Direct Costs of Modern Treatment of Aneurysmal Subarachnoid Hemorrhage in the First Year After Diagnosis

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Background and Purpose—The purpose of this study was to investigate the current direct costs of modern management of patients with aneurysmal subarachnoid hemorrhage in the first year after diagnosis.

Methods—During a 1-year period, we studied all admitted patients with subarachnoid hemorrhage from a population of 2 million people. We calculated the direct costs of treatment, which included the costs of medical and nursing care and the related travel expenses of patients. We calculated true costs for all major healthcare resources. National census data, if available, and standard charges were used to determine healthcare resource expenses.

Results—Hospital admissions and diagnostic and therapeutic interventions in 110 patients accounted for 85% of all costs; 64% of the total direct medical costs during admission were the medical, nursing, and overhead costs alone. Patients discharged directly to home generated 4% of the total budget, whereas admission to a nursing home accounted for the remaining 11% of the total costs. Of the diagnostic and therapeutic costs, 45% was caused by imaging and 42% by surgery or coiling. Angiography alone accounted for 52% of the total imaging costs and 24% of the total diagnostic and therapeutic costs. Prescribed medication accounted for only 3% of the total budget of diagnostic and therapeutic costs.

Conclusions—Most direct costs during the first year after aneurysmal subarachnoid hemorrhage are caused by the hospital inpatient days, accounting for two thirds of the total costs generated during the first year after the initial bleeding. If new costly treatments succeed in reducing the average length of inpatient hospital stays, then progress in therapy may prove cost effective and might even be cost saving. (Stroke. 2002;33:1595-1599.)

Key Words: costs and cost analysis ■ subarachnoid hemorrhage ■ therapeutics

Patients who survive an aneurysmal subarachnoid hemorrhage (SAH) are threatened in the first weeks after the initial hemorrhage by complications, of which rebleeding and cerebral ischemia are considered the most important.1–3 Many centers to which patients with SAH are referred aim at early obliteration of the aneurysm by surgery or by endovascular techniques using coils.3–6 The advantage of obliteration of the aneurysm in the acute stage is that rebleeding, which is accompanied by high mortality and morbidity, is prevented and that cerebral ischemia, when it occurs, can safely be treated.5 Therapy of cerebral ischemia after SAH may consist of hypervolemia, hemodilution, and induced hypertension.7–9 It is evident that this so-called triple-H therapy is not without risks in patients who still harbor an aneurysm.

The outcome of patients with SAH has improved, but despite modern treatment—early surgery, calcium antagonists, and triple-H therapy—mortality and morbidity rates are still considerable.3 Cerebral ischemia is generally considered one of the major causes of poor outcome; therefore, new treatment of SAH should aim at further decreasing the occurrence of this complication.10 The new treatments now being developed in costly procedures, eg, endothelin receptor antagonists to prevent cerebral ischemia after SAH, have subsequently to be tested in expensive clinical studies.11 When they are finally accepted in clinical practice, they will probably increase the costs of management of patients with SAH. However, by what proportion the costs will increase cannot be estimated because the costs of current modern treatment are not exactly known. The costs of aneurysmal SAH have been studied before, but most of the studies were retrospective and therefore only estimated the costs according to hospital inpatient days.12–16 Two studies did use a prospective protocol, but one of them only described patients in a trial concerning nimodipine treatment after SAH,17 and the other included only patients from a specific stroke center.18 Therefore, the aim of this study was to investigate in a prospective, multicenter study the direct costs of modern management of patients with SAH in the first year after diagnosis. Additionally, the effects of the initial clinical condition on admission, the occurrence of complications, and...
the effect of coiling on the length of in-hospital stay were investigated.

**Patients and Methods**

**Inclusion Procedure**

Between February 1996 and February 1997, patients consecutively admitted to hospital for treatment of an aneurysmal SAH were included in the study and were prospectively studied during a 1-year period ending February 1998. The diagnosis was based on clinical signs and symptoms and an aneurysmal bleeding pattern on the initial CT scan. Confirmation of the aneurysm on angiography was required only if the initial CT scan was negative and subsequent cerebrospinal fluid examination was positive (xanthochromia confirmed by spectrophotometry). Patients with a perimesencephalic bleeding pattern or another nonaneurysmal pattern of hemorrhage on CT scan were excluded.

**Hospitals and Treatment Protocol**

All hospitals in 2 regions of the Netherlands, Noord-Holland and Flevoland, contributed to the prospective cohort study. According to official data from the Dutch Central Bureau of Statistics, this region has ~2 million inhabitants. All 12 nonteaching hospitals in this area refer their SAH patients for neurosurgical interventions to the 3 neurosurgical units in Amsterdam. These neurosurgical units are all situated <85 km (50 miles) from the most remote regional hospital. The 3 neurosurgical units in Amsterdam are all teaching hospitals, and in each center, at least 3 neurosurgeons operate on cerebral aneurysms.

All 3 neurosurgical units adhered to the same management protocol, which included treatment with the calcium antagonist nimodipine (2 mg/h IV or 6×60 mg/d orally); hypervolemic, hypertensive treatment to prevent delayed cerebral ischemia (minimum of 3 L fluid intake daily); and early surgery or coiling to prevent rebleeding. Endovascular management of cerebral vasospasm by trans luminal angioplasty or intra-arterial injection with papaverine was not used in the 3 participating neurosurgical centers.

During the study period, endovascular coiling of aneurysms was a relatively new treatment method, not yet used on a large scale in the Netherlands. Therefore, the preferred method to obliterate an aneurysm was surgical clipping in most patients. Only in patients with an aneurysm that was difficult to secure by surgery, eg, a basilar aneurysm, was coiling the preferred treatment method.

**Data Collection: Sources, Patient Characteristics, and Disease Status**

Data registration was done in the participating centers by 2 research nurses using portable personal computers with database management software. All patients were identified and included in the study immediately after admission to the referring hospital. During admission, data were collected from medical records, hospital information subsystems, and case report forms on a day-to-day basis.

Administration of baseline and clinical data started on admission to the hospital where the patient was seen initially. The following patient and disease characteristics were recorded: age, sex, date of SAH, date of admission, Glasgow Coma Scale (GCS) score, SAH grade (World Federation of Neurological Surgeons score) on admission, results of the CT scan, cerebrospinal fluid examination results, and aneurysm location(s) on angiography.

**Data Collection: Inpatient, Outpatient, and Out-of-Hospital Resource Use**

On admission to the neurological ward, the San Joaquin classification method was used to differentiate patients daily along 4 levels of care (low, medium, high, and intensive care, respectively), depending on the estimated time spent on each patient by nursing staff. Additionally, the length of stay in the ward and intensive care unit (ICU) was recorded.

Furthermore, all details of performed laboratory tests (blood, urine, cerebrospinal fluid); diagnostic procedures (CT scan, MRI, angiography); therapeutic strategies, including details of the operation (aneurysm clipping, ventricular drain) and prescribed medication (antibiotics, ananetics, anticoagulants); and paramedical services were recorded.

At the 3-month follow-up, the patients’ clinical outcome was determined with the Glasgow Outcome Scale. Death, persistent vegetative state, and severe disability on the Glasgow Outcome Scale were combined as poor outcome, whereas moderate disability and good recovery were recorded on the study forms as good outcome.

After hospital discharge, data on hospital outpatient care by the neurologist were gathered from medical records, whereas information about out-of-hospital care was provided by the general practitioner and paramedical and nursing services. Home help was recorded with patient diaries. Patients received a new diary every 3 months. SAH-related travel was quantified by the number of contacts with healthcare providers and the estimated mean distance between a patient’s home and the hospitals or paramedical services involved. Data on nursing home stays were collected by telephone interview with the nursing home doctor.

All healthcare resource use data were collected and subsequently stored at the patient level.

**Calculation of Costs**

In this study, the direct costs of modern SAH treatment included the costs of medical and nursing care and the SAH-related travel expenses of patients. Costs were calculated as the product of the amount of resources used times the unit costs of those resources.

**Estimation of Unit Costs**

Standard cost-accounting procedures were followed in the participating centers to estimate the true costs of all major resources: inpatient hospital stays in the neurosurgical ward and ICU, presumably expensive imaging procedures (scans, x-rays), and operations (aneurysm clipping, ventricular draining). These costs included personnel, material, and overhead costs. The personnel costs of an inpatient day depended on the level of care provided to the individual patient and were calculated from the salaries of the staff involved. To estimate the overall costs of an inpatient day, the average expenditures per bed for hotel services, disposable items, supplies, medical equipment, and overhead (management, housing, investments, writing off of equipment) that were derived from the 1997 ledger were added to the personnel costs.

The costs of outpatient hospital consultations by the neurologist and of support at home were based on estimates of the true costs of these services available from 2 national standard cost-accounting studies. The costs of out-of-hospital consultations by the general practitioner and the physiotherapist, of days in a nursing home, and of ambulance care were all based on national census data (eg, total expenditures for general practitioner care divided by the number of insured patients and the average number of consultations per insured patient). The costs of SAH-related travel were based on the true variable costs of different means of transport per kilometer that were provided by a national consumer organization. For laboratory tests and function tests, standard charges were used as a surrogate for costs.

**Calculation of Drug Costs**

Prices for different drugs were derived from the Dutch Pharmacotherapeutic Guide 2000, supplemented if necessary with periodical information from the Royal Dutch Society for the Advancement of Pharmacy. The calculation of the total costs of drug use by SAH patients is laborious given the high number of different drugs and the different formulations (oral, intravenous, suppository) for many drugs. On the basis of our prior appraisal of a moderate share of drug costs in total costs, we decided to derive the total costs of drug use by extrapolation from a small subset of 10 patients (9%).
Currency, Index Year, and Discounting
All costs are expressed in 2001 Euros (1 Euro = 2.20371 Dutch Guilders = 0.90 US $). Price index figures were used to recalculate the 1997 cost data for the index year 1999. Given the 1-year follow-up period, no discounting took place.

Results
During the 1-year study period, 110 patients with aneurysmal SAH were admitted to the participating regional hospitals and neurosurgical centers. Table 1 shows the baseline characteristics of these patients, which are comparable to baseline characteristics in other population studies in aneurysmal SAH.6,30

The median time lapse between the SAH and admission was 0 days. Surgery or coiling was performed in 69% of all admitted patients; 43% of the patients had poor outcome at the 3-month follow-up. Outcome analysis at the 6-, 9-, and 12-month follow-up showed similar results. No patient was lost to follow-up, and the data set was complete.

Table 2 shows the costs of hospital inpatient days categorized according to the needed level of medical and nursing care. Patients with SAH demand a high level of care during admission: in 73% of the total admission time, patients were categorized as in need of high or intensive care. On average, a patient remained admitted to the hospital 35.4 days (95% CL, 29.7 to 41.1) in the ICU and 26.8 days (95% CL, 22.1 to 31.6) in the ward.

<table>
<thead>
<tr>
<th>Care Category</th>
<th>Days Admitted</th>
<th>Costs per Day, Euros/US $</th>
<th>Costs per 110 Patients, Euros/US $</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU</td>
<td>942</td>
<td>822.70/740.43</td>
<td>774 987/697 488</td>
</tr>
<tr>
<td>Ward (total)</td>
<td>2954</td>
<td>939 230/845 307</td>
<td></td>
</tr>
<tr>
<td>Low care</td>
<td>0</td>
<td>252.76/227.48</td>
<td>0/0</td>
</tr>
<tr>
<td>Medium care</td>
<td>805</td>
<td>287.70/258.93</td>
<td>231 596/208 436</td>
</tr>
<tr>
<td>High care</td>
<td>1884</td>
<td>317.65/285.89</td>
<td>598 445/538 601</td>
</tr>
<tr>
<td>Intensive care</td>
<td>265</td>
<td>412.03/370.83</td>
<td>109 189/98 270</td>
</tr>
<tr>
<td>Total</td>
<td>3896</td>
<td>1 714 217/1 542 795</td>
<td></td>
</tr>
</tbody>
</table>

n = 110. Average length of hospital stay: 3896/110 = 35.4 days (range, 1–130 days).

Admission to the ICU consisted of 24% of the total admission time, but the costs of admission to the intensive care ward accounted for 45% of the total costs of the hospital admission.

The subgroup analysis on the hospital inpatient days of the 49 patients with a good clinical condition (GCS = 15) on admission showed similar results: total admission of 37.0 days (95% CL, 28.7 to 45.3): 7.6 days (95% CL, 4.4 to 10.9) in the ICU and 29.4 days (95% CL, 22.0 to 36.8) on the ward. In patients who suffered from neurological complications (n = 61), the subgroup analysis showed a longer total in-hospital stay of 41 days (95% CL, 32.4 to 48.7): 9.6 days (95% CL, 7.2 to 12.0) in the ICU and 30.9 days (95% CL, 24.1 to 37.7) on the ward. In the 11 patients who were coiled, the total in-hospital stay was much longer: 61 days (95% CL, 33.4 to 88.6): 16.3 (95% CL, 2.4 to 30.1) in the ICU and 44.7 days (95% CL, 23.4 to 66.1) on the ward.

Table 3 shows the diagnostic and therapeutic procedures costs during hospital admission. Of these costs, 45% were from imaging and 42% from surgery and coiling. Angiography alone accounted for 52% of the total imaging costs and 24% of the total diagnostic and therapeutic costs. Prescribed medication accounted for 3% of the total budget of diagnostic and therapeutic costs.

Of the 110 admitted patients, 35 (32%) died in hospital, and 75 patients were discharged alive. Of these 75 patients, 12 were discharged to a nursing home. During the 1-year follow-up, these 12 patients stayed 2180 days (average, 181.7
TABLE 4. Out-of-Hospital Costs and Costs of Transport During
1-Year Follow-Up in 75 Patients Discharged From Hospital and
Not in Nursing Home

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>Total Costs, Euros/US $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outpatient clinic visit</td>
<td>274</td>
<td>19 894/17 905</td>
</tr>
<tr>
<td>General practitioner</td>
<td>200</td>
<td>4 704/4 234</td>
</tr>
<tr>
<td>Rehabilitation (physiotherapy, etc)</td>
<td>1804</td>
<td>31 926/28 733</td>
</tr>
<tr>
<td>Home help, etc.</td>
<td>599</td>
<td>20 386/18 347</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi</td>
<td>362</td>
<td>16 427/14 784</td>
</tr>
<tr>
<td>Private</td>
<td>1141</td>
<td>16 568/14 911</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>109 905/98 915</td>
</tr>
</tbody>
</table>

The direct out-of-hospital costs and costs of transport of all other patients after discharge from hospital are shown in Table 4. Of the total costs after discharge, 59% were transport costs and rehabilitation costs such as physiotherapy. The total direct costs generated by these patients during the period after discharge from hospital was 4.8% of the costs generated during inpatient and outpatient hospital care.

Table 5 provides an overview of all direct costs generated by patients with SAH during the 1-year follow-up. Hospital admission and diagnostic and therapeutic interventions accounted for 85% of all costs, whereas 64% of the total direct hospital costs were medical, nursing and overhead costs alone. Patients discharged directly to home generated 4% of the total budget, and admission to a nursing home accounted for the remaining 11% of the total costs.

Discussion

This study examined the direct medical costs and travel expenses generated during a 1-year follow-up in patients with aneurysmal SAH. The major costs were the costs of hospital inpatient days, which accounted for two thirds of the total costs. To calculate these costs, we used real costs generated by the medical and nursing staff and overhead costs as applicable in our hospital. Although these costs are variable among different hospitals in different settings, these costs will always be the major part of the total budget.

These costs can be reduced only by decreasing the average length of stay, especially in the ICU. Because subgroup analysis of the patients with a good clinical condition on admission (GCS, 15) showed results similar to those of an in-hospital stay, the total length of admission seems to depend particularly on whether patients suffer from complications or not. In a previous study, we showed that besides the effects of the initial bleeding, rebleeding was the most important complication causing poor outcome in these patients with SAH. Therefore, we concluded that all efforts should be directed at reducing the risk of rebleeding. Because some patients suffer from a rebleed the same day as the initial SAH, treatment to occlude the aneurysm should therefore be initiated directly after admission.

The subgroup analysis of the hospital inpatient days for patients who were coiled in this study showed much longer lengths of stay than for other patients. This was expected because during the study period (1996 to 1997), coiling of ruptured aneurysms was not easily available and therefore was considered only in patients with aneurysms that were difficult to secure by surgery. In 1 patient, for instance, the aneurysm was coiled several weeks after an attempt to secure the aneurysm surgically had failed.

Another important finding was that the second-most-expensive costs were the diagnostic and therapeutic procedures, of which imaging was the most expensive, far more expensive than the costs of surgery or coiling. The most expensive imaging procedure was angiography, which alone accounted for half of the total imaging costs and a quarter of the total diagnostic and therapeutic costs. Because in all 3 participating neurosurgical centers patients have 1 CT scan and 1 angiography standard after surgery, a possible way to reduce these costs would be to decrease the number of angiographies, especially those made after surgery to check clip position. However, unpublished data from our own center show that in 3% of these angiographies, an unexpected unfavorable clip position is found, sometimes necessitating operative repositioning of the clip.

In contrast to what we expected, the impact of prescribed medication was of relatively minor importance because medication accounted for <5% of the total budget of diagnostic and therapeutic costs. Among the most frequently prescribed medications were antibiotics, accounting for more than half of the total number of prescriptions. Because the majority of antibiotic therapy is given during the ICU stay, a reduction in the number of days in the ICU will probably be accompanied by a reduction in the costs of prescribed medication. But it should be stressed that this reduction will not have much impact on total costs.

New medical interventions to prevent or treat complications after the initial hemorrhage will undoubtedly increase the therapy costs in the short run, but it is not likely that this will have an important impact on the total costs of patients admitted for SAH. If such a treatment is effective, it is to be expected that fewer complications will occur and therefore that the length of hospital stay will decrease. A shorter stay in the ward or ICU will easily outweigh the increase in costs caused by new effective treatments. Moreover, if patients leave the hospital in better condition, this will also reduce the number of patients discharged to a nursing home and thus will reduce the costs of treatment after admission.

TABLE 5. Total 1-Year Direct Costs in 110 Patients With SAH

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Costs, Euros/US $</th>
<th>Costs per Patient, Euros/US $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical/nursing and overhead costs</td>
<td>1 714 217/1 542 795</td>
<td>15 584/14 026</td>
</tr>
<tr>
<td>Diagnostic/therapeutic costs</td>
<td>568 982/512 084</td>
<td>5 173/4 656</td>
</tr>
<tr>
<td>Nursing home</td>
<td>294 794/265 315</td>
<td>2 680/2 412</td>
</tr>
<tr>
<td>Out-of-hospital care and transport costs</td>
<td>109 905/98 915</td>
<td>999/899</td>
</tr>
<tr>
<td>Total 1-y direct medical costs of aneurysmal SAH</td>
<td>2 687 898/2 419 108</td>
<td>24 435/21 772</td>
</tr>
</tbody>
</table>
Endovascular aneurysm obliteration with platinum coils is a relatively new development that currently is under investigation in a large, multicenter study (International Subarachnoid Hernorrhage Trial, headquarters, The Radcliffe Infirmary, Oxford, UK).31–34 If this procedure appears to be at least as effective as surgery, it will replace surgery, which will certainly reduce the total direct medical costs generated by SAH patients. Because coiling is in general a less invasive procedure than surgery, the length of hospital stay will decrease. A reduction in the length of stay in the ICU will have a beneficial impact on the total direct medical costs. Second, if coiling is going to be incorporated into the diagnostic angiography procedure, this will reduce the costs not only by lowering the total number of angiographies but also by decreasing the number of complications because in this case obliteration of the aneurysm will be done immediately after the aneurysm has been demonstrated. If surgery has to be performed, there will always be a delay, during which rebleeding may occur, resulting in ICU admission and thus higher costs.

In conclusion, the major direct costs in aneurysmal SAH are caused by the hospital inpatient days, accounting for two thirds of the total costs generated during the first year after the initial bleeding. Therefore, despite the fact that new interventions to prevent or treat complications after SAH will increase costs, these interventions may eventually reduce the total direct costs by reducing the in-hospital stay.

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References


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