Statins for Stroke Prevention
Disappointment and Hope

Pierre Amarenco, MD; Andrew M. Tonkin, MD

Abstract—The occurrence of stroke increases with age, particularly affecting the older elderly, a population also at higher risk for coronary heart disease (CHD). Epidemiological and observational studies have not shown a clear association between cholesterol levels and all causes of stroke. Nonetheless, large, long-term statin trials in patients with established CHD or at high risk for CHD have shown that statins decrease stroke incidence in these populations. Combined data from 9 trials including 70 070 patients indicated relative and absolute risk reductions for stroke of 21% and 0.9%, respectively, with statins. The number of strokes prevented per 1000 patients treated for 5 years in patients with CHD is 9 for statins, compared with 17.3 for antiplatelet agents. Statins have not yet been shown to reduce stroke risk in the typical general population without known CHD, nor have they been shown to prevent recurrent stroke in patients with prior stroke. Potential reasons for the effects of statins on stroke and the non–cholesterol-lowering mechanisms that may be involved are discussed. Treatment strategies based on global cardiovascular risk may be most effective. Additional studies in patients representative of the typical stroke population are needed. (Circulation. 2004;109[suppl III]:III-44–III-49.)

Key Words: cardiovascular risk ■ prevention ■ statins ■ stroke

In the past decade, the 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase inhibitors, or “statins,” have been proven to significantly decrease coronary events in primary and secondary prevention of coronary heart disease (CHD). In patients with known CHD and high-risk patients (eg, those with hypertension or diabetes mellitus), stroke, a secondary end point, was also reduced by statin treatment. The neutral effect on stroke in older patients in the recent 3-year Prospective Study of Pravastatin in the Elderly at Risk (PROSPER) trial may have related to the relatively short period of follow-up, but has led some experts to again question whether stroke reduction by statins results from reductions in cardiac events and, therefore, systemic thromboembolism rather than from a direct effect on the cerebral arteries.

Cholesterol as a Risk Factor for Stroke
Whether increased serum cholesterol levels are a risk factor for stroke remains controversial. A meta-analysis of 45 prospective cohorts that included 450 000 subjects (total of 7.3 million patient-years; average follow-up: 16 years) and 13 000 incident strokes found no association between total cholesterol levels and stroke. The Multiple Risk Factor Intervention Trial (MRFIT), however, showed that the risk of death from nonhemorrhagic stroke increased with increasing serum cholesterol in 351 000 men aged 35 to 57 years. Conversely, in the same study, there was a negative association with hemorrhagic stroke for cholesterol levels <5.2 mmol/L (<201 mg/dL): the lower the total cholesterol level, the higher the risk of hemorrhagic stroke, suggesting a possible U-shaped relationship between cholesterol and stroke. The association between low cholesterol levels and hemorrhagic stroke was notable particularly in men with hypertension. The link between low cholesterol concentration and hemorrhagic stroke also was shown in a meta-analysis of 13 Chinese and Japanese cohorts, including 125 000 subjects and 1800 strokes, in which there was a tendency for increased risk of hemorrhagic stroke and decreased risk of ischemic stroke as cholesterol levels decreased. Finally, in the Copenhagen City Heart Study, total cholesterol was positively associated with risk of nonhemorrhagic stroke, but only for levels >8 mmol/L (>309 mg/dL), corresponding to levels in the upper 5% of the study cohort.

There are several possible explanations for the lack of association between cholesterol levels and stroke in most epidemiological and observational studies. Epidemiological studies did not consider the relation between blood cholesterol and the risk of incident strokes in a high-risk cohort selected on the basis of high global cardiovascular risk (eg, increased carotid intima-media thickness, high Framingham...
risk score). Also, because the cohorts were selected primarily to study CHD, they particularly included middle-aged subjects at risk of myocardial infarction (MI), whereas brain infarction typically occurs in much older subjects (>70 years). Moreover, the more likely aggressive risk-factor management in study patients may have accounted for a lower incidence of stroke. Finally, cerebrovascular events were not analyzed according to stroke subtypes in most case-control or prospective studies. Because of the U-shaped relationship observed in MRFIT, counting hemorrhagic strokes together with ischemic strokes could have masked a small, but true relation between cholesterol levels and ischemic stroke. The prevalence of atherothrombotic causes of stroke in middle-aged subjects is low, and the most frequent causes (eg, embolism associated with cardiomyopathy, arterial dissection) are usually unrelated to cholesterol levels.

**Statins for Stroke Prevention**

Older trials of lipid-modifying therapy with diet or drugs (eg, fibric acid derivatives) did not show a reduction in the incidence of stroke, nor did early long-term trials of statins for primary prevention of CHD.\(^5\) Because the mean age of patients in these primary prevention studies was low, the incidence of stroke was also low, so that these trials lacked adequate statistical power to reliably detect any significant effect. However, numerous statin trials in patients with known CHD\(^1\)–\(^3\),\(^4\)–\(^6\),\(^18\) and recent primary prevention trials including high-risk populations\(^6\),\(^8\) demonstrated a decrease in stroke incidence.

A compilation of data from 9 major long-term statin trials\(^1\)–\(^3\),\(^6\),\(^8\),\(^15\)–\(^18\) including 70 070 patients with known CHD or considered at increased risk shows that, on an intention-to-treat basis, an incident stroke occurred in 1501 of 34 739 patients (4.3%) randomized to the control group and 1215 of 35 331 patients (3.4%) randomized to statin therapy, yielding a 21% relative risk reduction in stroke and a modest 0.9% absolute risk reduction (ie, 9 strokes prevented per 1000 patients treated for 5 years; Table). By comparison, meta-analyses have shown that, in similar patients with known CHD, antiplatelet agents prevent 17.3 strokes and ramipril prevents 17 strokes per 1000 patients treated for 5 years; in patients with prior stroke, antiplatelet agents prevent 27 strokes per 1000 patients treated for 3 years, or 45 strokes/1000 projected to 5 years.\(^19\)

**Global Cardiovascular Risk**

In practice, the results achieved with statins in most major trials cannot be directly applied to all stroke patients. This is because the relatively modest effects on stroke (compared with other stroke prevention strategies) were obtained primarily in patients with established CHD, not in ischemic stroke patients without CHD. The latter constitute the majority of stroke patients.\(^2\),\(^3\),\(^11\),\(^15\) In addition, the majority of patients in the statin trials were male, whereas the sexes are approximately equally distributed in typical stroke patients (ie, \(\approx 53\%\) men\(^14\)). Further, subjects in the trials were relatively young and had lower rates of hypertension (\(\approx 40\%)\) than usual stroke patients (55% to 60%). Finally, stroke rates (3% to 5% over 5 to 6 years) were quite low compared with rates in patients with previous stroke (risk of recurrent stroke, 4% to 8% per year), resulting in a very small reduction in absolute risk with treatment.\(^20\)

In the Heart Protection Study (HPS), 65% of patients had established CHD, 16% had stroke before randomization, and, overall, 9% had previous stroke without known CHD.\(^6\) In the total cohort of 20 536 patients, simvastatin was associated

### Stroke End Points in Selected Long-Term Statin Trials and Combined Data

<table>
<thead>
<tr>
<th>Trial, Drug</th>
<th>No. Patients, Age Range (y)</th>
<th>Baseline TC (mmol/L), Other Criteria</th>
<th>Primary End Point, Follow-up (y)</th>
<th>Stroke Rate (%)</th>
<th>Risk Reduction (%)</th>
<th>No. Strokes Prevented/1000/5 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>4S(^*) Simvastatin</td>
<td>1444 35–70</td>
<td>5.5–8.0</td>
<td>Total mortality 5.4</td>
<td>4.3 2.7 0.024</td>
<td>1.6 30 [4–48]</td>
<td>16</td>
</tr>
<tr>
<td>CARE(^2) Pravastatin</td>
<td>4159 31–75</td>
<td>&lt;6.2</td>
<td>CHD events 5.0</td>
<td>3.8 2.6 0.03</td>
<td>1.2 31 [3–52]</td>
<td>12</td>
</tr>
<tr>
<td>LIPID(^3) Pravastatin</td>
<td>9014 31–75</td>
<td>4.0–7.0</td>
<td>CHD mortality 6.0</td>
<td>4.5 3.7 0.048</td>
<td>0.8 19 [0–34]</td>
<td>8</td>
</tr>
<tr>
<td>HPS(^4) Simvastatin</td>
<td>20,536 40–80</td>
<td>&gt;3.5 High-risk hypertensive</td>
<td>Total mortality 5.3</td>
<td>5.7 4.3 &lt;0.0001</td>
<td>1.4 25 [15–34]</td>
<td>14</td>
</tr>
<tr>
<td>PROSPER(^7) Pravastatin</td>
<td>5804 70–82</td>
<td>4.0–9.0 High-risk elderly</td>
<td>CHD death, nonfatal MI, stroke 3.2</td>
<td>4.5 4.7 0.81 (0.2)</td>
<td>(3 – 19–31)</td>
<td>—</td>
</tr>
<tr>
<td>ALLHAT-LLT(^6) Pravastatin</td>
<td>10,355 55</td>
<td>3.1–4.9 or 2.6–3.3 if CHD; Hypertension</td>
<td>All-cause mortality 4.8</td>
<td>4.5* 4.1 0.31</td>
<td>0.4 9 [25–9]</td>
<td>4</td>
</tr>
<tr>
<td>ASCOT-LLA(^3) Atorvastatin</td>
<td>10,305 40–79</td>
<td>&lt;6.5 High-risk hypertensive</td>
<td>CHD death, nonfatal MI stroke 3.3</td>
<td>2.4 1.7 0.024</td>
<td>0.7 27 [4–44]</td>
<td>7</td>
</tr>
<tr>
<td>GREACE(^7) Atorvastatin</td>
<td>1600 &lt;75</td>
<td>&gt;2.6 Prior CHD</td>
<td>Total &amp; coronary mortality, CHD events, stroke 3.0</td>
<td>2.1* 1.1 0.034</td>
<td>1.0 47 [†]</td>
<td>10</td>
</tr>
<tr>
<td>KLIS(^8) Pravastatin</td>
<td>3853 45–74</td>
<td>&gt;5.6</td>
<td>CHD events 5.0</td>
<td>2.5* 2.1 0.13 (one-sided)</td>
<td>0.4 22 [46–13]</td>
<td>4</td>
</tr>
<tr>
<td>Combined data</td>
<td>70 070</td>
<td>—</td>
<td>—</td>
<td>4.32† 3.44‡</td>
<td>—</td>
<td>0.9 21 9</td>
</tr>
</tbody>
</table>
with a 24% reduction in relative risk of major vascular events (coronary death, nonfatal MI, fatal or nonfatal stroke, revascularization procedures), and a 25% reduction in relative risk of ischemic stroke. Patients who had had a stroke before randomization had a 19% reduction in relative risk of major vascular events, and stroke patients without known CHD showed a 23% risk reduction. However, it is possible that the reduction in the composite end point in the latter subgroup related to reductions in CHD events alone, with no decrease in cerebrovascular events. Unlike other studies that found nonsignificant reductions in ischemic stroke with statin therapy in patients with diabetes, HPS demonstrated a significant reduction of 26% in stroke in this important group. Thus, HPS indicates that statins undoubtedly prevent stroke, as well as major vascular events, in patients with CHD, and they prevent major vascular events in stroke patients, but currently available HPS data do not demonstrate prevention of recurrent stroke in patients with prior stroke (ie, secondary prevention of stroke).

Age is the main determinant of the absolute risk of future cardiovascular events. In the PROSPER trial of 5804 men and women (52% women) aged 70 to 82 years with total cholesterol levels of 4.0 to 9.0 mmol/L (155 to 348 mg/dL), half of the patients had a high-risk profile (62% hypertension, 11% diabetes, 28% current smokers), and the other half had established vascular disease (44% cardiovascular disease, 11% stroke before randomization). The 15% reduction in relative risk of the primary composite end point (coronary death, nonfatal MI, fatal or nonfatal stroke) was significant (P=0.14). Pravastatin had no effect on stroke incidence (hazard ratio, 1.03; P=0.81) and did not slow the decline in cognitive function in the elderly. However, PROSPER confirmed that statins could be safely used in elderly as in younger patients. Possible explanations for the neutral effect on stroke incidence are a lack of power (the expected stroke rate in the placebo group was 8%, compared with an actual event rate of 4.5%) and the duration of the trial, which lasted only 3 years. In other large-scale pravastatin trials (Cholesterol and Recurrent Events [CARE] and the Long-term Intervention with Pravastatin in Ischemic Disease [LIPID]), the Kaplan–Meier curves for the stroke end point started to diverge after 3 years; if the analyses had been undertaken at 3 years, those trials would have yielded results consistent with those in PROSPER.

The Anglo-Scandinavian Cardiac Outcomes Trial (ASCOT) randomized 19 342 hypertensive persons who also had ≥3 other cardiovascular risk factors to treatment with either a β-blocker ± diuretic or amlopidine ± angiotensin-converting enzyme inhibitor with follow-up for 5 years. A total of 10 305 patients who had a total cholesterol <6.5 mmol/L (<251 mg/dL) were further randomized in a factorial design to atorvastatin 10 mg daily or placebo. On the recommendation of the study’s independent Data Safety Monitoring Board, the lipid-lowering arm was stopped prematurely (mean follow-up, 3.3 years) because of strong efficacy of active treatment on the primary trial end point (nonfatal MI and fatal CHD). Despite early termination of the lipid-lowering arm of the trial, there was a significant (27%) reduction in relative risk of fatal and nonfatal stroke with atorvastatin (P=0.024), and the benefits of treatment apparently began early during follow-up.

Findings from these trials are consistent with the need for a global approach to cardiovascular risk assessment for stroke prevention. Treatment with a statin was very effective in patients with CHD, patients at high risk because of multiple risk factors, and those with normal cholesterol levels but elevated blood pressure.

**Risk of Hemorrhagic Stroke?**

One concern from observational cohort data is the possibility of an increased risk of hemorrhagic stroke with cholesterol-lowering therapy. Possible supporting data have been discussed. However, the diagnosis of stroke subtype in those studies was limited in that imaging was not included. Among 172 patients from Korea who underwent brain MRI using T2*-weighted gradient-echo imaging, which identifies multifocal signal loss lesions believed to represent microhemorrhage, concentrations of total and low-density lipoprotein (LDL) cholesterol were significantly lower in patients with severe imaging defects. Multivariate analysis showed that imaging abnormalities were significantly associated with the lowest quartile of serum total cholesterol (<4.27 mmol/L [<165 mg/dL]), the highest quartile of high-density lipoprotein (>1.47 mmol/L [>57 mg/dL]), hypertension, and white-matter brain lesions (leukoaraiosis). However, an increase in hemorrhagic stroke was not observed in the long-term statin secondary prevention trials that examined hemorrhagic stroke as a secondary end point. The incidence of hemorrhagic stroke was ≤0.5% in both the placebo and statin-assigned groups. These results, in concert with the PROSPER trial finding of no increase in hemorrhagic stroke in the elderly, are reassuring.

**Statins and Stroke Prevention: Pending Questions**

The observational studies failed to find a clear association between cholesterol levels and stroke. However, as discussed, there should be some reservations concerning these studies. The statin trials and a trial of gemfibrozil in patients after MI provide strong arguments for an etiological role of lipids in stroke and also possible non–LDL-lowering and/or nonlipid effects of these medications. Results related to stroke prevention with statins must be reproduced in a broad population representative of stroke patients who do not have a history of previous acute coronary syndromes.

By preventing recurrent MI, statins may reduce left ventricular mural thrombosis, which could contribute to a decreased incidence of stroke. In the analysis of stroke subtypes in the LIPID trial, effects appeared to be greater in the cardioembolic subgroup (−32%) and the group with stroke presumably due to lacunar arteriopathy (−44%) than in the atherothrombotic group (−10%). In the Myocardial Ischemia Reduction with Aggressive Cholesterol Lowering (MIRACL) trial conducted in patients with unstable angina or non–Q-wave MI immediately after the qualifying event, there was a significant overall risk reduction in the secondary end point of stroke (51%; P=0.04). Of note is that only 9 of the 36 strokes were preceded by a nonfatal MI, and in these cases the stroke occurred from 2 to 86 days after the MI. Thus,
Statins. Several mechanisms contribute to the protective effect of statins, including the reduction of inflammation and oxidative stress, which are important contributors to plaque instability. Furthermore, statins may improve endothelial function, which plays a crucial role in maintaining vasodilation and preventing thrombosis. This improvement in endothelial function is partly due to the reduction of inflammation, which can impair endothelial function.

2. Lipid abnormalities: Statins reduce serum cholesterol levels, including LDL cholesterol, which is a key factor in the development and progression of atherosclerosis. Lowering cholesterol levels can reduce the risk of recurrent stroke by decreasing the burden of atherosclerotic plaques in the arteries.

3. Blood pressure: Statins may also reduce blood pressure, which is another important risk factor for stroke. Lowering blood pressure can reduce the risk of stroke by decreasing the force against the arterial walls, thereby reducing the risk of arterial rupture and subsequent ischemic injury.

4. Platelet activity: Statins reduce platelet aggregation, which is important in the formation of thrombi. Thrombi can occlude blood vessels and cause ischemic injury, leading to stroke.

5. Anti-inflammatory effects: Statins have anti-inflammatory effects, which can reduce the risk of stroke by decreasing the inflammation associated with atherosclerosis and reducing the risk of arterial wall rupture.

6. Protection against oxidative stress: Statins can reduce oxidative stress, which is a key factor in the development of atherosclerosis. Oxidative stress can damage arterial walls and increase the risk of arterial wall rupture.

These mechanisms work together to reduce the risk of recurrent stroke. However, further research is needed to fully understand the mechanisms by which statins reduce the risk of recurrent stroke.


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