Stroke Prevention
An Opportunity for Efficient Utilization of Health Care Resources During the Coming Decade

Philip B. Gorelick, MD, MPH, FACP

**Background** Stroke is unique among neurological diseases, since it has a high prevalence and burden of illness, high economic cost, and is preventable. Epidemiological approaches to stroke prevention include the “high-risk” and “mass” approaches. In this review we discuss these preventive strategies, target host and discretionary risk factors that are amenable to these measures, and discuss potential cost savings.

**Summary of Review** Projected numbers of strokes prevented for specific stroke risk factors were estimated by using the population-attributable risk estimation for hypertension, cigarette smoking, atrial fibrillation, and heavy alcohol consumption. The projected numbers of strokes that could be prevented were substantial and highest for hypertension and cigarette smoking. Projected yearly cost of stroke associated with these two treatable factors was also substantial.

**Conclusions** The prevention of stroke can be accomplished by the high-risk or mass approach or a combination of these approaches. The high-risk approach prevents strokes but is also expensive. The mass approach may be more cost-effective, which could lead to substantial savings, but this needs to be investigated. (Stroke. 1994;25:220-224.)

**Key Words** • costs and cost analysis • prevention, primary • risk factors

**Stroke Prevention**

Stroke is unique among neurological diseases because it is preventable. Stroke is ideally suited for prevention, as it has a high prevalence and burden of illness, high economic cost, and safe and effective prevention measures that have been validated by clinical trial. It is estimated that $25 billion is spent for stroke each year in the United States. This is not surprising, given the estimated 500,000 new cases of stroke, the 150,000 deaths attributable to stroke, and the approximately 3 million stroke survivors each year.

As our knowledge of stroke prevention and treatment surpasses that of other neurological disease, a concerted international effort to prevent stroke could lead to substantial economic savings and reduction in human suffering. In this article we will review preventive approaches to reduce stroke, target host and discretionary risk factors that are amenable to these measures, and discuss potential cost savings.

**Epidemiological Approaches to Stroke Prevention**

Chronic disease such as stroke has a long latent period before clinical symptoms become manifest. During this latent period, stroke risk factors (determinants) effect pathophysiological changes that may lead to clinically manifest disease. The presence of multiple risk factors heightens the likelihood of stroke.

The natural history of chronic disease may be schematically represented by four stages of disease with corresponding levels of prevention and intervention (Table 1). As noted in Table 1, the first two stages, “susceptibility” and “presymptomatic,” are amenable to early detection and prevention strategies. These two stages may be thought of as the “upstream” stages, as primary or secondary prevention is possible. Once the risk factors are targeted and identified through health promotion and screening, specific intervention to prevent or retard pathogenetic tissue damage that could lead to clinical disease and disability can be implemented. The last two stages, “clinical disease” and “disability or recovery,” are “downstream,” or at the point where the ravages of the risk factors are quite evident. In these stages, the greater part of our window of opportunity for prevention has lapsed as we attempt to treat and limit acute disease and disability. Clearly, our public health goal is prioritized to intervene in the early or upstream stages.

Public health strategies to avoid stroke by modification of risk factors amenable to medication, diet, or other interventions may be grouped into two major categories: (1) the “mass” approach and (2) the “high-risk” approach. The mass approach uses lifestyle modification to achieve modest reductions in the level of the risk factor in every individual in the population and is advanced through health education, legislation, and economic measures to discourage exposure to risk factors. Mass-market economy has taught us that there is greater profit from sales at reduced rates to the masses who possess more limited financial resources than from sales to the relatively few wealthy who are able to pay higher rates. Similarly, the prevention of disease among those substantial numbers of persons with mild or moderate levels of a risk factor (e.g., hypertension), who are not at the highest relative risk for disease, yields the greatest absolute savings or benefit from the standpoint of morbidity and mortality. Thus, the distinction be-
TABLE 1. Scheme for the Natural History of Chronic Disease and Levels of Prevention

<table>
<thead>
<tr>
<th>Stage of disease*</th>
<th>1: Susceptibility</th>
<th>2: Presymptomatic</th>
<th>3: Clinical</th>
<th>4: Disability or recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention level</td>
<td>Health promotion</td>
<td>Early detection,</td>
<td>Acute treatment</td>
<td>Rehabilitation</td>
</tr>
<tr>
<td>Intervention</td>
<td>Specific</td>
<td>diagnosis, and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>intervention</td>
<td>preventive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>treatment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Stages 1 and 2 may be thought of as "upstream" and stages 3 and 4 as "downstream" (see text).
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between relative and absolute benefit must be kept in
mind when considering the mass approach.7 Furthermore,
the "prevention paradox" (ie, a measure that
brings large benefits to the community may offer little to
the individual) must also be considered in this context.

The high-risk approach, on the other hand, identifies
individuals in the population with high levels of a risk
factor, and medication is usually administered to
achieve substantial reductions in that risk factor.8 This
approach is typically used by practicing physicians in
outpatient offices and clinics. When applied to a com-
munity or other large population, the high-risk ap-
proach can be a massive effort, the cost-effective
procedure that still fails to prevent a high percentage
of the target disease (ie, among those in the community
with lower levels of the risk factor).

Ideally, risk factor modification is most effective when
the risk factor to be targeted is common in the popula-
tion, there is a strong association between the risk factor
and disease, and there is a favorable effect of treatment
of the risk factor. Furthermore, valid, safe, and cost-
effective screening procedures and treatment are
necessary.9

Host and Discretionary Risk Factors to Target
for Stroke Prevention

There are two well-established risk factors, hyperten-
sion and cigarette smoking, and two less well-
established risk factors, alcohol consumption and blood
lipids, that are amenable to the mass approach. Hyper-
tension, whether systolic, diastolic, or combined, is a
well-documented risk factor for stroke, as seen in
observational and experimental epidemiological
study.5,10-14 Cigarette smoking has emerged more re-
cently as a risk factor for ischemic stroke and some
forms of intracranial hemorrhage.15-18 Heavy alcohol
consumption may elevate the risk of ischemic and
hemorrhagic stroke.19,20 Among white populations, a
J-shaped epidemiological curve has been proposed to
explain the relation between the relative risk of ischemic
stroke and customary alcohol consumption, whereas a
positive direct linear association has been proposed for
the relative risk of hemorrhagic stroke with customary
alcohol consumption.20 There is mounting epidemiologi-
cal evidence to link hypercholesterolemia or elevations
in low-density lipoproteins to ischemic stroke, although
blood lipids are not considered a well-established risk
factor for stroke.21-25 Furthermore, these same four
factors play an important role in coronary heart disease
risk.26

There is substantial epidemiological evidence to advo-
cate treatment of hypertension to reduce stroke.5,10-14
Although controversial, it has been estimated that up to
70% of strokes could be eliminated by treatment of
hypertension.8 Furthermore, observational epidemiologi-
cal study has shown that the stroke risk dramatically
reverses after abstinence from cigarette smoking for 2 to 5
years5 and after discontinuation of heavy alcohol con-
sumption.19 Treatment of blood lipids reaps substantial
benefit for coronary heart disease, but there is controversy
about the benefit of treatment of hypercholesterolemia
and low-density lipoprotein cholesterol for stroke. How-
ever, it has been estimated that hypercholesterolemia
could account for up to 20% of strokes in Caucasians with
cholesterol levels >5.7 mmol/L.8

There are several other risk factors to consider for stroke
prevention. Atrial fibrillation may be responsible for
75,000 strokes in the United States, and dramatic
risk reductions are noted when nonvalvular atrial fibril-
lation is treated with antithrombotic therapy.27-30 Fur-
thermore, clinical trials have shown that carotid endar-
terectomy is efficacious in the treatment of high-grade
(70% to 99%) carotid stenosis when there is mild stroke
or transient ischemic attack.31,32 However, while the
absolute risk reduction for ipsilateral stroke is 17% in
the carotid endarterectomy treatment group compared
with medically treated patients,31 the absolute benefit of
carotid endarterectomy in stroke prevention is substanc-
tially lower, as there are relatively few individuals who
qualify for this operation based on accepted criteria.
Other risk factors such as coronary heart disease and
cardiac failure contribute to the attributable risk of
stroke,33 but it is uncertain at the present time to what
extent the treatment of these factors affects stroke
prevention.

Illustrative Examples of Stroke Reduction
Through Risk Factor Modification
and Potential Cost Savings

Table 2 summarizes modifiable risk factors, popula-
tion-attributable risk, and theoretical numbers of
strokes that could be prevented by successful treatment
of these risk factors. These calculations are estimates
and are based on the following assumptions that may
vary by population. (1) The overall population-attribut-
able risks for hypertension and atrial fibrillation were
derived by averaging relative risk and prevalence data,
respectively, over age-specific categories (50 to 59, 60 to
69, 70 to 79, and 80 to 89 years) from the Framingham
Study.33 (2) The population-attributable risk of smoking
was calculated by averaging the given relative risks of
smoking for men and women from the Framingham
Study18 and using 27% as the estimate of the prevalence
of cigarette smoking in the population (data from Morbidity
and Mortality Weekly Report reprinted in
JAMA. 1987;258:1880). (3) As the population-attribut-
able risk of heavy alcohol consumption for stroke is unknown, it was estimated by taking the ratio of "problem" drinkers in the United States (18 million persons)\textsuperscript{19} to total persons in the United States (250 million) and using an estimate of relative risk of stroke of 1.68 for heavy alcohol consumption (after Gorelick et al\textsuperscript{19}). The population-attributable risk is an estimate of the percentage of excess stroke in a population that is attributable to a specific risk factor.

The reader should keep in mind that the population-attributable risk factor was calculated from the following formula: $A/(1 + A)$, where $A$ = prevalence multiplied by relative risk - 1. The projected number of strokes prevented was calculated by multiplying the estimated 500 000 new stroke cases per year in the United States by the population-attributable risk.

Relative risk and estimated percentage exposed were calculated by averaging the relative risks and prevalence rates for a risk factor across the four given age strata, respectively, according to the Framingham data.\textsuperscript{33} Relative risk was calculated by averaging the relative risks for men and women according to the Framingham data.\textsuperscript{18} and the percentage exposed was estimated to be 27% according to national data sources (JAMA. 1987;258:1880).

Relative risk for heavy drinkers was estimated to be 1.68 after Gorelick et al.\textsuperscript{19} and the percentage exposed was estimated by taking ratio of "problem drinkers" to the total population in the United States (18 million to 250 million).

The estimates in Table 3 suggest that substantial economic savings could occur by successful modification of stroke risk factors. Even if the effort were only 10% efficient, the estimate of total yearly economic savings...
could reach $1.23 billion for hypertension and $310 million for cigarette smoking. If medication is necessary to control selected risk factors (eg, hypertension, atrial fibrillation), these costs are then subtracted from the projected savings, as are costs that are incurred due to medication side effects or complications, to determine the overall savings. A recent assessment of the cost-effectiveness of primary stroke prevention in atrial fibrillation in Sweden showed that after the direct and indirect costs of “stroke saved,” numbers of strokes prevented, and cost of preventive treatment were calculated, primary stroke prevention with antithrombotics resulted in a net savings.\textsuperscript{35,36} Table 3 also suggests that the economic savings for acute hospitalization and rehabilitation could be substantial as well.

An alternate approach to medication would be to reduce the population’s level of stroke risk factors (eg, hypertension, cigarette smoking, heavy alcohol consumption, and hypercholesterolemia) by effecting lifestyle changes through behavioral modification using the mass approach of economic and legislative measures and education. The public needs to be educated about healthy lifestyles, risk factors for stroke and other major diseases, treatment of risk factors, and recognition of early warning signs of stroke and other major causes of mortality. Mass education to teach healthy lifestyles through behavioral modification, targeted to groups at risk for stroke and to the youth in our school systems, could be the most cost-effective of all approaches. Furthermore, even if risk-factor control were to delay onset of stroke by only 5 years in a high proportion of persons rather than eradicate stroke in those persons, for example, substantial economic and human savings could still be realized by postponing stroke onset.

Conclusion

Stroke is a preventable disease that has a high economic cost. As shown in this analysis, there is potential for substantial human and economic savings. The prevention of stroke can be accomplished by a high-risk or mass approach. The high-risk approach is effective in saving strokes but is also expensive and may not save money, especially in lower-risk groups.\textsuperscript{37} The mass approach, on the other hand, may be more cost-effective, although this needs to be clarified.

How our health care resources will be allocated and used in the coming decades has become a focus of major public and presidential attention. Prudent use of these resources is paramount. As concerned citizens we should support economic and legislative measures to educate the public about healthy lifestyles, at-risk behaviors, risk factors and warning signs of disease, and the importance of standard treatments that reduce the risk of disease. Now is the time to plan healthy lifestyles to prevent disease in later life and to add “life to years.” We must become responsible health care partners in this era of medical economic change.

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Gorelick  Stroke Prevention and Economic Savings  223

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