Direct Costs of Patients With Stroke Can Be Continuously Monitored on a National Level
Performance, Effectiveness, and Costs of Treatment Episodes in Stroke (PERFECT Stroke) Database in Finland

Atte Meretoja, MD, MSc(Stroke Med); Markku Kaste, MD, PhD, FAHA, FESO; Risto O. Roine, MD, PhD, FESO; Merja Juntunen, MSc(Stat); Miika Linna, DSc(Tech); Matti Hillbom, MD, PhD; Reijo Marttila, MD, PhD; Terttu Erilä, MD, PhD; Aimo Rissanen, MD, PhD; Juhani Sivenius, MD, PhD; Unto Häkkinnen, PhD(Health Econ)

Background and Purpose—Treatment of stroke consumes a significant portion of all healthcare expenditure. We developed a system for monitoring costs from individual patient data on a national level in Finland.

Methods—Multiple national administrative registers were linked to gain episode-of-care data on all hospital-treated patients with incident stroke over the years 1999 to 2007 (n=94 316). Inpatient and specialist outpatient costs were evaluated with a cost database, long-term care costs with fixed prices, and medication costs with true retail prices.

Results—For the patients of Year 2007, the mean 1-year costs after an ischemic stroke were $29 580, after an intracerebral hemorrhage $36 220, and after a subarachnoid hemorrhage $42 570, valued in Year 2008 US dollars. Only part of these costs are attributable to stroke, because the annual costs prior to stroke were significant, $8900 before ischemic stroke, $7600 before intracerebral hemorrhage, and $4200 before subarachnoid hemorrhage. Older patients with ischemic stroke, and, among patients with ischemic stroke and subarachnoid hemorrhage, women, incurred higher costs. The mean estimated lifetime costs were $130 000 after ischemic stroke or intracerebral hemorrhage and $80 000 after subarachnoid hemorrhage. Annually $1.6 billion is spent in the care of Finnish patients with stroke, which equals to 7% of the national healthcare expenditure, or 0.6% of the gross domestic product. Costs of patients with stroke are increasing with prolonged survival and the aging population.

Conclusions—Treatment of patients with stroke is a large national investment. Setting up a nationwide system for continuous monitoring of stroke costs is feasible. Cost data should optimally be evaluated in conjunction with effectiveness and performance indicators. (Stroke. 2011;42:00-00.)

Key Words: acute stroke ■ cost ■ economics ■ health policy ■ registry ■ stroke management

A part from being a major killer and disabler, stroke is also an expensive disease. Numerous economic evaluations on the consequences of stroke have been published, but their methodologies vary, estimates of costs differ, and the studies are difficult to compare.1 Cost-of-illness studies provide vital data input for political decision-making, decision-analytic models, and cost-effectiveness research, but with multiple external estimates for costs, there is a risk of selecting such data that produce desired results.1 Information on cost is easy to communicate and comprehend but difficult to generalize outside the population it was collected from. Decision-analytic models usually gather inputs for incidence, prevalence, recurrence, mortality, morbidity, quality of life, and costs from multiple sources across wide geographic locations and time points, often not representative of the population being evaluated.2,3 An optimal model would use all the data elements gathered from a single source representative of the population being evaluated.

The objective of this article is to describe the direct healthcare cost of stroke in Finland from individual patient data using the national Performance, Effectiveness, and Costs of Treatment episodes in Stroke (PERFECT Stroke) database.

Methods
The Finnish national stroke database PERFECT Stroke uses linkage of the national administrative hospital discharge, causes of death, and drug use registries, forming a database of all patients with incident stroke treated in Finnish hospitals and institutions since Year 1999.
Information on comorbidities and healthcare use both before and for years after stroke are included in the register. The details of the PERFECT Stroke database and patient baseline characteristics have been published earlier. Patients with stroke were selected with the International Classification of Diseases, 10th Revision diagnosis codes I60 (subarachnoid hemorrhage [SAH]), I61 (intracerebral hemorrhage [ICH]), and I63 (ischemic stroke [IS]) or 1 of these codes as the etiologic cause in stroke syndromes starting with the code G46. This article describes patients with their first-ever stroke (previous transient ischemic attack not being an exclusion criterion) between January 1, 1999, and December 31, 2007, focusing on the patients of the most recent Year 2007. Follow-up of all patients is available up to December 31, 2008.

According to Finnish legislature, neither ethical committee approval nor informed consent was required because patients were not contacted and the data were anonymized so that patients were not identifiable.

**Evaluation of Costs**

Only direct healthcare costs are included. All costs are reported from a societal perspective irrespective of payer (patient, healthcare provider, or any other third party). Costs were evaluated separately for inpatient care, specialist outpatient care, and outpatient medications.

Inpatient and specialist outpatient costs associated with stroke and any other care were evaluated using a standard cost database. The database contained average national daily costs for each diagnosis-related group (DRG) and specialist outpatient visit and were recalculated annually. Daily costs were calculated by allocating each related group (DRG) and specialist outpatient visit and were recalculated annually since Year 1998.

Future costs, when evaluating lifetime cost of a new stroke, are estimated in the Year 2001 and recalculated annually. Actual patient-level costs for outpatient medications were derived from the Social Insurance Institution register of prescribed medicines.

In this report, all costs are converted to year 2008 values using the Finnish hospital cost index (conversion values for years 1999 to 2007: 1.386, 1.335, 1.300, 1.265, 1.225, 1.186, 1.143, 1.101, 1.062) and then to Year 2008 US dollars using the exchange rate 1.47 $/€.

Total costs are reported for 1 year before first-ever stroke and annually up to 5 years since first-ever stroke. All these data were collected from the same sources and with same methodology as the first-year data.

To estimate lifetime cost of patients with stroke, we used the steady annual fatality rates observed from the PERFECT data for Years 2 to 5 after stroke among survivors (8.1% for IS, 7.1% for ICH, and 1.9% for SAH) and assumed this to continue thereafter up to 30 years to estimate the numbers of patients surviving each year after stroke. For annual costs among survivors, we used a similar method of observing a declining trend in costs over the Years 2 to 5 since stroke and extrapolating this trend over the Years 6 to 30. Future costs, when evaluating lifetime cost of a new stroke, are discounted at 5% per annum.

**Statistical Analysis**

To evaluate the effect of patient’s age, year of incident stroke, and female gender on total first-year costs, a generalized linear model with $y$ distribution and log link was estimated to derive univariate rate ratios and then all previously described potential confounders were added as covariates: age, gender, comorbidities (hypertension, diabetes, coronary heart disease, congestive heart failure, atrial fibrillation, peripheral artery disease, chronic obstructive pulmonary disease or asthma, alcoholism or drug abuse, cancer, Parkinson disease, dementia, depression, other mental illnesses), and prior statin or warfarin use to derive multivariate rate ratios. Rate ratio is the exponent of the model parameter calculated at the means of the independent variables and describes the ratio of change in costs per change of 1 year of age or 1 year of stroke and the ratio of female-to-male costs.

For dichotomous factors, marginal effects in dollars are reported from the multivariate model with pairwise comparisons between

![Figure 1. Mean 1-year costs of incident Finnish patients with stroke, Year 2007.](image-url)
patients with and without the factor, again setting the independent variables at their means. Two-tailed significance was set at 95%. Statistical analyses were done on IBM SPSS Statistics 18 (SPSS Inc, Chicago, IL).

**Results**

The total number of incident strokes treated in Finnish hospitals during the study period was 94,316. The total number of annual first-ever stroke patients ranged between 10,763 and 10,225, and was 10,338 in the Year 2007. Of these, 8,204 had IS (79%), 1,413 ICH (14%), and 721 SAH (7%) as their initial stroke.

In 2007, the IS patient median (interquartile range) length of stay was 6 days (3 to 12 days) in the initial hospital and 11 days (5 to 34 days) for the whole consecutive episode of care, including also inpatient postacute care and rehabilitation. The corresponding figures were 7 days (3 to 14 days) and 19 days (5 to 65 days) for patients with ICH and 9 days (4 to 15 days) and 14 days (6 to 37 days) for patients with SAH. Of the patients with IS, 77% were discharged home, and 44% had ≥1 new hospitalizations for any reason within 1 year of the incident stroke. The corresponding figure for patients with ICH were 56% and 36% and for patients with SAH patients 68% and 37%. Of the patients with IS and those with ICH, 6% had been living in an institution before the stroke, whereas the figure was 3% for patients with SAH.

The mean (median; interquartile range) first year costs were $29,580 (15,480; 7,650 to 36,840) after incident IS, $36,220 (18,300; 6,130 to 50,510) after ICH, and $42,570 (25,130; 8,510 to 54,070) after SAH, the costs being driven by the initial hospital episode of acute care and rehabilitation (Figure 1).

Figure 2 displays the mean total first-year costs for patients of Year 2007 by age and gender. The treatment of IS among the elderly was more expensive with costs increasing 0.9% per year of age (univariate rate ratio [RR], 1.009; 95% CI, 1.007 to 1.010) or 0.7% after adjusting for confounders (RR, 1.007; 95% CI, 1.006 to 1.009). Women cost on average 16% more than men ($31,700 versus $27,300; RR, 1.164; 95% CI, 1.115 to 1.216), 11% after adjusting for confounders (RR, 1.105; 95% CI, 1.055 to 1.157). With ICH, the costs did not differ with regard to age or gender neither before nor after adjustment for confounders (all P-values >0.5). With SAH, the oldest patients were the least expensive (RR, 0.991; 95% CI, 0.985 to 0.997), again partly explained by confounders (RR, 0.993; 95% CI, 0.986 to 1.001), whereas women were more expensive ($45,800 versus $38,500; RR, 1.190; 95% CI, 1.059 to 1.348) also after adjusting for confounders (RR, 1.231; 95% CI, 1.021 to 1.485).

Among patients with IS in 2007, those left in permanent institutional care were the most expensive, whereas those who died soon after their stroke incurred the lowest costs (Table). Some comorbidities were independently associated with higher costs, whereas being treated in a designated stroke center, with thrombolytic therapy, or having carotid endarterectomy had little effect on total costs. IS recurrence within the first year increased the total first year costs by 46%.

Cost of stroke care steadily increased over the study period (Figure 3). The change was most marked for SAH (univariate change in mean cost +5.0% annually; RR after adjustment for confounders; 1.050; 95% CI, 1.040 to 1.061) and ICH (+3.3%; RR, 1.033; 95% CI, 1.024 to 1.041), but was also significant for patients with IS (+1.4%; RR, 1.013; 95% CI, 1.010 to 1.016).

Five-year follow-up was available for the patients with their incident stroke in the year 2003. These patients had healthcare use and incurred significant costs also before their incident stroke and a long time after their stroke (Figure 4). The mean costs 1 year before stroke were highest for patients with IS ($8900, 31% of costs 1 year after stroke) followed by
ICH ($7600, 23%) and SAH ($4200, 12%). In the survivors, the annual costs after the first year since stroke were in the range of $21 000 among patients with ICH, $18 000 among patients with IS, and $9000 among patients with SAH.

The estimated lifetime costs of Finnish stroke patients were $131 000 after IS, $129 000 after ICH, and $81 000 after SAH. The total observed healthcare costs in 2008 for those stroke patients who had their incident stroke during 2003 to 2007 were $800 million. Adding the extrapolated costs of the patients who had their incident stroke earlier, or in the Year 2008, the total direct healthcare costs of all stroke survivors in Finland are $1.6 billion annually.

**Discussion**

We have gathered long-term cost information on 94 316 patients with stroke in Finland. As expected, first-year costs were mostly driven by the initial episode of acute and rehabilitation hospital costs, which together accounted for 60% of these in patients with IS, 75% in patients with ICH, and 80% in patients with SAH. New hospitalizations produced a significant portion of first-year costs, almost one fourth in patients with IS, probably explained by the patients’ old age and many comorbidities.4

Among patients with IS, those left in long-term institutional care after their stroke were the most expensive but represented only 6% of all patients with IS. The patients who died quickly produced the least expenses. Being treated in a designated stroke center incurred very little extra costs despite those patients surviving longer.7 Acute treatment by neurologists produced lower 1-year costs compared with treatment by other specialists, mostly on general or medical wards, a fact noted in Finland already in the 1980s.8

Total direct healthcare costs of patients with stroke in Finland were $1.6 billion in the Year 2008, which equals to 7% of the national healthcare expenditure, or 0.6% of the gross domestic product,9,10 high in international comparison11,12 but close to a previous 1980s estimate for stroke in Finland (6.1%).13

More and more patients with stroke survive their initial stroke, which will in the future increase their healthcare costs. All of these costs are not directly caused by stroke, but rather by the many existing comorbidities of these elderly patients, a fact underlined by the high healthcare costs even before their incident stroke. However, among the survivors, having an IS seems to permanently double and having an ICH triple the patients’ already high “baseline” healthcare costs. Treatment of stroke in Finland is getting more expensive due to the change in the age structure of the population and the increasing proportion of survivors. This cost increase applies especially to the hemorrhagic subtypes.

Our study does not evaluate non-healthcare costs. With one third of the patients with stroke being working age, and rarely returning to work after their stroke, production losses and early retirement costs are likely to be significant.

There are several limitations in this study. First, we had to use DRG-weighted costs to make data comparable. Most

---

### Table. Total 1-Year Costs of Patients With First-Ever Ischemic Stroke Treated in Finland, Year 2007

<table>
<thead>
<tr>
<th>No.</th>
<th>Mean 1-Y Cost per Patient</th>
<th>Marginal Effect* (95% CI), $</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients with ischemic stroke</td>
<td>$29 576</td>
<td>2909 (1569 to 4248)</td>
</tr>
<tr>
<td>Female patients</td>
<td>$31 748</td>
<td>3787 (1992 to 5581)</td>
</tr>
<tr>
<td>Patients with hypertension</td>
<td>$30 599</td>
<td>727 (−730 to 2184)</td>
</tr>
<tr>
<td>Patients with coronary heart disease</td>
<td>$30 166</td>
<td>−329 (−1890 to 1233)</td>
</tr>
<tr>
<td>Patients with diabetes</td>
<td>$32 609</td>
<td>3787 (1992 to 5581)</td>
</tr>
<tr>
<td>Patients with atrial fibrillation</td>
<td>$31 723</td>
<td>−217 (−2148 to 1713)</td>
</tr>
<tr>
<td>Patients on warfarin</td>
<td>$32 697</td>
<td>2600 (363 to 4837)</td>
</tr>
<tr>
<td>Comprehensive stroke center treatment†</td>
<td>$29 603</td>
<td>2790 (1384 to 4196)</td>
</tr>
<tr>
<td>Primary stroke center treatment†</td>
<td>$30 409</td>
<td>3667 (1822 to 5512)</td>
</tr>
<tr>
<td>General hospital treatment†</td>
<td>$29 182</td>
<td>Reference for stroke centers</td>
</tr>
<tr>
<td>Nonneurological ward treatment</td>
<td>$33 380</td>
<td>2249 (663 to 3835)</td>
</tr>
<tr>
<td>Thrombolytic therapy</td>
<td>$28 397</td>
<td>1456 (−2164 to 5075)</td>
</tr>
<tr>
<td>Carotid endarterectomy</td>
<td>$29 991</td>
<td>3363 (−1550 to 8275)</td>
</tr>
<tr>
<td>Recurrence within 1 y</td>
<td>$43 093</td>
<td>16 540 (13 740 to 19 340)</td>
</tr>
<tr>
<td>Continuous institutional care for 1 y</td>
<td>$102 150</td>
<td>75 276 (66 972 to 83 581)</td>
</tr>
<tr>
<td>Case-fatality within 28 d</td>
<td>$643</td>
<td>−26 216 (−26 982 to −25 451)</td>
</tr>
<tr>
<td>Case-fatality within 3 mo</td>
<td>$12 161</td>
<td>−21 794 (−22 727 to −20 860)</td>
</tr>
<tr>
<td>Case-fatality within 1 y</td>
<td>$24 837</td>
<td>−8468 (−9788 to −7148)</td>
</tr>
</tbody>
</table>

*Evaluated for each factor one at a time with a generalized linear model adjusting for age, gender, comorbidities, and prior medication use.

†Centers designated according to published criteria.7

ICH ($7600, 23%) and SAH ($4200, 12%). In the survivors, the annual costs after the first year since stroke were in the range of $21 000 among patients with ICH, $18 000 among patients with IS, and $9000 among patients with SAH.

The estimated lifetime costs of Finnish stroke patients were $131 000 after IS, $129 000 after ICH, and $81 000 after SAH. The total observed healthcare costs in 2008 for those stroke patients who had their incident stroke during 2003 to 2007 were $800 million. Adding the extrapolated costs of the patients who had their incident stroke earlier, or in the Year 2008, the total direct healthcare costs of all stroke survivors in Finland are $1.6 billion annually.

Discussion

We have gathered long-term cost information on 94 316 patients with stroke in Finland. As expected, first-year costs were mostly driven by the initial episode of acute and rehabilitation hospital costs, which together accounted for 60% of these in patients with IS, 75% in patients with ICH, and 80% in patients with SAH. New hospitalizations produced a significant portion of first-year costs, almost one fourth in patients with IS, probably explained by the patients’ old age and many comorbidities.4

Among patients with IS, those left in long-term institutional care after their stroke were the most expensive but represented only 6% of all patients with IS. The patients who died quickly produced the least expenses. Being treated in a designated stroke center incurred very little extra costs despite those patients surviving longer.7 Acute treatment by neurologists produced lower 1-year costs compared with treatment by other specialists, mostly on general or medical wards, a fact noted in Finland already in the 1980s.8

Total direct healthcare costs of patients with stroke in Finland were $1.6 billion in the Year 2008, which equals to 7% of the national healthcare expenditure, or 0.6% of the gross domestic product,9,10 high in international comparison11,12 but close to a previous 1980s estimate for stroke in Finland (6.1%).13

More and more patients with stroke survive their initial stroke, which will in the future increase their healthcare costs. All of these costs are not directly caused by stroke, but rather by the many existing comorbidities of these elderly patients, a fact underlined by the high healthcare costs even before their incident stroke. However, among the survivors, having an IS seems to permanently double and having an ICH triple the patients’ already high “baseline” healthcare costs. Treatment of stroke in Finland is getting more expensive due to the change in the age structure of the population and the increasing proportion of survivors. This cost increase applies especially to the hemorrhagic subtypes.

Our study does not evaluate non-healthcare costs. With one third of the patients with stroke being working age, and rarely returning to work after their stroke, production losses and early retirement costs are likely to be significant.

There are several limitations in this study. First, we had to use DRG-weighted costs to make data comparable. Most
healthcare districts in Finland do not have sophisticated costing systems which would allow for reliable comparison of individual patient costs. We had detailed patient-level cost data for the patients from the Helsinki and Uusimaa hospital district only. The Helsinki and Uusimaa hospital district includes a population of 1.5 million, 30% of Finnish total population, and incorporates 1 university hospital, which treats 59% of the district’s patients with stroke, 3 larger regional hospitals, and 3 local hospitals, a structure representative of other Finnish hospital districts. Patient-level costing data were collected from all of the Helsinki and Uusimaa hospitals irrespective of treating specialty. For the rest of the patients, we had individual patient data on the level of care, length of stay, procedures, and DRG groups for each department stay during the stroke episode and any inpatient episodes and specialist outpatient visits thereafter. The data should amount to correct figure on a national level despite some inaccuracy at individual patient level.

Second, we cannot differentiate between rehabilitation and other inpatient costs because rehabilitation is not currently separately coded.

Third, outpatient nursing or general practice costs are not included in the figure because these are currently not nationally recorded. Any outpatient visits at hospitals or at private physicians are included, however.

Fourth, we have certainly missed some national patients. Finland has a stroke hospitalization rate of 95% to 98%, so almost no patients with stroke are treated completely as outpatients, but with some of the patients with stroke being coded as transient ischemic attack or nonstroke, we estimate to have included 85% to 90% of all population-based strokes.4

Fifth, we do not have information on stroke severity because this is not currently included in the national registries.

Sixth, to evaluate lifetime costs we extrapolated observed costs and survival of the first 5 years to the next 25 years. Such extrapolations are highly uncertain.

There are strengths in this study. Full nationwide coverage, a large numbers of patients, comprehensive follow-up, and uniform means of data collection increase the validity of the data. This study also fulfills the criteria previously set for cost-of-illness studies in stroke.1,11 A recent review of stroke cost literature showed an average 1-year cost reported in 48 studies performed in Organisation for Economic Co-operation and Development (OECD) countries to be $28 525 for IS or any stroke (reported in Year 2006 currency, practically identical to our results).1 Few costs studies in unselected stroke populations with ≥2 years of follow-up have been reported, all from Sweden, the United States, Germany, or Australia.14–19 No cost study on stroke with as large a sample size as ours has been published before.1 Our cost information should be well applicable for national decision-making.

Figure 3. Trends in mean total 1-year cost of incident Finnish patients with stroke, Years 1999 to 2007.

Figure 4. Direct medical costs 1 year before and 5 years poststroke among incident Finnish patients with stroke of Year 2003. Annual mean values reported for patients alive at the start of each year.
Conclusions
We have been able to produce a comprehensive database on Finnish patients with stroke with long-term data on costs both before and after the incident stroke. A special strength of our database, together with its high nationwide coverage, is the fact that long-term information on treatment interventions, recurrences, morbidity, and mortality are available for the same patients. The data are thus well suited for cost-effectiveness analyses. Although cost data are always country-specific, the methodology described here may be used elsewhere where high-quality nationwide registers with comprehensive coverage are available.

Sources of Funding
This study was supported by the Finnish Academy, Finnish Neurological Foundation, Finnish Innovation Fund STIF, Aarne Koskelo Foundation, Orion-Farmos Research Foundation, Maire Taponen Foundation, Paavo Ahvenainen Foundation, Instrumentarium Science Foundation, Helsinki University Central Hospital EVO Foundation, Paavo Ahvenainen Foundation, Instrumentarium Science Foundation, Orion-Farmos Research Foundation, Finnish Medical Foundation, Yrjö Jahnsson Foundation, Emil Aaltosen Foundation, Finnish–Norwegian Medical Foundation, Biomedicum Helsinki Foundation, and Päivikki and Sakari Sohlberg Foundation.

Disclosures
None.

References
Direct Costs of Patients With Stroke Can Be Continuously Monitored on a National Level: Performance, Effectiveness, and Costs of Treatment Episodes in Stroke (PERFECT Stroke) Database in Finland

Atte Meretoja, Markku Kaste, Risto O. Roine, Merja Juntunen, Miika Linna, Matti Hillbom, Reijo Marttila, Terttu Erilä, Aimo Rissanen, Juhani Sivenius and Unto Häkkinen

Stroke. published online April 28, 2011;
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2011 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/early/2011/04/28/STROKEAHA.110.612119

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/