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# Factors affecting cardiovascular and cerebrovascular complications of carotid artery stenting in Northern Michigan: A retrospective study☆,☆☆

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ABSTRACT

*Background:* This study seeks to identify factors associated with periprocedural complications of carotid artery stenting (CAS) to best understand CAS complication rates and optimize patient outcomes. Periprocedural complications include major adverse cardiovascular and cerebrovascular events (MACCE) that include myocardial infarction (MI), stroke, or death.

*Methods:* We retrospectively analyzed 181 patients from Northern Michigan who underwent CAS. Rates of stroke, MI, and death occurring within 30 days post-procedure were examined. Associations of open vs. closed cell stent type, demographics, comorbidities, and symptomatic carotid stenosis were compared to determine significance. All patients had three NIH Stroke Scale (NIHSS) exams: at baseline, 24 h post-procedure, and at the one-month visit. Cardiac enzymes were measured twice in all patients, within 24 h post-procedure. All patients were treated with dual anti-platelet therapy for at least 6 months post-procedure.

*Results:* Three patients (1.66%) experienced a major complication within one-month post-procedure. These complications included one MI (0.55%), one stroke (0.55%), and one death (0.55%). The following variable factors were not associated with the occurrence of MACCE complications within 30 days post-procedure: stent design (open vs. closed cell) ($p = 1.000$), age ≥80 ($p = 0.559$), smoking history ($p = 0.569$), hypertension ($p = 1.000$), diabetes ($p = 1.000$), and symptomatic carotid stenosis ($p = 0.254$).

*Conclusions:* Age of 80 years old or above, symptomatic carotid stenosis, open-cell stent design, and history of diabetes, smoking, or hypertension were not found to have an association with MACCE within 1 month after CAS. Future studies using a greater sample size will be beneficial to better assess periprocedural complication risks of CAS, while also considering the effect of operator experience and technological advancements on decreasing periprocedural complication rates.



## 1. Introduction

The carotid artery stenting (CAS) procedure was approved in 2004 and is designed as an alternative for patients who are considered high risk candidates for carotid endarterectomy (CEA) and would benefit equally from stenting or surgery for carotid artery stenosis. CAS is used as an alternative to CEA as an intervention for carotid artery stenosis, as it may prove to be less invasive [1]. Both procedures seek to improve blood flow and minimize the risk of distal embolization to the brain tissue. Findings of the Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy (SAPPHIRE) trial and the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) established CAS as a safe and efficacious alternative to CEA for long term stroke prevention among patients at high surgical risk for CEA [2]. Another advantage is that CAS can be utilized for high cervical lesions (i.e. at the level of C2 or above) of the carotid artery [1]. It is necessary to continuously work towards further reducing the rate of adverse events in order to optimize patient outcomes [3]. Major adverse cardiovascular and cerebrovascular events (MACCE) that may occur following CAS include myocardial infarction (MI) within 24 h post procedure, any new cerebrovascular event 1–31 days post procedure, or death 1–31 days post procedure [4]. Prior studies have found that octogenarians and patients with symptomatic carotid stenosis may be at increased risk for an MI, stroke, or death following CAS, while sex and comorbidities do not affect the risk of periprocedural complications [5–7]. Studies also suggest that use of an open cell stent may increase patients' risk for complications by virtue of creating less scaffolding of the atheromatous plaque [3,8]. This study analyzes cardiovascular and cerebrovascular periprocedural complications of CAS, seeking to identify risk factors and areas of improvement to prevent adverse outcomes in a small community hospital setting.

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## 2. Material and methods

We retrospectively analyzed 181 patients from Northern Michigan who underwent CAS. Rates of stroke, MI, and death occurring within 30 days post procedure were examined. Statistical analysis using descriptive statistics and Fisher's Exact Test was performed. Associations of open vs. closed cell stent type, demographics (age), comorbidities, and symptomatic carotid stenosis with p-values for two-sided test ≤0.05 were considered statistically significant. Six patients were excluded from the stent type analysis as their procedures were classified as an in-stent restenosis. In determining complications, several factors were evaluated. All patients had three NIH Stroke Scale (NIHSS) exams: at baseline, at 24 h post procedure, and a third one at the one-month visit. The baseline and post procedural NIHSS exams were performed by an independent neurologist, and the same neurologist was maintained for each case (pre and post procedural). The NIHSS exams at the one-month visits were completed by the research nurse and team during the office visit. The NIH Stroke Scale was used to further subclassify cerebrovascular events into TIA, minor stroke, or major stroke. Cardiac enzymes, including Troponin I levels, were measured twice in all patients, within 24 h post procedure at intervals of 6–8 h. Additionally, all patients were treated with dual anti-platelet therapy for at least 6 months post procedure. Myocardial infarction was defined as any positive troponin I within 24 h post procedure. Major strokes were defined by an increase in NIHSS of more than 3 points from the baseline NIHSS, while minor strokes were defined by an increase in the NIHSS by equal or less than 3 points from baseline. TIAs were defined as any new neurological event that occurred and resolved spontaneously within 24 h from the time of onset.

### 2.1. Statistical analysis

The type of stent patients received (open vs closed cell), the patient with symptomatic carotid stenosis or not (yes vs no), the patient greater than 80 years old or not (yes vs no), and the patient with comorbidities such as diabetes mellitus (yes vs no), smoking (yes vs no), and hypertension (yes vs no) are considered as categorical data. The associations of those variables to CAS complications that include myocardial infarction (MI), stroke, or death (yes vs no) were tested using the Fisher's Exact Test. Each variable was examined by performing descriptive statistics. The analytical results were considered to be significant when $p$ values were less than or equal to 0.05. All the analysis was implemented using IBM SPSS Statistics version 23.0.

## 3. Results

Demographics, clinical variables, and complication outcomes were collected from 181 patients of whom 37% were female, 45% had symptomatic carotid stenosis, 40% were diabetic, 93% had hypertension, 74% had a history of smoking, and 24% were octogenarians (Table 1). The mean age was 72 (range: 51–92), with the majority of patients younger than 80 years old. Of the 175 patients who received an open or closed cell stent, 76% received an open cell stent. Out of all 181 patients, only three patients (1.66%) experienced a major complication within 1-month post procedure. These complications were comprised of one MI event (0.55%), one stroke event defined as a major stroke (0.55%), and one death event (0.55%). All three CAS complications occurred in male patients who received an open cell stent type, had a history of smoking and hypertension, and did not have symptomatic carotid stenosis. Of the three patients, one was an octogenarian and two were under the age of 80. Therefore, the Fisher's Exact Test is used to account for the unequally distributed data. The results from Fisher's Exact Test indicated that there is insufficient evidence to support associations between CAS complications and the variables. The following variable factors were not associated with the occurrence of MACCE within 30 days post procedure: stent design (open vs. closed cell) ($p = 1.000$), age ≥ 80 ($p = 0.559$), smoking history ($p = 0.569$), hypertension ($p = 1.000$), diabetes ($p = 1.000$), and symptomatic carotid stenosis ($p = 0.254$), as presented in Table 2. Demographic and clinical characteristics are outlined in Table 1 for all patients and for patients who experienced complications.

**Table 1**
Descriptive statistics of demographic and clinical features of patients who underwent CAS.

| Feature | All Patients who Underwent CAS (n = 181) Number (%) | Patients With Complications After CAS (n = 3) Number (%) |
|---|---|---|
| Age | | |
| ≥80 | 43 (24) | 1 (33) |
| <80 | 138 (76) | 2 (67) |
| Sex | | |
| Male | 114 (63) | 3 (100) |
| Female | 67 (37) | 0 (0) |
| Symptomatic | | |
| Yes | 81 (45) | 0 (0) |
| No | 100 (55) | 3 (100) |
| Diabetic | | |
| Yes | 73 (40) | 1 (33) |
| No | 108 (60) | 2 (67) |
| Hypertension | | |
| Yes | 169 (93) | 3 (100) |
| No | 12 (7) | 0 (0) |
| Smoking History | | |
| Yes | 134 (74) | 3 (100) |
| No | 47 (26) | 0 (0) |
| Stent Type[a] | | |
| Open Cell | 133 (76) | 3 (100) |
| Closed Cell | 42 (24) | 0 (0) |

CAS = Carotid Artery Stenting.
[a] n = 175 for all patients who underwent CAS; 6 patients were excluded from the stent type analysis as neither an open or closed cell stent was used.

## 4. Discussion

This study found no association between sex, age, symptomatic carotid stenosis, stent type, smoking, hypertension, or diabetes and increased risk of MACCE within 30 days of CAS. In terms of sex-based differences for MACCE risk following CAS, in our study there was no statistical significance that the sex of the patient would increase or decrease the risk of a stroke, MI, or death when undergoing CAS. Similarly, other studies examining how sex may impact CAS patients showed no difference in MACCE rates when comparing men and women, indicating that sex does not correlate to the perioperative risk of MACCE after CAS [7]. In a study by Howard et al., 30-day stroke and death rates following CAS were comparable among 579 women and 985 men, and there was no correlation found between the effect of sex on CAS complications when looking at stroke alone, MI alone, death alone, or stroke, MI, and death compositely [7].

Considering the effect of age on CAS complications, Doig et al. found that age increased the risk of MACCE following CAS by 1.24 for each 5 years (95% CI 1.07–1.42, $p = .003$) [9]. Similarly, a study by Cheng et al. showed age as a risk factor (HR: 1.027, 95% CI: 1.002–1.053) for

**Table 2**
Fisher's exact test results for the prevalence of complications after undergoing CAS.

| Feature | P value |
|---|---|
| Age ≥ 80 vs. <80 | 0.559 |
| Symptomatic | 0.254 |
| Diabetic | 1.000 |
| Hypertension | 1.000 |
| Smoking History | 0.569 |
| Open vs. Closed Cell Stent Type | 1.000 |

P-values ≤0.05 were considered statistically significant.
CAS = Carotid Artery Stenting.

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