30-Day Readmissions Following Carotid Endarterectomy and Stenting

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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, using CCSR: CAR006
  + 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 Outcome:
    - Binary indicator of 30-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 30-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 30-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 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

### Baseline Characteristics

| **Characteristic** | **Overall** N = 58,379*1* | **Without Readmission** N = 52,867*1* | **With 30-day readmission** N = 5,512*1* | **p-value***2* |
| --- | --- | --- | --- | --- |
| Age (years) |  |  |  | 0.005 |
| 18–49 | 4,144 (7.1%) | 3,815 (7.2%) | 329 (6.0%) |  |
| 50–64 | 16,407 (28%) | 14,967 (28%) | 1,440 (26%) |  |
| 65–79 | 26,527 (45%) | 23,939 (45%) | 2,588 (47%) |  |
| 80+ | 11,301 (19%) | 10,145 (19%) | 1,155 (21%) |  |
| Sex |  |  |  | 0.010 |
| Male | 33,827 (58%) | 30,767 (58%) | 3,061 (56%) |  |
| Female | 24,552 (42%) | 22,100 (42%) | 2,452 (44%) |  |
| Median Income Quartile |  |  |  | 0.010 |
| 0-25th percentile | 17,406 (30%) | 15,601 (30%) | 1,806 (33%) |  |
| 26th to 50th percentile | 16,285 (28%) | 14,762 (28%) | 1,523 (28%) |  |
| 51st to 75th percentile | 14,008 (24%) | 12,790 (25%) | 1,218 (22%) |  |
| 76th to 100th percentile | 9,778 (17%) | 8,881 (17%) | 897 (16%) |  |
| Hospital Bed Size |  |  |  | 0.13 |
| Small | 4,164 (7.1%) | 3,715 (7.0%) | 450 (8.2%) |  |
| Large | 40,335 (69%) | 36,530 (69%) | 3,805 (69%) |  |
| Medium | 13,880 (24%) | 12,622 (24%) | 1,258 (23%) |  |
| Hospital Teaching Status |  |  |  | 0.091 |
| Metropolitan, non-teaching | 11,220 (19%) | 10,130 (19%) | 1,090 (20%) |  |
| Metropolitan, teaching | 45,340 (78%) | 41,048 (78%) | 4,292 (78%) |  |
| Non-metropolitan | 1,819 (3.1%) | 1,688 (3.2%) | 131 (2.4%) |  |
| Insurance |  |  |  | <0.001 |
| Private | 11,585 (20%) | 10,758 (20%) | 827 (15%) |  |
| Medicaid | 5,235 (9.0%) | 4,770 (9.0%) | 466 (8.5%) |  |
| Medicare | 38,078 (65%) | 34,134 (65%) | 3,944 (72%) |  |
| Other | 3,402 (5.8%) | 3,131 (5.9%) | 272 (4.9%) |  |
| DISPUNIFORM |  |  |  | <0.001 |
| Home health care | 10,124 (17%) | 8,983 (17%) | 1,141 (21%) |  |
| Other | 2,855 (4.9%) | 2,827 (5.4%) | 28 (0.5%) |  |
| Routine discharge to home/self-care | 31,900 (55%) | 29,340 (56%) | 2,560 (46%) |  |
| Transfer to another short-term hospital | 463 (0.8%) | 399 (0.8%) | 64 (1.2%) |  |
| Transfer to SNF / intermediate / other facility | 13,005 (22%) | 11,290 (21%) | 1,716 (31%) |  |
| No. of comorbidities |  |  |  | <0.001 |
| No comorbidities | 839 (1.4%) | 790 (1.5%) | 50 (0.9%) |  |
| One comorbidity | 10,456 (18%) | 9,791 (19%) | 665 (12%) |  |
| Two or more comorbidities | 47,084 (81%) | 42,287 (80%) | 4,797 (87%) |  |
| Hypertension | 49,029 (84%) | 44,244 (84%) | 4,784 (87%) | <0.001 |
| Diabetes | 20,864 (36%) | 18,520 (35%) | 2,344 (43%) | <0.001 |
| Congestive heart failure | 10,461 (18%) | 8,963 (17%) | 1,499 (27%) | <0.001 |
| Hyperlipidemia | 37,611 (64%) | 34,092 (64%) | 3,519 (64%) | 0.5 |
| Obesity | 8,313 (14%) | 7,508 (14%) | 804 (15%) | 0.6 |
| Coronary artery disease | 21,514 (37%) | 19,057 (36%) | 2,457 (45%) | <0.001 |
| Valvular disease | 6,050 (10%) | 5,343 (10%) | 706 (13%) | <0.001 |
| Atrial fibrillation | 11,787 (20%) | 10,391 (20%) | 1,397 (25%) | <0.001 |
| Peripheral vascular disease | 12,770 (22%) | 11,323 (21%) | 1,447 (26%) | <0.001 |
| Chronic pulmonary disease | 13,329 (23%) | 11,788 (22%) | 1,541 (28%) | <0.001 |
| Chronic kidney disease | 10,332 (18%) | 9,005 (17%) | 1,327 (24%) | <0.001 |
| Anemia | 14,444 (25%) | 12,674 (24%) | 1,770 (32%) | <0.001 |
| Coagulopathy | 3,889 (6.7%) | 3,444 (6.5%) | 445 (8.1%) | 0.002 |
| Metastatic Cancer | 621 (1.1%) | 537 (1.0%) | 85 (1.5%) | 0.017 |
| Dementia | 2,749 (4.7%) | 2,403 (4.5%) | 347 (6.3%) | <0.001 |
| Fluid and electrolyte imbalance | 14,933 (26%) | 13,160 (25%) | 1,773 (32%) | <0.001 |
| Liver disease | 1,174 (2.0%) | 1,018 (1.9%) | 157 (2.8%) | 0.002 |
| Depression | 7,412 (13%) | 6,594 (12%) | 818 (15%) | 0.002 |
| Previous PCI | 6,527 (11%) | 5,821 (11%) | 707 (13%) | 0.006 |
| Previous CABG | 6,771 (12%) | 5,977 (11%) | 794 (14%) | <0.001 |
| prio MI | 6,016 (10%) | 5,318 (10%) | 698 (13%) | <0.001 |
| Prior Stroke | 17,088 (29%) | 15,435 (29%) | 1,653 (30%) | 0.4 |
| *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): 266
2. Death Rate (%): 4.85%
3. Death Rate (95% CI): 4% to 5.71%

### Resource Utilization During Readmission

Readmission hospitalizations resulted in:

1. Median Length of Stay (IQR), days: 3 (IQR: 2–7)
2. Median Total Charges (IQR): $38,239 (IQR: $21,684–$75,185)

## 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

### 30-Day Readmission:

| **Characteristic** | **OR** | **95% CI** | **p-value** |
| --- | --- | --- | --- |
| Age (years) | 1.00 | 0.99, 1.00 | 0.067 |
| Sex |  |  |  |
| Male | — | — |  |
| Female | 1.12 | 1.03, 1.22 | 0.011 |
| Insurance |  |  |  |
| Private | — | — |  |
| Medicaid | 1.11 | 0.92, 1.33 | 0.3 |
| Medicare | 1.28 | 1.10, 1.49 | 0.001 |
| Other | 1.07 | 0.84, 1.35 | 0.6 |
| Median Income Quartile |  |  |  |
| 0-25th percentile | — | — |  |
| 26th to 50th percentile | 0.91 | 0.81, 1.02 | 0.095 |
| 51st to 75th percentile | 0.84 | 0.74, 0.96 | 0.010 |
| 76th to 100th percentile | 0.90 | 0.79, 1.03 | 0.13 |
| Hospital Bed Size |  |  |  |
| Small | — | — |  |
| Large | 0.86 | 0.72, 1.03 | 0.11 |
| Medium | 0.80 | 0.66, 0.98 | 0.028 |
| Hospital Teaching Status |  |  |  |
| Metropolitan, non-teaching | — | — |  |
| Metropolitan, teaching | 0.97 | 0.87, 1.07 | 0.5 |
| Non-metropolitan | 0.70 | 0.52, 0.94 | 0.019 |
| DISPUNIFORM |  |  |  |
| Home health care | — | — |  |
| Other | 0.07 | 0.04, 0.12 | <0.001 |
| Routine discharge to home/self-care | 0.86 | 0.76, 0.96 | 0.010 |
| Transfer to another short-term hospital | 1.33 | 0.90, 1.95 | 0.2 |
| Transfer to SNF / intermediate / other facility | 1.17 | 1.04, 1.32 | 0.008 |
| No. of comorbidities |  |  |  |
| No comorbidities | — | — |  |
| One comorbidity | 1.19 | 0.76, 1.85 | 0.4 |
| Two or more comorbidities | 1.30 | 0.84, 2.01 | 0.2 |
| Hypertension |  |  |  |
| No | — | — |  |
| Yes | 1.08 | 0.94, 1.24 | 0.3 |
| Diabetes |  |  |  |
| No | — | — |  |
| Yes | 1.19 | 1.09, 1.31 | <0.001 |
| Congestive heart failure |  |  |  |
| No | — | — |  |
| Yes | 1.38 | 1.23, 1.56 | <0.001 |
| Hyperlipidemia |  |  |  |
| No | — | — |  |
| Yes | 0.85 | 0.77, 0.93 | <0.001 |
| Obesity |  |  |  |
| No | — | — |  |
| Yes | 0.91 | 0.81, 1.03 | 0.13 |
| Coronary artery disease |  |  |  |
| No | — | — |  |
| Yes | 1.15 | 1.03, 1.28 | 0.014 |
| Valvular disease |  |  |  |
| No | — | — |  |
| Yes | 1.01 | 0.88, 1.16 | 0.9 |
| Atrial fibrillation |  |  |  |
| No | — | — |  |
| Yes | 1.16 | 1.04, 1.30 | 0.008 |
| Peripheral vascular disease |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 1.00, 1.23 | 0.045 |
| Chronic pulmonary disease |  |  |  |
| No | — | — |  |
| Yes | 1.13 | 1.03, 1.25 | 0.011 |
| Chronic kidney disease |  |  |  |
| No | — | — |  |
| Yes | 1.17 | 1.06, 1.30 | 0.003 |
| Anemia |  |  |  |
| No | — | — |  |
| Yes | 1.18 | 1.07, 1.30 | <0.001 |
| Coagulopathy |  |  |  |
| No | — | — |  |
| Yes | 1.08 | 0.92, 1.26 | 0.3 |
| Metastatic Cancer |  |  |  |
| No | — | — |  |
| Yes | 1.61 | 1.13, 2.28 | 0.008 |
| Dementia |  |  |  |
| No | — | — |  |
| Yes | 1.15 | 0.96, 1.38 | 0.13 |
| Fluid and electrolyte imbalance |  |  |  |
| No | — | — |  |
| Yes | 1.20 | 1.09, 1.32 | <0.001 |
| Liver disease |  |  |  |
| No | — | — |  |
| Yes | 1.29 | 0.99, 1.68 | 0.056 |
| Depression |  |  |  |
| No | — | — |  |
| Yes | 1.11 | 0.97, 1.27 | 0.14 |
| Previous PCI |  |  |  |
| No | — | — |  |
| Yes | 1.0 | 0.86, 1.15 | >0.9 |
| Previous CABG |  |  |  |
| No | — | — |  |
| Yes | 1.10 | 0.95, 1.27 | 0.2 |
| prio MI |  |  |  |
| No | — | — |  |
| Yes | 1.04 | 0.90, 1.20 | 0.6 |
| Prior Stroke |  |  |  |
| No | — | — |  |
| Yes | 0.94 | 0.86, 1.04 | 0.2 |
| Abbreviations: CI = Confidence Interval, OR = Odds Ratio | | | |