90-Day Readmissions Following Carotid Endarterectomy and Stenting

2025\_June\_NRD\_A26\_90Days

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## Preamble:

* **Reference Studies:**
  + [Lima et al., 2018](https://www.ahajournals.org/doi/10.1161/CIRCINTERVENTIONS.119.008508)
* **Study Objective:**
* To identify patient- and hospital-level predictors of 90-day all-cause hospital readmission among adults undergoing carotid endarterectomy and stenting using a nationally representative dataset. This study also evaluates the clinical and economic burden of readmission in this high-risk population, including its associations with in-hospital mortality, length of stay (LOS), and hospital charges.
* **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:
  + Adults aged ≥18 years
  + Undergoing carotid endarterectomy and stenting, using CCSR: CAR006
  + Non-elective admission
  + Index discharge by the end of November to allow for a complete 90-day follow-up period
  + Complete data on LOS and NRD\_DAYSTOEVENT, required to compute discharge dates
* **Outcomes of Interest:**
  + Primary Outcome:
    - Binary indicator of 90-day readmission (Yes/No)
  + Secondary Outcomes:
    - In-hospital mortality (binary)
    - Length of stay (LOS, in days)
    - Total hospitalization charges (inflation-adjusted to 2017 USD)
* **Outcome Definitions:**
  + Readmission:
    - Defined using NRD’s linkage variables. Readmissions were identified only among patients with qualifying index events.
    - Trauma-related hospitalizations were excluded only from the readmission pool to avoid injury-related returns.
  + 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
* **Covariates:**
  + Demographic & Socioeconomic Factors:
    - Age (categorized: 18–49, 50–64, 65–79, 80+)
    - Sex
    - Primary expected payer (Insurance; Medicare, Medicaid, Private, Other)
    - ZIP-based median income quartile
  + Clinical Characteristics:
    - Hypertension
    - Diabetes
    - Congestive\_HF
    - Hyperlipidemia
    - Obesity
    - Coronary artery disease
    - Valvular disease
    - Atrial fibrillation
    - Peripheral vascular disease
    - Chronic pulmonary disease
    - Chronic kidney disease
    - Anemia
    - Coagulopathy
    - MetCancer
    - Dementia
    - Fluid\_electrolyte\_disorders
    - Liver\_disease
    - Depression
    - PreviousPCI
    - PreviousCABG
    - prioMI
    - PriorStroke
  + Hospital Characteristics:
    - Hospital bed size (Small, Medium, Large)
    - Urban/rural teaching status (Metropolitan, teaching vs non-teaching, etc.)
  + Disposition and Severity:
    - Discharge disposition
    - Number of comorbidities
    - Length of stay (categorized as above)
* **Statistical Methods:**
  + Survey Design and Weighting:
    - All analyses incorporated NRD’s complex sampling design via the survey and srvyr packages.
  + Descriptive Statistics:
    - Weighted baseline characteristics of index hospitalizations were summarized and stratified by 90-day readmission status to compare patients who were readmitted versus those who were not.
    - Stratification was performed using a derived binary variable, which categorized patients as:
      * With 90-day readmission
      * Without readmission
    - P-values from statistical tests (Rao–Scott adjusted chi-square for categorical variables; Kruskal–Wallis test for continuous variables).
    - The ten most common principle diagnoses for readmission were reported according to decreasing prevalence
  + Multivariable Regression:
    - A survey-weighted logistic regression modeled predictors of 90-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.
* **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 = 48,207*1* | **Without Readmission** N = 39,457*1* | **With 90-day readmission** N = 8,750*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) |  |  |  | 0.001 |
| 18–49 | 3,390 (7.0%) | 2,848 (7.2%) | 543 (6.2%) |  |
| 50–64 | 13,605 (28%) | 11,268 (29%) | 2,337 (27%) |  |
| 65–79 | 21,908 (45%) | 17,869 (45%) | 4,039 (46%) |  |
| 80+ | 9,304 (19%) | 7,473 (19%) | 1,831 (21%) |  |
| Sex |  |  |  | 0.3 |
| Male | 27,917 (58%) | 22,914 (58%) | 5,003 (57%) |  |
| Female | 20,290 (42%) | 16,543 (42%) | 3,747 (43%) |  |
| Median Income Quartile |  |  |  | 0.020 |
| 0-25th percentile | 14,355 (30%) | 11,598 (30%) | 2,758 (32%) |  |
| 26th to 50th percentile | 13,470 (28%) | 11,008 (28%) | 2,462 (29%) |  |
| 51st to 75th percentile | 11,552 (24%) | 9,601 (25%) | 1,951 (23%) |  |
| 76th to 100th percentile | 8,087 (17%) | 6,633 (17%) | 1,454 (17%) |  |
| Hospital Bed Size |  |  |  | 0.10 |
| Small | 3,432 (7.1%) | 2,737 (6.9%) | 695 (7.9%) |  |
| Large | 33,362 (69%) | 27,404 (69%) | 5,959 (68%) |  |
| Medium | 11,413 (24%) | 9,317 (24%) | 2,097 (24%) |  |
| Hospital Teaching Status |  |  |  | 0.081 |
| Metropolitan, non-teaching | 9,246 (19%) | 7,539 (19%) | 1,708 (20%) |  |
| Metropolitan, teaching | 37,496 (78%) | 30,667 (78%) | 6,828 (78%) |  |
| Non-metropolitan | 1,465 (3.0%) | 1,251 (3.2%) | 214 (2.4%) |  |
| Insurance |  |  |  | <0.001 |
| Private | 9,614 (20%) | 8,168 (21%) | 1,446 (17%) |  |
| Medicaid | 4,279 (8.9%) | 3,523 (8.9%) | 756 (8.6%) |  |
| Medicare | 31,467 (65%) | 25,330 (64%) | 6,137 (70%) |  |
| Other | 2,777 (5.8%) | 2,375 (6.0%) | 402 (4.6%) |  |
| DISPUNIFORM |  |  |  | <0.001 |
| Home health care | 8,411 (17%) | 6,669 (17%) | 1,742 (20%) |  |
| Other | 2,304 (4.8%) | 2,264 (5.7%) | 40 (0.5%) |  |
| Routine discharge to home/self-care | 26,444 (55%) | 22,241 (56%) | 4,203 (48%) |  |
| Transfer to another short-term hospital | 396 (0.8%) | 320 (0.8%) | 75 (0.9%) |  |
| Transfer to SNF / intermediate / other facility | 10,634 (22%) | 7,947 (20%) | 2,687 (31%) |  |
| No. of comorbidities |  |  |  | <0.001 |
| No comorbidities | 714 (1.5%) | 655 (1.7%) | 60 (0.7%) |  |
| One comorbidity | 8,613 (18%) | 7,556 (19%) | 1,057 (12%) |  |
| Two or more comorbidities | 38,880 (81%) | 31,246 (79%) | 7,633 (87%) |  |
| Hypertension | 40,507 (84%) | 32,959 (84%) | 7,548 (86%) | <0.001 |
| Diabetes | 17,220 (36%) | 13,579 (34%) | 3,641 (42%) | <0.001 |
| Congestive heart failure | 8,583 (18%) | 6,316 (16%) | 2,267 (26%) | <0.001 |
| Hyperlipidemia | 31,226 (65%) | 25,597 (65%) | 5,629 (64%) | 0.5 |
| Obesity | 6,878 (14%) | 5,577 (14%) | 1,301 (15%) | 0.2 |
| Coronary artery disease | 17,820 (37%) | 13,924 (35%) | 3,897 (45%) | <0.001 |
| Valvular disease | 4,979 (10%) | 3,869 (9.8%) | 1,111 (13%) | <0.001 |
| Atrial fibrillation | 9,638 (20%) | 7,546 (19%) | 2,091 (24%) | <0.001 |
| Peripheral vascular disease | 10,609 (22%) | 8,332 (21%) | 2,277 (26%) | <0.001 |
| Chronic pulmonary disease | 10,946 (23%) | 8,507 (22%) | 2,440 (28%) | <0.001 |
| Chronic kidney disease | 8,519 (18%) | 6,456 (16%) | 2,064 (24%) | <0.001 |
| Anemia | 11,884 (25%) | 9,222 (23%) | 2,662 (30%) | <0.001 |
| Coagulopathy | 3,192 (6.6%) | 2,498 (6.3%) | 695 (7.9%) | <0.001 |
| Metastatic Cancer | 509 (1.1%) | 374 (0.9%) | 135 (1.5%) | <0.001 |
| Dementia | 2,286 (4.7%) | 1,743 (4.4%) | 542 (6.2%) | <0.001 |
| Fluid and electrolyte imbalance | 12,322 (26%) | 9,590 (24%) | 2,732 (31%) | <0.001 |
| Liver disease | 954 (2.0%) | 730 (1.8%) | 224 (2.6%) | 0.004 |
| Depression | 6,134 (13%) | 4,777 (12%) | 1,356 (16%) | <0.001 |
| Previous PCI | 5,375 (11%) | 4,309 (11%) | 1,066 (12%) | 0.024 |
| Previous CABG | 5,585 (12%) | 4,345 (11%) | 1,241 (14%) | <0.001 |
| prio MI | 4,966 (10%) | 3,889 (9.9%) | 1,077 (12%) | <0.001 |
| Prior Stroke | 14,120 (29%) | 11,492 (29%) | 2,628 (30%) | 0.3 |
| *1*n (%) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment | | | | |

## Readmission Hospitalization Characteristics

### In-Hospital Mortality Among Readmitted Patients

Readmission hospitalizations resulted in:

1. Deaths (n): 314
2. Death Rate (%): 3.61%
3. Death Rate (95% CI): 2.98% to 4.23%

### Resource Utilization During Readmission

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 3 (IQR: 2–6)
2. Median Total Charges (IQR): $38,973 (IQR: $22,234–$73,794)

## Top causes of readmission

| Diagnosis Code | ICD-10 Description | Proportion |
| --- | --- | --- |
| I65 | Occlusion and stenosis of precerebral arteries, not resulting in cerebral infarction | 0.0881 |
| A41 | Other sepsis | 0.0857 |
| I63 | Cerebral infarction | 0.0787 |
| I69 | Sequelae of cerebrovascular disease | 0.0383 |
| I25 | Chronic ischemic heart disease | 0.0291 |
| N17 | Acute kidney failure | 0.0253 |
| K92 | Other diseases of the digestive system | 0.0229 |
| I61 | Nontraumatic intracerebral hemorrhage | 0.0213 |
| I50 | Heart failure | 0.0212 |
| I21 | Acute myocardial infarction | 0.0200 |

## Multivariable Regression

### 90-Day Readmission:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Age (years) | 1.00 | 0.99, 1.00 | 0.035 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.03 | 0.95, 1.11 | 0.5 |
| Insurance |  |  |  |
| Private | — | — |  |
| Medicaid | 1.06 | 0.92, 1.22 | 0.4 |
| Medicare | 1.16 | 1.03, 1.31 | 0.015 |
| Other | 0.93 | 0.76, 1.13 | 0.4 |
| Median Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.95 | 0.87, 1.04 | 0.3 |
| 51st to 75th percentile | 0.88 | 0.79, 0.97 | 0.014 |
| 76th to 100th percentile | 0.95 | 0.85, 1.06 | 0.3 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.86 | 0.74, 1.00 | 0.050 |
| Medium | 0.88 | 0.75, 1.03 | 0.12 |
| Hospital Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 0.98 | 0.89, 1.07 | 0.6 |
| Non-metropolitan | 0.75 | 0.58, 0.96 | 0.025 |
| DISPUNIFORM |  |  |  |
| Home health care | — | — |  |
| Other | 0.06 | 0.04, 0.10 | <0.001 |
| Routine discharge to home/self-care | 0.89 | 0.81, 0.98 | 0.015 |
| Transfer to another short-term hospital | 0.94 | 0.64, 1.38 | 0.7 |
| Transfer to SNF / intermediate / other facility | 1.27 | 1.15, 1.40 | <0.001 |
| No. of comorbidities |  |  |  |
| No comorbidities | — | — |  |
| One comorbidity | 1.73 | 1.18, 2.54 | 0.005 |
| Two or more comorbidities | 2.04 | 1.38, 3.00 | <0.001 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 1.02 | 0.90, 1.16 | 0.7 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.08, 1.27 | <0.001 |
| Congestive heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.39 | 1.26, 1.54 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.83 | 0.76, 0.90 | <0.001 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.85, 1.04 | 0.2 |
| Coronary artery disease |  |  |  |
| No | — | — |  |
| Yes | 1.25 | 1.13, 1.37 | <0.001 |
| Valvular disease |  |  |  |
| No | — | — |  |
| Yes | 1.06 | 0.95, 1.18 | 0.3 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 1.01, 1.22 | 0.031 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.10 | 1.01, 1.20 | 0.034 |
| Chronic pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.07, 1.28 | <0.001 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 1.21 | 1.10, 1.34 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 1.02, 1.21 | 0.015 |
| Coagulopathy |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 0.97, 1.26 | 0.14 |
| Metastatic Cancer |  |  |  |
| No | — | — |  |
| Yes | 1.80 | 1.33, 2.43 | <0.001 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 1.16 | 1.00, 1.36 | 0.057 |
| Fluid and electrolyte imbalance |  |  |  |
| No | — | — |  |
| Yes | 1.22 | 1.12, 1.33 | <0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 1.20 | 0.94, 1.54 | 0.14 |
| Depression |  |  |  |
| No | — | — |  |
| Yes | 1.20 | 1.06, 1.35 | 0.003 |
| Previous PCI |  |  |  |
| No | — | — |  |
| Yes | 0.89 | 0.79, 1.02 | 0.092 |
| Previous CABG |  |  |  |
| No | — | — |  |
| Yes | 1.08 | 0.95, 1.22 | 0.2 |
| prio MI |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.89, 1.14 | >0.9 |
| Prior Stroke |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.87, 1.03 | 0.2 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |