Meta-analysis and Meta-Regression Analysis of Outcomes of Carotid Endarterectomy and Stenting in the Elderly

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IMPORTANCE Uncertainty exists about the influence of advanced age on the outcomes of carotid revascularization.

OBJECTIVE To undertake a comprehensive review of the literature and conduct an analysis of the outcomes of carotid interventions in the elderly.

DESIGN AND SETTING A systematic literature review was conducted to identify articles comparing early outcomes of carotid endarterectomy (CEA) or carotid stenting (CAS) in elderly and young patients.

MAIN OUTCOMES AND MEASURES Combined overall effect sizes were calculated using fixed or random effects models. Meta-regression models were formed to explore potential heterogeneity as a result of changes in practice over time.

RESULTS Our analysis comprised 44 studies reporting data on 512,685 CEA and 75,201 CAS procedures. Carotid stenting was associated with increased incidence of stroke in elderly patients compared with their young counterparts (odds ratio [OR], 1.56; 95% CI, 1.40-1.75), whereas CEA had equivalent cerebrovascular outcomes in old and young age groups (OR, 0.94; 95% CI, 0.88-0.99). Carotid stenting had similar peri-interventional mortality risks in old and young patients (OR, 0.86; 95% CI, 0.72-1.03), whereas CEA was associated with heightened mortality in elderly patients (OR, 1.62; 95% CI, 1.47-1.77). The incidence of myocardial infarction was increased in patients of advanced age in both CEA and CAS (OR, 1.64; 95% CI, 1.57-1.72 and OR, 1.30; 95% CI, 1.16-1.45, respectively). Meta-regression analyses revealed a significant effect of publication date on peri-interventional stroke (P = .003) and mortality (P < .001) in CAS.

CONCLUSIONS AND RELEVANCE Age should be considered when planning a carotid intervention. Carotid stenting has an increased risk of adverse cerebrovascular events in elderly patients but mortality equivalent to younger patients. Carotid endarterectomy is associated with similar neurologic outcomes in elderly and young patients, at the expense of increased mortality.
The effectiveness of carotid endarterectomy (CEA) in stroke prevention in patients with symptomatic or asymptomatic extracranial carotid disease has been established in randomized controlled trials. Patients older than 80 years were excluded from these landmark trials; therefore, uncertainty exists regarding the influence of advanced age on the outcomes of carotid revascularization. In total, 39 observational studies have reported controversial results of CEA in elderly patients. Yet, it is this age group of patients who have significant risks of stroke and would potentially benefit from carotid intervention.

Angioplasty and stenting has emerged as an alternative, less invasive therapeutic method of treating carotid disease. Even though it might be intuitively considered a suitable treatment for the elderly patient at high surgical risk, early reports demonstrate increased incidence of cerebrovascular complications in this group of patients. The uncertainty of applying carotid angioplasty and carotid stenting (CAS) in advanced age is compounded by contradictory results of more recent studies, using modern endovascular technology and cerebral protection devices, which have demonstrated equivalent outcomes in selected old and young age groups of patients.

In recent years, there has been much debate about the most appropriate treatment for carotid disease, as well as the safety and efficacy of CEA and CAS in elderly patients. Our objective was to undertake a comprehensive review of the literature and conduct an analysis of the outcomes of carotid interventions in the elderly.

Methods

Eligibility Criteria
All observational studies reporting perioperative or early (within 30 days) outcomes of CEA or CAS in distinct old and young age groups of patients were considered. No specific cutoff age to define old or young age groups was applied; however, age 65 years was considered the minimum age above which patients were considered elderly (eg, studies comparing outcomes in patients younger or older than 50 years were considered ineligible). If studies reported more than 2 age categories, age 80 years was selected as the cutoff point to define age groups and calculate outcome data. Carotid endarterectomy was performed in adult patients for symptomatic or asymptomatic atherosclerotic carotid disease. Studies evaluating the effects of various risk factors, including advanced age, on the outcomes of CEA or CAS were excluded, because not enough data for the meta-analysis models were provided by most of these studies, and we think it is methodologically more correct to include studies specifically evaluating outcomes in old and young age groups of patients. Furthermore, studies reporting patients receiving concomitant treatment of coronary artery disease or reconstruction of supra-aortic vessels were excluded.

We planned to analyze specific outcome parameters, which included stroke, transient ischemic attack (TIA), all-cause mortality, and myocardial infarction (MI) occurring either perioperatively or within 30 days of treatment. All strokes affecting either hemisphere (fetal or nonfetal, contralateral or ipsilateral, resulting from hemorrhage or infarction) were included. Where possible, the Society for Vascular Surgery reporting standards for carotid interventions were used to specify and define the outcome parameters.

Information Sources and Search Strategy
A 2-level literature search was performed to identify relevant articles. The primary search included interrogation of electronic information sources. The following electronic bibliographic databases were examined: MEDLINE (1950 to present), EMBASE (1980 to present), and Allied and Complementary Medicine (1985 to present). A supplementary search of related articles suggested by the PubMed search engine was conducted. The Medical Subject Headings terms endarterectomy, carotid, stents, and carotid stenosis were combined with key terms associated with age (eg, age, elderly, young, and octogenarians) and the word risk. The last search was run in January 2013. A secondary search consisted of manual scrutiny of the reference lists of relevant articles retrieved in the first-level search. Only English- and German-language articles were considered.

Study Selection and Data Collection
Eligibility assessment and data extraction were performed independently by 2 reviewers (G.A.A. and S.A.A.). Once all potentially relevant full-text articles were identified, consensus was achieved after consulting an arbitrator (G.S.G.) for adjudication if disagreements existed. Standard information was extracted into a spreadsheet. The data sought included (1) study characteristics (year of publication, patient recruitment period, number of patients or procedures, age categories, and inclusion and exclusion criteria for patient enrollment in the selected studies); (2) baseline demographic and clinical characteristics of the patients (age, sex, hypertension, diabetes mellitus, coronary artery disease, dyslipidemia, chronic obstructive pulmonary disease, renal dysfunction, smoking status, and symptomatic or asymptomatic carotid disease); (3) procedural characteristics (type of anesthesia, use of shunt [in CEA] or embolic protection device [in CAS], and type of CEA [conventional or eversion CEA]); and (4) outcome parameters, as defined earlier.

Quality Assessment and Statistical Analysis
Study quality was quantified with the Newcastle-Ottawa Scale. We have used this method assessment tool for case-control observational studies, according to which the study quality is judged by the selection of the study groups, the comparability of cases and controls, and the ascertainment of outcomes of interest. This scale uses a star system, with a maximum of 9 stars.

Individual study odds ratios (ORs) and 95% CIs were calculated from event numbers extracted from each study before data pooling. In calculating the ORs, the total number of procedures (instead of patients) in each group was used as the denominator. Summary estimates of ORs were determined using the Mantel-Haenszel fixed-effects model, unless evi-
dence of between-study heterogeneity existed, in which case random-effects models from DerSimonian and Laird were applied. The percentage of variability across studies attributable to heterogeneity beyond chance was estimated with the $I^2$ statistic. Potential publication bias was assessed with the Egger test and represented graphically with Begg funnel plots of the natural log of the OR vs its standard error. Additional sensitivity analyses were performed to evaluate the potential effect of key assumptions and study-level factors on the overall results. Meta-regression models were formed to explore potential heterogeneity as a result of changes in practice over time.

All $P$ values were 2-sided; we judged the threshold of significance to be $\alpha = 0.01$. Analyses were performed using the Review Manager 5 software (The Nordic Cochrane Centre, The Cochrane Collaboration) and Comprehensive Meta-Analysis 2.0 software (Bios tat).

**Results**

**Literature Search Results and Description of Studies**

Our literature search identified 44 studies comparing outcomes of CEA (39 articles)$^{4-42}$ or CAS (18 articles)$^{39,40,42-46,50-60}$ in old and young age groups of patients, fulfilling our inclusion criteria. Figure 1 shows the flow diagram of study selection for the analysis. Studies reporting CAs were published between 1986 and 2012, whereas the patient recruitment period expanded from 1964 through 2010. The total number of CEs (using any cutoff age as defined earlier) included in our analysis was 512 685 (the old age group included 269 596 CEs and the young age group included 243 089 CEs). Inclusion and exclusion criteria for patient enrollment in the studies were inconsistently reported; most authors included patients with symptomatic and asymptomatic carotid disease, whereas several excluded patients receiving concomitant coronary artery grafting or those undergoing treatment for recurrent carotid stenosis. Twenty-five studies used age 80 years as the cutoff for study group definition, 12 used age 75 years, 1 study used age 70 years, and another study used age 65 years. The methodologic quality of the studies was low, with only 3 studies achieving a Newcastle-Ottawa Scale score of 7 or more. The study characteristics are outlined in eTable 1 in the Supplement.

Studies investigating outcomes of CAS in old and young groups of patients were published between 1999 and 2012, and the patient recruitment period was between 1994 and 2010. The entire population included in our analysis comprised 75 179 CAS cases (38 751 cases in the old age group and 36 450 cases in the young age group). The study characteristics, along with the inclusion and exclusion criteria for patient enrollment, are presented in eTable 2 in the Supplement. Thirteen studies used age 80 years as the cutoff for study group definition, 2 studies used age 75 years, another 2 studies used age 70 years, and 1 study used age 65 years. Most studies had high methodologic quality, with 71% achieving Newcastle-Ottawa Scale scores of 7 or more. Patient demographic and clinical data, including cardio vascular risk factors and procedural characteristics (type of anesthesia, conventional or eversion CEA, and use of a shunt in CEA and an embolic protection device in CAS), are shown in eTable 3 and eTable 4 in the Supplement.

**Synthesis of Outcome Parameters in CEA**

**Stroke**

All articles reported stroke rates perioperatively or within 30 days of treatment (Figure 2). The incidence of stroke in the old and young age groups was 0.9% and 1.2%, respectively, and this difference was not statistically significant (OR, 0.94; 95% CI, 0.88-0.99; $P = .02$). No significant heterogeneity among the studies was identified ($I^2 = 0$%), and the possibility of publication bias was low ($P = .20$).

**Transient Ischemic Attack**

Fourteen studies reported TIAs (Figure 3). The incidence of TIA in the old and young age groups was 1.9% and 1.8%, respectively (OR, 1.23; 95% CI, 0.84-1.81; $P = .29$). There was no significant heterogeneity among the studies entering the analysis ($I^2 = 0$%), and the likelihood of publication bias was low ($P = .43$).
Similarly, the total incidence of neurologic events (stroke plus TIA) was reported in 14 studies (Figure 4). The incidence of such events in the old age group (3.3%) did not differ significantly from that in the young age group (3.2%; OR, 1.06; 95% CI, 0.78-1.44; \( P = .69 \)). No significant heterogeneity among the studies was detected (\( I^2 = 16\% \)), and the probability of publication bias was low (\( P = .39 \)).

**Mortality**

All but 2 studies reported mortality rates in the 2 groups of patients (Figure 5). The overall mortality rate within 30 days of treatment for the old and young age groups was 0.5% and 0.4%, respectively, and the difference between the groups was significant (OR, 1.62; 95% CI, 1.47-1.77; \( P < .001 \)). No significant heterogeneity among the studies existed (\( I^2 = 0\% \)), and the likelihood of publication bias was low (\( P = .78 \)).
Myocardial Infarction

Myocardial infarction occurring within the perioperative or 30-day period was reported in 22 studies (Figure 6). The old age group had a significantly increased risk of developing MI compared with the young age group (2.2% and 1.4%, respectively; OR, 1.64; 95% CI, 1.57-1.72; P < .001). No significant heterogeneity among the studies included in the analysis was identified ($I^2 = 2\%$), and the probability of publication bias was low ($P = .32$).
Stroke
All studies reported stroke rates in the groups of patients (Figure 7). The incidence of stroke within 30 days of CAS in the old and young age groups was 2.4% and 1.7%, respectively. Older patients undergoing CAS had a significantly increased risk of developing stroke compared with younger patients (OR, 1.56; 95% CI, 1.40-1.75; \( P < .001 \)). No significant heterogeneity among the studies analyzed was identified (I\(^2\) = 24%), and the probability of publication bias was low (\( P = .05 \)). (Figure 8, 9, 10, 11)

### Synthesis of Outcome Parameters in CAS

#### Stroke
All studies reported stroke rates in the groups of patients (Figure 7). The incidence of stroke within 30 days of CAS in the old and young age groups was 2.4% and 1.7%, respectively. Older patients undergoing CAS had a significantly increased risk of developing stroke compared with younger patients (OR, 1.56; 95% CI, 1.40-1.75; \( P < .001 \)). No significant heterogeneity among the studies analyzed was identified (I\(^2\) = 24%), and the probability of publication bias was low (\( P = .05 \)). (Figure 8, 9, 10, 11)

#### Transient Ischemic Attack
Nine studies reported the incidence of TIA in the groups of patients (Figure 8). Older patients receiving CAS had an increased incidence of developing TIA within 30 days of treatment compared with younger patients (3.6% and 2.1%, respectively; OR, 1.75; 95% CI, 1.17-2.63; \( P = .007 \)). No sig-
significant heterogeneity among the studies existed ($I^2 = 0\%$), and the likelihood of publication bias was low ($P = .21$).

**Stroke Plus TIA**

Rates of stroke plus TIA were reported in 9 studies (Figure 9). Similarly, older patients had an increased risk of developing a neurologic event (stroke or TIA) within 30 days of CAS compared with younger patients ($7.1\%$ vs $4.1\%$; OR, $1.67$; $95\%$ CI, $1.04-10.14$). No significant heterogeneity among the studies was identified ($I^2 = 0\%$), and the probability of publication bias was low ($P = .12$).

**Mortality**

Sixteen studies reported mortality rates within 30 days of CAS (Figure 10). No significant difference in mortality between the old and young age groups was found ($0.6\%$ vs $0.7\%$; OR, $0.86$; $95\%$ CI, $0.72-1.03$; $P = .10$). Significant heterogeneity among the studies was identified ($I^2 = 58\%$), and the probability of publication bias was high ($P = .001$).

**Myocardial Infarction**

Fifteen studies reported the occurrence of MI within 30 days of treatment (Figure 11). Older patients had an increased risk of developing MI ($2.3\%$) compared with younger patients ($1.5\%$; OR, $1.30$; $95\%$ CI, $1.16-1.45$; $P < .001$). No heterogeneity among the studies existed ($I^2 = 0\%$), and the likelihood of publication bias was low ($P = .17$).

**Sensitivity and Meta-Regression Analyses**

The primary analysis was repeated with altered data sets excluding studies reporting data from national databases or those from registries of vascular societies (eg, the Society for Vascular Surgery Vascular Registry). Exclusion of these studies or any single study from the analysis did not substantially affect the combined outcome estimates.

Furthermore, we performed separate sensitivity analyses, including in the meta-analysis models homogeneous groups in terms of age. Because most studies (25 of the 39 CAS studies and 13 of the 18 MI studies) used age 80 years as the cutoff, we meta-analyzed these studies separately to see how the outcomes were affected. No differences in stroke (OR, $1.00$; $95\%$ CI, $0.80-1.23$; $P = .97$), TIA (OR, $1.40$; $95\%$ CI, $0.91-2.14$; $P = .12$), and stroke plus TIA (OR, $1.16$; $95\%$ CI, $0.82-1.64$; $P = .40$) between patients younger and older than 80 years undergoing CEA were identified. Mortality (OR, $1.65$; $95\%$ CI, $1.28-2.13$; $P < .001$) and MI (OR, $1.47$; $95\%$ CI, $1.18-1.82$; $P = .005$) occurred more frequently in patients older than 80 years.

The incidence of stroke (OR, $1.89$; $95\%$ CI, $1.48-2.41$; $P < .001$), TIA (OR, $1.77$; $95\%$ CI, $1.16-2.68$; $P = .007$), and stroke plus TIA (OR, $1.71$; $95\%$ CI, $1.26-2.31$; $P = .005$) was
higher in patients older than 80 years than in younger patients undergoing CAS. No significant differences in mortality (OR, 1.75; 95% CI, 1.12-2.73; \( P = .01 \)) and the incidence of MI (OR, 1.23; 95% CI, 0.61-2.48; \( P = .56 \)) between the 2 groups were identified.

Meta-regression analysis investigating potential effects of publication date of each study on perioperative adverse events associated with CEA in the old and young age groups of patients revealed no significant relationship between stroke (OR = 1.11), TIA (OR = .12), stroke plus TIA (OR = .22), mortality (OR = .79), and MI (OR = .70) and year of publication. Similarly, meta-regression analyses were performed to evaluate changes in peri-interventional outcome variables of CAS over publication time (Figure 12). Such analyses found a significant effect of publication date on peri-interventional stroke (OR = .003) and mortality rates (\( P < .001 \)), whereas no significant association
between year of publication and TIA ($P = .75$), stroke plus TIA ($P = .67$), and MI ($P = .09$) was revealed.

### Discussion

In view of the aging population and the rising prevalence of diabetes mellitus, the global burden of cerebrovascular disease is likely to grow significantly, and an increasing number of carotid revascularization procedures is anticipated in the foreseeable future. Advanced age has been shown to be associated with an increased incidence of stroke and stroke-related mortality.\(^{61}\) Therefore, this segment of the population, consisting of elderly patients diagnosed with extracranial carotid disease, would benefit most from stroke prevention with carotid interventions. The North American Symptomatic Carotid Endarterectomy Trial demonstrated that elderly patients (older than 75 years) benefited more from CEA...
than did younger patients\textsuperscript{22}; this benefit resulted from the high risk of ipsilateral ischemic stroke, if medical treatment in this group of patients was applied. Nonetheless, uncertainty exists as to the safety of performing CEA or CAS in the elderly, mainly because of the surgical risks in patients of this age, accompanied by comorbid conditions in the former and the increased incidence of adverse neurologic events associated with the latter. We conducted analyses of outcomes reported in institutional and multi-institutional studies to examine pooled estimates of rare events in a large meta-analysis patient cohort.

Our analysis revealed equivalent outcomes of CEA in old and young age groups, as expressed by the incidence of adverse cerebrovascular events. In contrast to CEA, elderly patients undergoing CAS had a higher risk of developing stroke, TIA, or stroke plus TIA early after the intervention than did younger patients. Moreover, CEA was associated with increased mortality in elderly patients compared with younger patients (0.5\% vs 0.4\%; OR, 1.62; 95\% CI, 1.47-1.77), whereas CAS had similar peri-interventional mortality risks in old and young age groups (0.6\% vs 0.7\%; OR, 0.86; 95\% CI, 0.72-1.03), but the clinical significance of this small difference may be narrow. The incidence of MI was increased in patients of advanced age in both CEA and CAS. We validated the robustness of the observed outcomes by performing sensitivity analyses, excluding the study of Khatri et al.\textsuperscript{42} who analyzed data from the Nationwide Inpatient Sample representing all admissions in the United States between 2005 and 2008. A limitation of the primary analysis was that different authors used different cutoff ages to define the groups of patients (eg, some studies defined elderly as those patients older than 65 years, whereas others used 80 years or older as the cutoff). To overcome this limitation, we undertook meta-analyses of studies evaluating the outcomes of carotid interventions in similar age groups (eg, patients younger and older than 80 years). Such analyses confirmed the results of our primary analysis, expressed by the incidence of cerebrovascular events, MI, and overall mortality.

An interesting finding of the meta-regression analysis is that in recent studies, the log odds ratio for stroke and mortality in CAS decreases. This essentially means that in older studies (old devices, inexperience with the CAS technique, and initial phase of the learning curve), the difference in stroke or mortality is large, becoming less as the years pass, and this reduction in difference is statistically significant. This is not the case with CEA. This finding possibly reflects improvements in CAS technique and devices, such as the routine application of the embolic protection device, and the learning curve in recent years.

To understand the increased neurologic risk in elderly patients undergoing CAS, one needs to consider factors inherent to the intra-arterial nature of the procedure in this age group. Analyses of anatomic factors and age have highlighted the contribution of embolization originating from sources proximal to the treated lesion. Elderly patients have a more unfavorable anatomy than their younger counterparts, such as heavily calcified and tortuous supra-aortic branches, and adverse morphologic characteristics of the aortic arch, such as type III aortic arch, elongation, distortion, and stenosis.\textsuperscript{55,55,62} It has been hypothesized that the higher risk of neurologic com-

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**Figure 11. Forest Plot for Carotid Stenting and Myocardial Infarction**

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Old Age Group</th>
<th>Young Age Group</th>
<th>Odds Ratio</th>
<th>Year</th>
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<tr>
<td></td>
<td>Events</td>
<td>Total</td>
<td>Events</td>
<td>Total</td>
</tr>
<tr>
<td>Chastain et al\textsuperscript{44}</td>
<td>1 27</td>
<td>0 189</td>
<td>0.0</td>
<td>21.45 (0.85-54.33)</td>
</tr>
<tr>
<td>Longo et al\textsuperscript{17}</td>
<td>0 29</td>
<td>0 129</td>
<td>0.0</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Stanziale et al\textsuperscript{11}</td>
<td>1 87</td>
<td>2 295</td>
<td>0.2</td>
<td>1.70 (0.15-19.01)</td>
</tr>
<tr>
<td>Setacci et al\textsuperscript{15}</td>
<td>2 144</td>
<td>11 1078</td>
<td>0.5</td>
<td>1.37 (0.30-6.23)</td>
</tr>
<tr>
<td>Kadic-Radotan et al\textsuperscript{34}</td>
<td>1 21</td>
<td>1 157</td>
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</tr>
<tr>
<td>Lam et al\textsuperscript{11}</td>
<td>1 37</td>
<td>2 96</td>
<td>0.2</td>
<td>1.11 (0.11-14.84)</td>
</tr>
<tr>
<td>Zahn et al\textsuperscript{19}</td>
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<td>2 2557</td>
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</tr>
<tr>
<td>Henry et al\textsuperscript{17}</td>
<td>0 124</td>
<td>1 806</td>
<td>0.1</td>
<td>2.16 (0.09-53.23)</td>
</tr>
<tr>
<td>Chaturvedi et al\textsuperscript{18}</td>
<td>1 1166</td>
<td>16 4131</td>
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</tr>
<tr>
<td>Bacharach et al\textsuperscript{46}</td>
<td>0 78</td>
<td>0 157</td>
<td>0.0</td>
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</tr>
<tr>
<td>Voeks et al\textsuperscript{19}</td>
<td>7 333</td>
<td>7 929</td>
<td>0.6</td>
<td>2.83 (0.98-8.12)</td>
</tr>
<tr>
<td>Almelshlahi et al\textsuperscript{59}</td>
<td>1 59</td>
<td>1 152</td>
<td>0.1</td>
<td>2.60 (0.16-42.31)</td>
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<tr>
<td>Jim et al\textsuperscript{40}</td>
<td>33 2536</td>
<td>8 861</td>
<td>2.1</td>
<td>1.41 (0.65-3.06)</td>
</tr>
<tr>
<td>Khatri et al\textsuperscript{42}</td>
<td>835 33563</td>
<td>468 24063</td>
<td>94.5</td>
<td>1.29 (1.15-1.44)</td>
</tr>
<tr>
<td>Alkins et al\textsuperscript{50}</td>
<td>2 81</td>
<td>2 78</td>
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<td>0.96 (0.13-7.00)</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>38606</td>
<td>35678</td>
<td>100.0</td>
<td>1.30 (1.16-1.45)</td>
</tr>
</tbody>
</table>

Comparison of myocardial infarction rates between old and young age groups subjected to carotid angioplasty and stenting. M-H indicates Mantel-Haenszel.
Complications associated with CAS in elderly patients is related to wire manipulation and navigation through adverse aortic arch and supra-aortic vessel morphologic features.\textsuperscript{39,40} It is also likely that these unfavorable anatomic factors make the CAS procedure technically more difficult, resulting in increased risk of endothelial trauma, thrombus dislodgment, and thromboembolic events. In addition, elderly patients with significant extracranial atherosclerotic disease are likely to have a compromised cerebrovascular reserve, which makes them more susceptible to ischemic events from cerebral microembolization.

Adequate power is difficult to achieve in institutional or even multicenter studies to make meaningful comparisons of rare events, but our analysis has an advantage in that a large patient cohort was used to calculate pooled outcome estimates, such as mortality and stroke. However, our report is limited by the heterogeneous groups of patients entering the meta-analysis models. No adjustments for differences in clinical characteristics of the study populations, such as presenting symptom status and atherosclerotic comorbidity, could be made. Variability in surgical (eg, conventional vs eversion endarterectomy or use of a shunt) or interventional practices (eg, use of an embolic protection device or different types of carotid stent) among the studies included in the analysis existed. Moreover, the methodologic quality of the reports selected for the meta-analysis varied significantly, with several studies being limited by poor case selection and exposure of the study sample.

The results of the present analysis suggest that careful consideration of a constellation of clinical and anatomic factors is required before an appropriate treatment of carotid disease in elderly patients is selected. The cardiovascular disease burden and general health of the individual patient should be meticulously evaluated, before interventional instead of optimal medical treatment is applied. It seems that CEA is associated with improved neurologic outcomes compared with CAS in elderly patients, at the expense of increased perioperative mortality, whereas both procedures are associated with increased risk of adverse cardiac events in advanced age. The presence of unfavorable anatomic characteristics should be assessed carefully before endovascular therapy is planned. Direct comparisons of the outcomes of CAS and CEA in elderly patients should be the subject of future research, including well-conducted randomized trials, if solid conclusions of the comparative efficacy of these treatments in this age group are to be reached. Technological advancements with newer generation carotid stents and embolic protection devices, as well as improvements in endovascular expertise of high-volume centers, may assist to circumvent present current limitations of CAS in this age group.
Carotid Endarterectomy and Stenting in the Elderly

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REFERENCES
Carotid Intervention in the Elderly
Who Is Old and Who Benefits?

R. Clement Darling III, MD

Antoniou et al provide a very well-written article on the meta-analysis and meta-regression analysis of outcomes of carotid endarterectomy (CEA) and stenting in the elderly. The conclusions are what most of us have seen in randomized prospective studies, such as the recent publication of Carotid Revascularization Endarterectomy vs Stenting Trial (CREST).2 Carotid endarterectomy fared well within the elderly when one considers stroke, transient ischemic attack (TIA), or both. However, patients undergoing CEA had a higher mortality (0.5% vs 0.4%), but the clinical significance of such a difference is doubtful. Conversely, those elderly patients undergoing carotid stenting (CAS) had a higher incidence of stroke, TIA, or both, yet there was no significant difference in mortality between young and old patients. The incidence of myocardial infarction was significantly higher in those patients undergoing CEA (2.2% vs 1.4%). Also, elderly patients had an increased risk of myocardial infarction compared with younger patients. These conclusions are not startling and are consistent with what many of us have seen in our clinical practices.

One thing somewhat unusual was that the rate of myocardial infarction was higher in the elderly undergoing CAS, which is not corroborated in CREST or other randomized studies.2-4 A major concern I have about the article by Antoniou et al is the definition of elderly. One really has to wonder what is “elderly” since 64% of the trials used 80 years as the cutoff, 31% used 75 years, 1 study defined elderly as 70 years, and another study even used age 65 years. This inconsistent approach incorporates tremendous variation; thus, it is more difficult to decide, if all things are equal, which intervention would best benefit the patient. This, combined with the inference from CREST that younger patients do better with CAS and older patients do better with CEA, leaves us with numerous moving targets. As one gets older, the concept of elderly begins to take on new meaning. To my 21-year-old daughter, 65 years may seem ancient. As I approach age 60, 80 years does not seem too old. The bottom line is, CEA and CAS seem to work equally well in younger patients, in expert hands. However, in the “elderly” (at any age), CEA has better outcomes with low morbidity, mortality, and stroke rate and remains the gold standard.