <0.001 |
| Hypertension | 22,164 (48%) | 11,033 (50%) | 11,131 (47%) | <0.001 |
| Diabetes | 18,482 (40%) | 10,630 (48%) | 7,852 (33%) | <0.001 |
| Chronic Kidney Disease | 14,668 (32%) | 8,048 (36%) | 6,620 (28%) | <0.001 |
| Anemia | 11,330 (25%) | 6,065 (27%) | 5,265 (22%) | <0.001 |
| Family history of sudden cardiac death | 261 (0.6%) | 33 (0.1%) | 229 (1.0%) | <0.001 |
| Previous PCI | 9,660 (21%) | 8,068 (36%) | 1,592 (6.7%) | <0.001 |
| Previous CABG | 8,224 (18%) | 7,135 (32%) | 1,089 (4.6%) | <0.001 |
| Prior myocardial infarction | 13,311 (29%) | 10,612 (48%) | 2,699 (11%) | <0.001 |
| Drug abuse | 2,274 (4.9%) | 711 (3.2%) | 1,563 (6.5%) | <0.001 |
| Smoking | 7,043 (15%) | 3,602 (16%) | 3,442 (14%) | <0.001 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### Outcomes of Index Hospitalizations

| **Characteristic** | **Overall** N = 46,137*1* | **Ischemic Cardiomyopathy** N = 22,212*1* | **Non-Ischemic Cardiomyopathy** N = 23,925*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| In-Hospital Mortality | 434 (0.9%) | 242 (1.1%) | 192 (0.8%) | 0.026 |
| Length of Stay (days) | 6 (3, 10) | 6 (3, 10) | 6 (3, 9) | 0.075 |
| Inflation-Adjusted Total Charges ($) | 170,610 (115,395, 255,833) | 171,624 (115,770, 260,484) | 169,674 (115,117, 251,358) | 0.052 |
| Discharged to Non-Home Setting | 6,118 (13%) | 3,368 (15%) | 2,750 (11%) | <0.001 |
| *1*n (%); Median (Q1, Q3) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | |

### Outcomes of Readmission Hospitalization

| **Characteristic** | **Overall** N = 3,971*1* | **Ischemic Cardiomyopathy** N = 1,908*1* | **Non-Ischemic Cardiomyopathy** N = 2,064*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| In-Hospital Mortality | 171 (4.3%) | 109 (5.7%) | 62 (3.0%) | 0.003 |
| Length of Stay (days) | 4.0 (2.0, 7.0) | 4.0 (2.0, 7.0) | 4.0 (2.0, 6.0) | 0.066 |
| Inflation-Adjusted Total Charges ($) | 33,055 (17,926, 64,528) | 34,874 (17,662, 66,132) | 31,876 (18,093, 63,452) | 0.6 |
| Discharged to Non-Home Setting | 885 (22%) | 505 (26%) | 380 (18%) | <0.001 |
| *1*n (%); Median (Q1, Q3) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | |

## Multivariable Analyses

### 30-Day Readmission:

Stratified 1 - level Cluster Sampling design (with replacement)  
With (1115) 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 | 0.3 |
| Sex |  |  |  |
| Female | — | — |  |
| Male | 0.99 | 0.90, 1.09 | 0.9 |
| Length of stay (days) | 1.00 | 1.00, 1.01 | 0.051 |
| Median Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 1.02 | 0.92, 1.13 | 0.7 |
| 51st to 75th percentile | 0.98 | 0.88, 1.10 | 0.8 |
| 76th to 100th percentile | 0.99 | 0.88, 1.11 | 0.9 |
| Hospital Bed Size |  |  |  |
| Large | — | — |  |
| Medium | 1.01 | 0.92, 1.11 | 0.9 |
| Small | 0.89 | 0.78, 1.02 | 0.090 |
| Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 1.01 | 0.92, 1.12 | 0.8 |
| Non-metropolitan | 1.22 | 0.95, 1.58 | 0.12 |
| Cardiac Resynchronization Therapy |  |  |  |
| No | — | — |  |
| Yes | 1.14 | 0.70, 1.83 | 0.6 |
| Cardiomyopathy |  |  |  |
| Ischemic Cardiomyopathy | — | — |  |
| Non-Ischemic Cardiomyopathy | 0.96 | 0.86, 1.06 | 0.4 |
| Atrial Fibrillation or Flutter |  |  |  |
| No | — | — |  |
| Yes | 1.07 | 0.99, 1.16 | 0.10 |
| Ventricular Tachycardia |  |  |  |
| No | — | — |  |
| Yes | 0.96 | 0.88, 1.04 | 0.3 |
| Congestive heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.62, 1.65 | >0.9 |
| Chronic pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.93, 1.11 | 0.7 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 1.09 | 0.93, 1.27 | 0.3 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 1.00 | 0.90, 1.11 | >0.9 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.88, 1.09 | 0.7 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.00 | 0.92, 1.09 | >0.9 |
| Chronic Kidney Disease |  |  |  |
| No | — | — |  |
| Yes | 1.05 | 0.95, 1.17 | 0.3 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 0.99 | 0.91, 1.08 | 0.8 |
| Family history of sudden cardiac death |  |  |  |
| No | — | — |  |
| Yes | 0.88 | 0.55, 1.42 | 0.6 |
| Previous PCI |  |  |  |
| No | — | — |  |
| Yes | 1.03 | 0.92, 1.14 | 0.6 |
| Previous CABG |  |  |  |
| No | — | — |  |
| Yes | 0.99 | 0.89, 1.10 | 0.8 |
| Prior myocardial infarction |  |  |  |
| No | — | — |  |
| Yes | 0.96 | 0.87, 1.05 | 0.4 |
| Drug abuse |  |  |  |
| No | — | — |  |
| Yes | 1.10 | 0.91, 1.33 | 0.3 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.90, 1.07 | 0.6 |
| Smoking |  |  |  |
| No | — | — |  |
| Yes | 0.91 | 0.81, 1.01 | 0.087 |
| Abbreviations: CI = Confidence Interval, HR = Hazard Ratio | | | |

## Top Causes of Readmissions

Top 10 causes of 30-day re-admissions among patients with ischemic and non-ischemic cardiomyopathy undergoing ICD implantation.

Top 10 Diagnoses by Weighted Proportion

| Diagnosis | Proportion |
| --- | --- |
| I50 | 0.1527600 |
| I13 | 0.1138924 |
| I47 | 0.0905311 |
| I11 | 0.0635041 |
| A41 | 0.0553415 |
| N17 | 0.0346646 |
| I48 | 0.0332641 |
| R07 | 0.0201506 |
| I21 | 0.0201048 |
| J96 | 0.0200025 |