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 hospitalized with 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
  + 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 Outcomes:
    - 90-day readmission for coronary stenting vs endarterectomy
  + 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.
* **Covariates:**
  + Demographic & Socioeconomic Factors:
    - Age
    - Sex
    - Primary expected payer (Insurance; Medicare, Medicaid, Private, Other)
    - ZIP-based median income quartile
  + Clinical Characteristics:
    - Hypertension
    - Diabetes
    - Congestive heart failure
    - Hyperlipidemia
    - Obesity
    - Coronary artery disease
    - Valvular disease
    - Atrial fibrillation
    - Peripheral vascular disease
    - Chronic pulmonary disease
    - Chronic kidney disease
    - Anemia
    - Coagulopathy
    - Metastatic Cancer
    - Dementia
    - Fluid and electrolyte disorders
    - Liver disease
    - Depression
    - Previous PCI
    - Previous CABG
    - Prior MI
    - Prior Stroke
  + 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 that resulted in 90 day readmissions were summarized and stratified.
    - Stratification was performed using a derived binary variable, which categorized patients as:
      * Those udergoing carotid stenting
      * Those udergoing carotid endarterectomy
    - 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

### Characteristics of Index hospitalizations

| **Characteristic** | **Overall** N = 228,949*1* | **Carotid endarterectomy** N = 181,601*1* | **Carotid stenting** N = 47,348*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 70 (11) | 71 (10) | 66 (13) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 131,688 (58%) | 106,785 (59%) | 24,902 (53%) |  |
| Female | 97,261 (42%) | 74,816 (41%) | 22,445 (47%) |  |
| Median Income Quartile |  |  |  | 0.3 |
| 0-25th percentile | 64,285 (28%) | 50,705 (28%) | 13,580 (29%) |  |
| 26th to 50th percentile | 67,080 (30%) | 53,619 (30%) | 13,461 (29%) |  |
| 51st to 75th percentile | 56,682 (25%) | 44,694 (25%) | 11,988 (26%) |  |
| 76th to 100th percentile | 37,587 (17%) | 29,966 (17%) | 7,621 (16%) |  |
| Hospital Bed Size |  |  |  | <0.001 |
| Small | 24,326 (11%) | 22,138 (12%) | 2,188 (4.6%) |  |
| Large | 146,149 (64%) | 111,103 (61%) | 35,046 (74%) |  |
| Medium | 58,473 (26%) | 48,360 (27%) | 10,113 (21%) |  |
| Hospital Teaching Status |  |  |  | <0.001 |
| Metropolitan, non-teaching | 52,175 (23%) | 45,641 (25%) | 6,534 (14%) |  |
| Metropolitan, teaching | 166,463 (73%) | 126,572 (70%) | 39,891 (84%) |  |
| Non-metropolitan | 10,310 (4.5%) | 9,388 (5.2%) | 922 (1.9%) |  |
| Insurance |  |  |  | <0.001 |
| Private | 42,550 (19%) | 31,212 (17%) | 11,338 (24%) |  |
| Medicaid | 12,608 (5.5%) | 8,715 (4.8%) | 3,893 (8.2%) |  |
| Medicare | 165,572 (72%) | 135,933 (75%) | 29,639 (63%) |  |
| Other | 8,041 (3.5%) | 5,621 (3.1%) | 2,420 (5.1%) |  |
| Discharge Disposition |  |  |  | <0.001 |
| Home health care | 22,079 (9.6%) | 18,053 (9.9%) | 4,026 (8.5%) |  |
| Other | 3,806 (1.7%) | 2,683 (1.5%) | 1,123 (2.4%) |  |
| Routine discharge to home/self-care | 182,492 (80%) | 146,172 (81%) | 36,320 (77%) |  |
| Transfer to another short-term hospital | 696 (0.3%) | 471 (0.3%) | 225 (0.5%) |  |
| Transfer to SNF / intermediate / other facility | 19,785 (8.6%) | 14,181 (7.8%) | 5,604 (12%) |  |
| No. of comorbidities |  |  |  | <0.001 |
| No comorbidities | 1,277 (0.6%) | 151 (<0.1%) | 1,126 (2.4%) |  |
| One comorbidity | 63,109 (28%) | 49,186 (27%) | 13,923 (29%) |  |
| Two or more comorbidities | 164,564 (72%) | 132,264 (73%) | 32,299 (68%) |  |
| Hypertension | 188,251 (82%) | 152,388 (84%) | 35,863 (76%) | <0.001 |
| Diabetes | 78,455 (34%) | 64,260 (35%) | 14,195 (30%) | <0.001 |
| Congestive heart failure | 28,820 (13%) | 22,505 (12%) | 6,315 (13%) | 0.006 |
| Hyperlipidemia | 150,878 (66%) | 123,831 (68%) | 27,046 (57%) | <0.001 |
| Obesity | 29,709 (13%) | 23,971 (13%) | 5,738 (12%) | 0.009 |
| Coronary artery disease | 92,566 (40%) | 76,268 (42%) | 16,298 (34%) | <0.001 |
| Valvular disease | 19,259 (8.4%) | 15,769 (8.7%) | 3,489 (7.4%) | <0.001 |
| Atrial fibrillation | 31,932 (14%) | 26,139 (14%) | 5,793 (12%) | <0.001 |
| Peripheral vascular disease | 51,369 (22%) | 41,091 (23%) | 10,278 (22%) | 0.084 |
| Chronic pulmonary disease | 52,467 (23%) | 42,020 (23%) | 10,447 (22%) | 0.026 |
| Chronic kidney disease | 33,074 (14%) | 26,897 (15%) | 6,177 (13%) | <0.001 |
| Anemia | 30,894 (13%) | 23,393 (13%) | 7,501 (16%) | <0.001 |
| Coagulopathy | 7,207 (3.1%) | 5,416 (3.0%) | 1,791 (3.8%) | <0.001 |
| Metastatic Cancer | 968 (0.4%) | 596 (0.3%) | 372 (0.8%) | <0.001 |
| Dementia | 5,571 (2.4%) | 4,312 (2.4%) | 1,259 (2.7%) | 0.021 |
| Fluid and electrolyte imbalance | 23,763 (10%) | 16,979 (9.3%) | 6,784 (14%) | <0.001 |
| Liver disease | 3,084 (1.3%) | 2,405 (1.3%) | 678 (1.4%) | 0.2 |
| Depression | 22,680 (9.9%) | 17,452 (9.6%) | 5,228 (11%) | <0.001 |
| Previous PCI | 29,613 (13%) | 24,341 (13%) | 5,272 (11%) | <0.001 |
| Previous CABG | 34,304 (15%) | 28,835 (16%) | 5,469 (12%) | <0.001 |
| prio MI | 26,367 (12%) | 21,747 (12%) | 4,620 (9.8%) | <0.001 |
| Prior Stroke | 66,182 (29%) | 52,241 (29%) | 13,941 (29%) | 0.14 |
| *1*Mean (SD); n (%) | | | | |
| *2*Design-based KruskalWallis test; Pearson's X^2: Rao & Scott adjustment | | | | |

### Outcomes of Index hospitalizations

| **Characteristic** | **Overall** N = 46,481*1* | **Carotid endarterectomy** N = 33,064*1* | **Carotid stenting** N = 13,418*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| In-Hospital Mortality | 2,027 (4.4%) | 1,391 (4.2%) | 637 (4.8%) | 0.13 |
| Length of Stay (days) | 9 (11) | 9 (10) | 11 (13) | 0.004 |
| Inflation-Adjusted Total Charges ($) | 157,249 (178,388) | 138,216 (146,852) | 204,055 (232,313) | <0.001 |
| Discharge Disposition |  |  |  | <0.001 |
| Home health care | 7,992 (17%) | 6,073 (18%) | 1,919 (14%) |  |
| Other | 2,159 (4.6%) | 1,482 (4.5%) | 678 (5.1%) |  |
| Routine discharge to home/self-care | 25,655 (55%) | 18,158 (55%) | 7,497 (56%) |  |
| Transfer to another short-term hospital | 378 (0.8%) | 236 (0.7%) | 142 (1.1%) |  |
| Transfer to SNF / intermediate / other facility | 10,281 (22%) | 7,114 (22%) | 3,167 (24%) |  |
| *1*n (%); Mean (SD) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | |

## Multivariable Regression

### 90-Day Readmission:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Procedure |  |  |  |
| Carotid endarterectomy | — | — |  |
| Carotid stenting | 1.12 | 1.03, 1.22 | 0.010 |
| Age (years) | 1.00 | 0.99, 1.00 | 0.13 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.02 | 0.94, 1.11 | 0.6 |
| Insurance |  |  |  |
| Private | — | — |  |
| Medicaid | 1.05 | 0.90, 1.22 | 0.5 |
| Medicare | 1.15 | 1.02, 1.29 | 0.022 |
| Other | 0.93 | 0.76, 1.14 | 0.5 |
| Median Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.98 | 0.89, 1.08 | 0.6 |
| 51st to 75th percentile | 0.88 | 0.79, 0.98 | 0.018 |
| 76th to 100th percentile | 0.96 | 0.85, 1.08 | 0.5 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.83 | 0.71, 0.97 | 0.017 |
| Medium | 0.87 | 0.74, 1.02 | 0.084 |
| Hospital Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 0.96 | 0.87, 1.05 | 0.4 |
| Non-metropolitan | 0.73 | 0.57, 0.95 | 0.019 |
| Discharge disposition |  |  |  |
| Home health care | — | — |  |
| Other | 0.06 | 0.04, 0.10 | <0.001 |
| Routine discharge to home/self-care | 0.88 | 0.80, 0.96 | 0.006 |
| Transfer to another short-term hospital | 0.98 | 0.66, 1.44 | >0.9 |
| Transfer to SNF / intermediate / other facility | 1.26 | 1.14, 1.39 | <0.001 |
| No. of comorbidities |  |  |  |
| No comorbidities | — | — |  |
| One comorbidity | 1.21 | 0.79, 1.85 | 0.4 |
| Two or more comorbidities | 1.45 | 0.95, 2.22 | 0.089 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 1.03 | 0.90, 1.17 | 0.7 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.18 | 1.09, 1.28 | <0.001 |
| Congestive heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.39 | 1.26, 1.54 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.84 | 0.77, 0.91 | <0.001 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.95 | 0.86, 1.06 | 0.4 |
| Coronary artery disease |  |  |  |
| No | — | — |  |
| Yes | 1.26 | 1.15, 1.39 | <0.001 |
| Valvular disease |  |  |  |
| No | — | — |  |
| Yes | 1.04 | 0.92, 1.17 | 0.5 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 1.01, 1.22 | 0.025 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.07 | 0.98, 1.17 | 0.14 |
| Chronic pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 1.16 | 1.06, 1.26 | 0.002 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 1.20 | 1.09, 1.32 | <0.001 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 1.02, 1.22 | 0.019 |
| Coagulopathy |  |  |  |
| No | — | — |  |
| Yes | 1.10 | 0.96, 1.27 | 0.2 |
| Metastatic Cancer |  |  |  |
| No | — | — |  |
| Yes | 1.89 | 1.39, 2.56 | <0.001 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 1.15 | 0.98, 1.35 | 0.080 |
| Fluid and electrolyte imbalance |  |  |  |
| No | — | — |  |
| Yes | 1.22 | 1.12, 1.33 | <0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 1.23 | 0.95, 1.59 | 0.11 |
| Depression |  |  |  |
| No | — | — |  |
| Yes | 1.19 | 1.05, 1.34 | 0.005 |
| Previous PCI |  |  |  |
| No | — | — |  |
| Yes | 0.88 | 0.77, 1.01 | 0.060 |
| Previous CABG |  |  |  |
| No | — | — |  |
| Yes | 1.07 | 0.95, 1.22 | 0.3 |
| prio MI |  |  |  |
| No | — | — |  |
| Yes | 1.00 | 0.88, 1.14 | >0.9 |
| Prior Stroke |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.86, 1.02 | 0.15 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

## Top Causes of Readmission

### Top Causes of Readmission – Carotid Endarterectomy

| Diagnosis | Proportion |
| --- | --- |
| I65 | 0.937 |
| I63 | 0.0259 |
| I25 | 0.0117 |
| I21 | 0.00602 |
| I69 | 0.00464 |
| I97 | 0.00441 |
| G45 | 0.00295 |
| D64 | 0.00174 |
| E11 | 0.00161 |
| D44 | 0.00135 |

### Top Causes of Readmission – Carotid Stenting

| Diagnosis | Proportion |
| --- | --- |
| I65 | 0.698 |
| I67 | 0.141 |
| I63 | 0.0448 |
| I69 | 0.0287 |
| I72 | 0.0258 |
| I60 | 0.0167 |
| I25 | 0.0118 |
| I77 | 0.00844 |
| G45 | 0.00757 |
| I70 | 0.00457 |