30-Day Readmissions Following Carotid Endarterectomy and Stenting

2025\_June\_NRD\_A26\_30Days

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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 30-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 30-day follow-up period
  + Complete data on LOS and NRD\_DAYSTOEVENT, required to compute discharge dates
* **Outcomes of Interest:**
  + Primary Outcomes:
    - 30-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 30 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 30-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 = 56,207*1* | **Carotid endarterectomy** N = 39,912*1* | **Carotid stenting** N = 16,295*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) | 69 (12) | 70 (11) | 65 (14) | <0.001 |
| Sex |  |  |  | <0.001 |
| Male | 32,446 (58%) | 23,445 (59%) | 9,001 (55%) |  |
| Female | 23,761 (42%) | 16,467 (41%) | 7,294 (45%) |  |
| Median Income Quartile |  |  |  | 0.5 |
| 0-25th percentile | 16,661 (30%) | 11,778 (30%) | 4,883 (30%) |  |
| 26th to 50th percentile | 15,702 (28%) | 11,278 (29%) | 4,423 (28%) |  |
| 51st to 75th percentile | 13,542 (24%) | 9,542 (24%) | 3,999 (25%) |  |
| 76th to 100th percentile | 9,440 (17%) | 6,683 (17%) | 2,757 (17%) |  |
| Hospital Bed Size |  |  |  | <0.001 |
| Small | 4,023 (7.2%) | 3,490 (8.7%) | 533 (3.3%) |  |
| Large | 38,722 (69%) | 26,251 (66%) | 12,471 (77%) |  |
| Medium | 13,462 (24%) | 10,171 (25%) | 3,291 (20%) |  |
| Hospital Teaching Status |  |  |  | <0.001 |
| Metropolitan, non-teaching | 10,978 (20%) | 8,929 (22%) | 2,049 (13%) |  |
| Metropolitan, teaching | 43,465 (77%) | 29,392 (74%) | 14,074 (86%) |  |
| Non-metropolitan | 1,764 (3.1%) | 1,591 (4.0%) | 172 (1.1%) |  |
| Insurance |  |  |  | <0.001 |
| Private | 11,055 (20%) | 6,865 (17%) | 4,190 (26%) |  |
| Medicaid | 4,841 (8.6%) | 3,018 (7.6%) | 1,823 (11%) |  |
| Medicare | 37,062 (66%) | 27,917 (70%) | 9,144 (56%) |  |
| Other | 3,172 (5.7%) | 2,063 (5.2%) | 1,109 (6.8%) |  |
| Discharge Disposition |  |  |  | <0.001 |
| Home health care | 9,631 (17%) | 7,300 (18%) | 2,331 (14%) |  |
| Other | 2,672 (4.8%) | 1,849 (4.6%) | 824 (5.1%) |  |
| Routine discharge to home/self-care | 30,908 (55%) | 21,817 (55%) | 9,091 (56%) |  |
| Transfer to another short-term hospital | 439 (0.8%) | 275 (0.7%) | 164 (1.0%) |  |
| Transfer to SNF / intermediate / other facility | 12,526 (22%) | 8,661 (22%) | 3,865 (24%) |  |
| No. of comorbidities |  |  |  | <0.001 |
| No comorbidities | 518 (0.9%) | 71 (0.2%) | 447 (2.7%) |  |
| One comorbidity | 9,981 (18%) | 6,407 (16%) | 3,574 (22%) |  |
| Two or more comorbidities | 45,708 (81%) | 33,434 (84%) | 12,274 (75%) |  |
| Hypertension | 47,457 (84%) | 34,730 (87%) | 12,727 (78%) | <0.001 |
| Diabetes | 20,374 (36%) | 15,143 (38%) | 5,232 (32%) | <0.001 |
| Congestive heart failure | 10,082 (18%) | 7,502 (19%) | 2,580 (16%) | <0.001 |
| Hyperlipidemia | 36,690 (65%) | 27,672 (69%) | 9,018 (55%) | <0.001 |
| Obesity | 7,933 (14%) | 5,865 (15%) | 2,068 (13%) | <0.001 |
| Coronary artery disease | 20,979 (37%) | 15,954 (40%) | 5,025 (31%) | <0.001 |
| Valvular disease | 5,759 (10%) | 4,507 (11%) | 1,252 (7.7%) | <0.001 |
| Atrial fibrillation | 11,330 (20%) | 9,012 (23%) | 2,318 (14%) | <0.001 |
| Peripheral vascular disease | 11,649 (21%) | 8,490 (21%) | 3,159 (19%) | 0.007 |
| Chronic pulmonary disease | 12,784 (23%) | 9,255 (23%) | 3,528 (22%) | 0.028 |
| Chronic kidney disease | 9,913 (18%) | 7,523 (19%) | 2,390 (15%) | <0.001 |
| Anemia | 13,309 (24%) | 9,119 (23%) | 4,190 (26%) | <0.001 |
| Coagulopathy | 3,517 (6.3%) | 2,482 (6.2%) | 1,035 (6.4%) | 0.7 |
| Metastatic Cancer | 581 (1.0%) | 351 (0.9%) | 230 (1.4%) | <0.001 |
| Dementia | 2,680 (4.8%) | 2,020 (5.1%) | 660 (4.0%) | <0.001 |
| Fluid and electrolyte imbalance | 14,060 (25%) | 9,349 (23%) | 4,711 (29%) | <0.001 |
| Liver disease | 1,059 (1.9%) | 749 (1.9%) | 310 (1.9%) | >0.9 |
| Depression | 7,135 (13%) | 5,051 (13%) | 2,085 (13%) | 0.8 |
| Previous PCI | 6,393 (11%) | 4,715 (12%) | 1,678 (10%) | <0.001 |
| Previous CABG | 6,620 (12%) | 5,014 (13%) | 1,605 (9.9%) | <0.001 |
| prio MI | 5,871 (10%) | 4,423 (11%) | 1,448 (8.9%) | <0.001 |
| Prior Stroke | 16,735 (30%) | 12,308 (31%) | 4,427 (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 = 56,207*1* | **Carotid endarterectomy** N = 39,912*1* | **Carotid stenting** N = 16,295*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| In-Hospital Mortality | 2,492 (4.4%) | 1,716 (4.3%) | 776 (4.8%) | 0.2 |
| Length of Stay (days) | 9 (11) | 9 (10) | 11 (13) | 0.006 |
| Inflation-Adjusted Total Charges ($) | 158,972 (181,837) | 139,063 (147,158) | 207,627 (240,034) | <0.001 |
| Discharge Disposition |  |  |  | <0.001 |
| Home health care | 9,631 (17%) | 7,300 (18%) | 2,331 (14%) |  |
| Other | 2,672 (4.8%) | 1,849 (4.6%) | 824 (5.1%) |  |
| Routine discharge to home/self-care | 30,908 (55%) | 21,817 (55%) | 9,091 (56%) |  |
| Transfer to another short-term hospital | 439 (0.8%) | 275 (0.7%) | 164 (1.0%) |  |
| Transfer to SNF / intermediate / other facility | 12,526 (22%) | 8,661 (22%) | 3,865 (24%) |  |
| *1*n (%); Mean (SD) | | | | |
| *2*Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test | | | | |

## Multivariable Regression

### 30-Day Readmission:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Procedure |  |  |  |
| Carotid endarterectomy | — | — |  |
| Carotid stenting | 1.11 | 0.99, 1.24 | 0.065 |
| Age (years) | 1.00 | 0.99, 1.00 | 0.3 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.14 | 1.04, 1.24 | 0.004 |
| Insurance |  |  |  |
| Private | — | — |  |
| Medicaid | 1.09 | 0.90, 1.33 | 0.4 |
| Medicare | 1.27 | 1.09, 1.47 | 0.002 |
| Other | 1.12 | 0.88, 1.42 | 0.4 |
| Median Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.92 | 0.82, 1.04 | 0.2 |
| 51st to 75th percentile | 0.84 | 0.74, 0.96 | 0.011 |
| 76th to 100th percentile | 0.91 | 0.80, 1.05 | 0.2 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.84 | 0.70, 1.01 | 0.061 |
| Medium | 0.79 | 0.65, 0.97 | 0.022 |
| Hospital Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 0.93 | 0.84, 1.04 | 0.2 |
| Non-metropolitan | 0.67 | 0.49, 0.91 | 0.011 |
| Discharge disposition |  |  |  |
| Home health care | — | — |  |
| Other | 0.07 | 0.04, 0.13 | <0.001 |
| Routine discharge to home/self-care | 0.85 | 0.76, 0.96 | 0.011 |
| Transfer to another short-term hospital | 1.37 | 0.92, 2.03 | 0.12 |
| Transfer to SNF / intermediate / other facility | 1.17 | 1.04, 1.32 | 0.009 |
| No. of comorbidities |  |  |  |
| No comorbidities | — | — |  |
| One comorbidity | 0.78 | 0.48, 1.28 | 0.3 |
| Two or more comorbidities | 0.89 | 0.55, 1.45 | 0.6 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 1.06 | 0.93, 1.22 | 0.4 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.20 | 1.10, 1.32 | <0.001 |
| Congestive heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.40 | 1.25, 1.58 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.86 | 0.78, 0.95 | 0.003 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.92 | 0.82, 1.04 | 0.2 |
| Coronary artery disease |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.05, 1.31 | 0.005 |
| Valvular disease |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.85, 1.13 | 0.8 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.05, 1.31 | 0.006 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.04 | 0.94, 1.16 | 0.4 |
| Chronic pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 1.12 | 1.01, 1.23 | 0.030 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 1.16 | 1.04, 1.29 | 0.007 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.06, 1.30 | 0.002 |
| Coagulopathy |  |  |  |
| No | — | — |  |
| Yes | 1.05 | 0.89, 1.24 | 0.5 |
| Metastatic Cancer |  |  |  |
| No | — | — |  |
| Yes | 1.69 | 1.19, 2.40 | 0.003 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 1.13 | 0.95, 1.36 | 0.2 |
| Fluid and electrolyte imbalance |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.07, 1.29 | 0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 1.36 | 1.04, 1.79 | 0.025 |
| Depression |  |  |  |
| No | — | — |  |
| Yes | 1.10 | 0.96, 1.26 | 0.2 |
| Previous PCI |  |  |  |
| No | — | — |  |
| Yes | 0.98 | 0.85, 1.13 | 0.8 |
| Previous CABG |  |  |  |
| No | — | — |  |
| Yes | 1.07 | 0.92, 1.25 | 0.3 |
| prio MI |  |  |  |
| No | — | — |  |
| Yes | 1.03 | 0.89, 1.20 | 0.7 |
| Prior Stroke |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.85, 1.04 | 0.2 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |

## Top Causes of Readmission

### Top Causes of Readmission – Carotid Endarterectomy

| Diagnosis | Proportion |
| --- | --- |
| I65 | 0.851 |
| I63 | 0.0496 |
| I25 | 0.0242 |
| I21 | 0.0201 |
| I97 | 0.0150 |
| G45 | 0.0120 |
| I69 | 0.00938 |
| E11 | 0.00438 |
| I70 | 0.00429 |
| D44 | 0.00369 |

### Top Causes of Readmission – Carotid Stenting

| Diagnosis | Proportion |
| --- | --- |
| I65 | 0.639 |
| I67 | 0.150 |
| I63 | 0.0438 |
| I69 | 0.0418 |
| I25 | 0.0245 |
| I77 | 0.0225 |
| I72 | 0.0209 |
| I60 | 0.0207 |
| I70 | 0.0133 |
| I78 | 0.0132 |