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 September 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 = 46,481*1* | **Carotid endarterectomy** N = 33,064*1* | **Carotid stenting** N = 13,418*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 69 (12) | 70 (11) | 65 (14) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 26,819 (58%) | 19,401 (59%) | 7,418 (55%) |  |
| Female | 19,662 (42%) | 13,663 (41%) | 5,999 (45%) |  |
| Median Income Quartile |  |  |  | 0.6 |
| 0-25th percentile | 13,770 (30%) | 9,736 (30%) | 4,034 (31%) |  |
| 26th to 50th percentile | 13,000 (28%) | 9,355 (29%) | 3,645 (28%) |  |
| 51st to 75th percentile | 11,179 (24%) | 7,907 (24%) | 3,272 (25%) |  |
| 76th to 100th percentile | 7,824 (17%) | 5,561 (17%) | 2,263 (17%) |  |
| Hospital Bed Size |  |  |  | <0.001 |
| Small | 3,316 (7.1%) | 2,879 (8.7%) | 437 (3.3%) |  |
| Large | 32,100 (69%) | 21,859 (66%) | 10,241 (76%) |  |
| Medium | 11,065 (24%) | 8,325 (25%) | 2,740 (20%) |  |
| Hospital Teaching Status |  |  |  | <0.001 |
| Metropolitan, non-teaching | 9,062 (19%) | 7,386 (22%) | 1,677 (12%) |  |
| Metropolitan, teaching | 35,990 (77%) | 24,389 (74%) | 11,602 (86%) |  |
| Non-metropolitan | 1,428 (3.1%) | 1,289 (3.9%) | 139 (1.0%) |  |
| Insurance |  |  |  | <0.001 |
| Private | 9,203 (20%) | 5,732 (17%) | 3,470 (26%) |  |
| Medicaid | 3,966 (8.5%) | 2,494 (7.6%) | 1,472 (11%) |  |
| Medicare | 30,663 (66%) | 23,111 (70%) | 7,552 (56%) |  |
| Other | 2,582 (5.6%) | 1,684 (5.1%) | 898 (6.7%) |  |
| 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%) |  |
| No. of comorbidities |  |  |  | <0.001 |
| No comorbidities | 438 (0.9%) | 65 (0.2%) | 374 (2.8%) |  |
| One comorbidity | 8,241 (18%) | 5,339 (16%) | 2,902 (22%) |  |
| Two or more comorbidities | 37,802 (81%) | 27,660 (84%) | 10,142 (76%) |  |
| Hypertension | 39,286 (85%) | 28,754 (87%) | 10,531 (78%) | <0.001 |
| Diabetes | 16,844 (36%) | 12,502 (38%) | 4,342 (32%) | <0.001 |
| Congestive heart failure | 8,279 (18%) | 6,138 (19%) | 2,141 (16%) | <0.001 |
| Hyperlipidemia | 30,489 (66%) | 23,010 (70%) | 7,479 (56%) | <0.001 |
| Obesity | 6,567 (14%) | 4,864 (15%) | 1,703 (13%) | 0.002 |
| Coronary artery disease | 17,396 (37%) | 13,190 (40%) | 4,205 (31%) | <0.001 |
| Valvular disease | 4,755 (10%) | 3,704 (11%) | 1,051 (7.8%) | <0.001 |
| Atrial fibrillation | 9,283 (20%) | 7,365 (22%) | 1,918 (14%) | <0.001 |
| Peripheral vascular disease | 9,713 (21%) | 7,037 (21%) | 2,676 (20%) | 0.068 |
| Chronic pulmonary disease | 10,517 (23%) | 7,613 (23%) | 2,904 (22%) | 0.058 |
| Chronic kidney disease | 8,199 (18%) | 6,207 (19%) | 1,992 (15%) | <0.001 |
| Anemia | 10,979 (24%) | 7,541 (23%) | 3,437 (26%) | <0.001 |
| Coagulopathy | 2,901 (6.2%) | 2,062 (6.2%) | 839 (6.3%) | >0.9 |
| Metastatic Cancer | 478 (1.0%) | 285 (0.9%) | 192 (1.4%) | <0.001 |
| Dementia | 2,238 (4.8%) | 1,695 (5.1%) | 543 (4.0%) | 0.001 |
| Fluid and electrolyte imbalance | 11,626 (25%) | 7,742 (23%) | 3,883 (29%) | <0.001 |
| Liver disease | 866 (1.9%) | 620 (1.9%) | 246 (1.8%) | 0.8 |
| Depression | 5,903 (13%) | 4,175 (13%) | 1,728 (13%) | 0.6 |
| Previous PCI | 5,254 (11%) | 3,872 (12%) | 1,382 (10%) | 0.005 |
| Previous CABG | 5,459 (12%) | 4,119 (12%) | 1,341 (10.0%) | <0.001 |
| prio MI | 4,863 (10%) | 3,659 (11%) | 1,204 (9.0%) | <0.001 |
| Prior Stroke | 13,831 (30%) | 10,157 (31%) | 3,674 (27%) | <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 = 46,481*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 |