The most appropriate treatment of cerebral aneurysms, whether ruptured or not, is currently under debate. The long-lived supremacy of surgery as the sole therapy for aneurysms is now challenged by the results of a growing number of clinical studies that support endovascular coil occlusion as an equal or better alternative.

Object. The most appropriate treatment for cerebral aneurysms, both ruptured and unruptured, is currently under debate, and updated guidelines have yet to be defined. The authors attempted to identify trends in therapy for cerebral aneurysms in the US as well as outcomes.

Methods. The authors retrospectively reviewed data from the Nationwide Inpatient Sample hospital discharge database (Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality) for the period 1993–2003. Multiple variables were categorized and subjected to statistical analysis for International Classification of Diseases, 9th Revision, Clinical Modification codes related to subarachnoid hemorrhage (SAH), unruptured aneurysm, and clipping and endovascular treatment of cerebral aneurysm.

Results. During the study period, the numbers of discharges remained stable for SAH but doubled for unruptured aneurysms. Concomitantly, the number of aneurysms treated with clip placement remained stable, and the number treated by means of endovascular procedures doubled. By the study’s end, the mortality rates had decreased 20% for SAH and 50% for unruptured aneurysms. Increasing age was associated with increased mortality rates, mean length of hospital stay (LOS), and mean charges ($p < 0.01$). Endovascular treatment was used more often in older patients ($p < 0.01$). Teaching status and larger hospital size were associated with higher charges and longer hospital stays (although the association was not statistically significant) and with better outcomes ($p < 0.05$) and lower mortality rates ($p < 0.05$), especially in patients who underwent aneurysm clipping ($p < 0.01$). Endovascular treatment was associated with significantly higher mortality rates in small hospitals ($p < 0.001$) and steadily increasing morbidity rates (45%). Morbidity rates, mean LOS, and mean charges were higher for aneurysm clipping ($p < 0.01$).

Conclusions. From 1993 to 2003, endovascular techniques for aneurysm occlusion have been increasingly used, while the use of surgical clipping procedures has remained stable. Toward the end of the study period, better overall outcomes were observed in the treatment of cerebral aneurysms, both ruptured and unruptured. Large academic centers were associated with better results, particularly for surgical clip placement. (DOI: 10.3171/JNS/2008/108/6/1163)

Key Words • aneurysm • subarachnoid hemorrhage • unruptured aneurysm

Abbreviations used in this paper: AHRQ = Agency for Healthcare Research and Quality; HCUP = Healthcare Cost and Utilization Project; ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification; ISAT = International Subarachnoid Aneurysm Trial; LOS = length of hospital stay; NIS = Nationwide Inpatient Sample; SAH = subarachnoid hemorrhage.

Recent trends in the treatment of cerebral aneurysms: analysis of a nationwide inpatient database
all-payer inpatient care database in the US. The data include 100% of discharges from a stratified random sample of nonfederal hospitals in 19–28 states. Thus, a representative 20% subsample of the entire US is included in these hospital discharges, equating to approximately 8 million hospital stays from 1000 hospitals. The NIS is one in a family of databases and software tools developed as part of the HCUP. These data may be accessed via the HCUP online query system, HCUPnet, on the Internet at http://hcupnet.ahrq.gov. The HCUPnet query system generates statistics using data from HCUP’s NIS, Kids’ Inpatient Database, and State Inpatient Databases for those states that have agreed to participate. The website also provides statistics based on AHRQ’s Patient Safety Indicators that have been applied to the NIS and includes a “Quick Statistics” option that provides ready-to-use tables with commonly requested information.

Data are available via HCUPnet by year beginning with 1997. Trend information is available beginning with 1993. Trend data were therefore obtained from the NIS for the period between 1993 and 2003, the earliest and latest years for which data were available at the time of the study. Categorized data were available from 1997 to 2003. Discharge data were retrieved by searching principal diagnoses and procedures as listed in the ICD-9-CM. Utilizing a search strategy used by others, the following codes were used for data query: 430 (SAH), 437.3 (nonruptured cerebral aneurysm), 39.51 (clipping of cerebral aneurysm), 39.52 (other repair of aneurysm), 38.82 (occlusion of head/neck vessels), and 39.72 (endovascular repair or occlusion of head and neck vessels). Trend data were calculated using the software provided by the NIS and were downloaded to a Microsoft Excel spreadsheet.

Separate tables were created for analyzing categorized data from 1997 to 2003. The attributes considered were: teaching status, hospital size, and patient age. The outcome measures considered included: in-hospital deaths, routine discharge (used as a surrogate for good outcome), discharge other than routine (used as a surrogate for morbidity), mean LOS, and mean hospital charges. The definitions of data categories are summarized in Appendix 1. Graphics were built for trend analysis and comparison of outcomes based on selected categories. Statistical analysis was carried out by means of the chi-square test with the Yates correction.

Results

Using ICD-9-CM codes for SAH and unruptured aneurysm, a sample of 506,040 patients was accrued for review.

Trend Analysis

The results of our trend analysis indicate that the numbers of discharges remained stable for patients with SAH but more than doubled for those with unruptured aneurysms (Table 1 and Fig. 1). Concomitantly, the number of aneurysm clipping procedures remained stable, whereas that of endovascular procedures doubled (Table 2 and Fig. 2). By the study’s end, the mortality rates had decreased 20% for SAH and 50% for unruptured aneurysms (Fig. 3). Length of hospital stay decreased progressively for unruptured aneurysms, with the initial values being almost halved by the end of the study period. For patients with SAH, mean LOS also demonstrated a slowly progressive decrease throughout the study. By the end of the study period mean hospital charges had nearly doubled ($1.85) for SAH and had more than doubled ($2.25) for unruptured aneurysms. Following a similar trend, the mean costs of aneurysm clipping and endovascular therapy increased, respectively, to 1.8 and 2.1 times their initial levels (Fig. 4). Routine discharges (used as a surrogate for good outcome) remained stable for SAH and showed a modest increase for unruptured aneurysms. This 7% increase in better outcomes for unruptured aneurysms, combined with the decrease by half of in-hospital mortality, resulted in a statistically significant reduction in the number of discharges to locations other than home (used as a surrogate for morbidity) by the end of the study.

Analysis by Category

Incidences of SAH and unruptured aneurysms were consistently higher for the age group 45–64 years throughout the study period. Increasing age was associated with statistically significant increases in mortality rate, mean LOS, and mean charges for SAH. Conversely, younger age was associated with higher incidences of routine discharges. Endovascular treatment was used more often in older patients. For clipping, increasing age was associated with longer hospital stays and higher hospital charges, a tendency not observed in the endovascular group.

Scrutiny of the workload share for treatment modality by teaching status for surgical clipping showed trends with a stable ratio of 80 and 20% for teaching and nonteaching hospitals, respectively (Fig. 5 upper). For endovascular therapy, trends revealed a steadily increasing number of procedures performed at nonteaching institutions that eventually reversed toward the original levels of 70 and 30% for teaching and nonteaching institutions, respectively (Fig. 5 lower).

Teaching status and larger hospital size were associated with higher charges and longer LOS (although the association was not statistically significant), and with significantly better outcomes and lower mortality rates (p < 0.01), especially in patients who underwent aneurysm clipping (Fig. 6). Endovascular treatment was associated with significantly higher mortality rates in small hospitals and overall steadily increasing numbers of discharges other than routine.

Discharges other than routine, mean LOS, and mean hospital charges were significantly higher for patients who underwent aneurysm clipping (Table 2). However, in-hospital mortality rates for patients who underwent clip placement procedures exhibited a statistically significant 30% decrease throughout the study, almost reaching the mortality rates associated with endovascular therapy, which in turn showed no significant change in in-hospital mortality (Fig. 7). Surgical clip placement exhibited a modest incremental trend for good outcomes by the end of the study, whereas there was a slow and steady 8% decline in discharges home (as a surrogate for good outcome) for endovascular therapy. Discharge other than home (as a surrogate for morbidity) showed a steady trend with a modest decline for surgical clip placement. In contrast, endovascular ther-
apy was associated with a progressive increase in morbidity rates to a statistically significant increase of 30% (p < 0.01, Fig. 8).

By the end of the study, a trend was identified toward an increasing number of aneurysm patients being treated at large, teaching centers in preference to smaller, nonteaching hospitals.

Discussion

In this observational study, we attempted to delineate trends in the treatment of aneurysms after the introduction of endovascular therapy in the US, based on discharge data obtained from the country's largest all-payer inpatient care database. The purpose of this study was to provide a glimpse of recent trends in the treatment of cerebral aneurysms and the overall measurable results associated with their management strategies in the US in general. This information is new to the literature. It is not our purpose to establish a comparison between these data collected from coded discharge summaries and more rigorously collected data previously published in reports from large, academic, multispecialty institutions, but rather to form an approximate impression of what has happened, on average, to patients with cerebral aneurysms at hospitals across the US.

The validity of the data provided by the NIS, which relies purely on ICD-9-CM codes, has been questioned. However, despite coding errors and limited clinical data availability that do not seem to have any statistically significant effect on overall results, the NIS has positioned itself as the standard tool for research involving large samples of patients. Furthermore, it is likely that neurosurgeons will need to be familiar with these kinds of data in light of evolving strategies in health policy-making and reimbursement (that is, pay for performance).

Our study reveals several interesting findings. First of all, more aneurysms are being diagnosed and treated in the US. This increment is represented almost exclusively by unruptured aneurysms. Considering the demographic growth during the study period, the increase is real. Simultaneous with the significant increase in unruptured aneurysms diagnosed and treated, there has been a similar trend in the use of endovascular therapy for the treatment of aneurysms. In contrast, the numbers of ruptured aneurysms and surgical clipping procedures remained stable.

The second important finding is a significant decrease in in-hospital mortality rates. For unruptured aneurysms, a reduction from 2.8% at the beginning of the study to 1.4% represented a 50% decrease (p < 0.01). For ruptured aneurysms, the decrease from 30.2% to 24% represented a statistically significant 20% reduction in the in-hospital mortality rate (p < 0.01). In contrast with these encouraging figures, the numbers of good outcomes (as a surrogate for routine discharge) remained stable for ruptured aneurysms and exhibited a 7% increase for unruptured aneurysms by the end of the study. There was therefore a significant decrease in morbidity (as a surrogate for discharge to a location other than home) associated with unruptured aneurysms as a result of improvement in the number of good outcomes and decreased mortality rates. For patients with SAH, the morbidity rate remained stable. These results came with a cost; mean hospital charges steadily increased.

---

**TABLE 1**

Data categorization for SAH and unruptured aneurysm discharges for the period 1993–2003

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of discharges</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unruptured aneurysm</td>
<td>11,451</td>
<td>11,124</td>
<td>12,629</td>
<td>14,248</td>
<td>15,093</td>
<td>15,794</td>
<td>18,141</td>
<td>18,410</td>
<td>17,714</td>
<td>18,686</td>
<td>25,224</td>
</tr>
<tr>
<td>SAH</td>
<td>43,495</td>
<td>43,925</td>
<td>48,199</td>
<td>50,491</td>
<td>50,835</td>
<td>50,643</td>
<td>61,384</td>
<td>64,630</td>
<td>67,136</td>
<td>74,166</td>
<td>94,140</td>
</tr>
<tr>
<td>unruptured aneurysm</td>
<td>26,616</td>
<td>30,778</td>
<td>30,939</td>
<td>31,941</td>
<td>29,362</td>
<td>29,987</td>
<td>35,369</td>
<td>37,483</td>
<td>37,123</td>
<td>38,265</td>
<td>49,374</td>
</tr>
<tr>
<td>in-hospital mortality rate (%)</td>
<td>30.20</td>
<td>29.00</td>
<td>27.99</td>
<td>28.53</td>
<td>27.04</td>
<td>27.89</td>
<td>25.99</td>
<td>25.78</td>
<td>26.71</td>
<td>27.50</td>
<td>23.99</td>
</tr>
<tr>
<td>SAH</td>
<td>35.01</td>
<td>33.03</td>
<td>32.41</td>
<td>31.43</td>
<td>32.63</td>
<td>32.22</td>
<td>32.04</td>
<td>33.98</td>
<td>31.11</td>
<td>31.33</td>
<td>35.23</td>
</tr>
<tr>
<td>unruptured aneurysm</td>
<td>73.70</td>
<td>71.31</td>
<td>71.23</td>
<td>72.63</td>
<td>72.92</td>
<td>72.83</td>
<td>75.72</td>
<td>75.48</td>
<td>76.51</td>
<td>74.92</td>
<td>78.81</td>
</tr>
<tr>
<td>routine discharge (% of cases)</td>
<td>35.01</td>
<td>33.03</td>
<td>32.41</td>
<td>31.43</td>
<td>32.63</td>
<td>32.22</td>
<td>32.04</td>
<td>33.98</td>
<td>31.11</td>
<td>31.33</td>
<td>35.23</td>
</tr>
<tr>
<td>discharge other than routine</td>
<td>22.91</td>
<td>26.02</td>
<td>25.81</td>
<td>24.85</td>
<td>24.56</td>
<td>24.33</td>
<td>22.15</td>
<td>22.44</td>
<td>21.63</td>
<td>22.56</td>
<td>18.78</td>
</tr>
</tbody>
</table>

**Fig. 1.** Graph illustrating trends in discharges for SAH and unruptured aneurysms.
to almost double the level at the beginning of the study for patients with SAH, and to 2.25 times their original level for patients treated for unruptured aneurysms.

Data breakdown according to hospital size and teaching status reveals that larger hospital size and teaching status were associated with better outcomes and lower mortality rates. These findings were more evident for surgical clip placement. With respect to comparison of treatment modality trends, even though endovascular therapy was associated with better outcomes and lower mortality rates than surgical clip placement, the significant gaps seen at the beginning of the study had markedly narrowed due to the concomitant worsening in outcomes of endovascular therapy contrasting with the trend toward better outcomes for surgical clipping. This phenomenon was more striking in terms of morbidity rates, with endovascular therapy showing a steady increase to levels 30% higher than those at the beginning of the study. Also, the mortality rate associated with clip placement declined by 30%, and by the end of the study it nearly equaled the mortality rate associated with endovascular therapy, which remained stable.

Recently, Cowan et al. reported the results of an analysis of categorized NIS data analysis pertaining to cerebral aneurysms and their treatment modalities during the period 1993–2003. In their analysis, they reported more unruptured aneurysms being treated, while treatment of ruptured aneurysms remained stable. Use of endovascular treatment was increased for both ruptured and, most significantly, unruptured aneurysms. Endovascular treatment was associated with shorter length of stay for both ruptured and unruptured aneurysms and with a higher rate of discharges home in patients with unruptured aneurysms. However, a higher mortality rate was encountered for endovascular therapy for ruptured cerebral aneurysms. Hospital case volume was a significant predictor of mortality in a regression model.

Even though, at first impression, it may appear that there are strongly similar as well as strikingly different findings...
Trends in the treatment of cerebral aneurysms

in our study and that of Cowan et al., both appreciations are erroneous. Different methodologies were used in these 2 studies. In their study, Cowan et al. focused exclusively on detailed data (demographic, comorbidity, and payer information) from categorized data for the period 1998–2003 pertaining to patients who had cerebral aneurysms and underwent either endovascular or surgical treatment. In our study, we report on trends of discharge diagnoses (as opposed to treatment) for the period 1993–2003 and categorized trend data of discharge diagnoses for 1997–2003. Also, in their analysis, Cowan et al. included patients with the diagnosis of intracerebral hemorrhage (ICD-9-CM 431.0), whereas we did not. Another difference from our study was that Cowan et al. combined all the codes used for endovascular treatment in 2003 (ICD-9-CM codes 39.52, 39.72, and 39.79). In our study, we elected not to use ICD-9-CM codes 431.0 (intracerebral hemorrhage) and 39.79 (other endovascular graft repair of aneurysm—implantation of graft in lower extremity artery[-ies]: celiac, femoral, hepatic, iliac, mesenteric, popliteal, renal, splenic, tibial, thoracic aorta; upper extremity artery[-ies]: axillary, brachial, bra-

Fig. 4. Graph illustrating trends in mean hospital charges according to treatment modality. Values on y axis are US dollars.

Fig. 5. Graph illustrating trends in workload share for clip placement (upper) for SAH and unruptured aneurysms (lower) by hospital status.

chlorocephalic, carotid, radial, ulnar) to avoid potential over-estimation in our data samples, and we used a search strategy previously used by others, as described earlier in this article.

Far from establishing any comparison between treatment modalities, the trends identified in our study represent a developing therapeutic paradigm that reconciles a long-standing modality, surgical clip placement, and a developing method, endovascular therapy. As suggested by our results, and as also indicated in the literature, regionalization at large academic centers may be the end result of these trends in the treatment of cerebral aneurysms.

Finally, the majority of the data analyzed predate the release of the ISAT trial, which demonstrated that endovascular therapy may be the treatment of choice in selected patients with cerebral aneurysms. Follow-up of data trends for the years following the release of ISAT (not yet available at the time of our analysis) will be pursued to assess the impact of its results on the care of patients with cerebral aneurysms.

Fig. 6. Graphs illustrating trends in in-hospital mortality rates associated with clip placement (upper) and endovascular treatment (lower) stratified by hospital status.

Fig. 7. Graph illustrating overall trends in in-hospital mortality rates associated with clip placement and endovascular therapy.
Conclusions

Data trend analysis from the NIS revealed an increased selection of endovascular therapy for treatment of cerebral aneurysms. A significant decrease in mortality was encountered for both endovascular therapy and surgical clipping for the treatment of cerebral aneurysms. There was a modest increase in good outcomes for unruptured aneurysms treated with either modality. Large, academic centers were associated with better outcomes and lower mortality rates.

Appendix 1

Definitions of terms used in HCUP databases

Died generally indicates an in-hospital death. Some unknown number of patients may have died outside the hospital but still be included in HCUP databases.

Discharge status indicates the disposition of the patient at discharge from the hospital, for example, routine (home), to another short-term hospital, to a nursing home, to home health care, or against medical advice.

Gender is coded as male or female.

Hospital charges is the amount the hospital charged for the entire hospital stay. It does not include professional fees (physicians’ fees). Charges will reflect the total hospital charges, not the charge for a given procedure.

Hospital discharge is the unit of analysis for HCUP. Data are the hospital discharge (that is, the hospital stay), not a person or patient. This means that a person who is admitted to the hospital multiple times in 1 year will be counted each time as a separate “discharge” from the hospital.

Length of stay (LOS) is the number of nights the patient remained in the hospital for this stay.

Patient age in years is calculated on the basis of the date of admission to the hospital.

Teaching status indicates whether the hospital in which the stay occurred is a teaching or a nonteaching hospital. A hospital is considered to be a teaching hospital if the American Hospital Association Annual Survey indicates that it has an American Medical Association–approved residency program, is a member of the Council of Teaching Hospitals, or has a ratio of full-time equivalent interns and residents to beds ≥ 0.25.

References


N. Andaluz and M. Zuccarello

J. Neurosurg. / Volume 108 / June 2008

1168
Trends in the treatment of cerebral aneurysms


Address correspondence to: Norberto Andaluz, M.D., 13000 Bruce B. Downs Boulevard, ML 112, Tampa, Florida 33612. email: nandaluz@hsc.usf.edu.