Paradoxical Trends in the Management of Unruptured Cerebral Aneurysms in the United States
Analysis of Nationwide Database Over a 10-Year Period

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Background and Purpose—The objective of this study was to characterize demographics, treatments, and outcomes in the management of unruptured cerebral aneurysms in the United States using a national healthcare database.

Methods—Clinical data were derived from the Nationwide Inpatient Sample for the years 1997 through 2006. Patients with unruptured cerebral aneurysms were identified using the appropriate International Classification of Diseases, 9th Revision code (437.3). Hospitalizations, length of stay, hospital charges, discharge pattern, age and gender distribution, and nature of intervention were analyzed. A Bureau of Labor statistics tool was used to adjust hospital and national charges for inflation. Population-adjusted rates were calculated using population estimates generated by the US Census Bureau.

Results—Over 100 000 records were retrieved for analysis. During the time period studied, there was a 75% increase in the number of hospitalizations associated with unruptured cerebral aneurysms. Inflation adjusted hospital charges increased by 60%, whereas the total national bill increased by 200%. Overall, length of stay decreased by 37% and in-hospital mortality rates decreased by 54%. The increasing number of hospitalizations and total national charges related to inpatient treatment of unruptured aneurysms were significantly associated with endovascular treatment rather than surgical clipping.

Conclusions—Despite recent studies suggesting a low risk of rupture of incidentally diagnosed cerebral aneurysms, data from this study suggest an increasing trend of treatment for this entity in the United States. Furthermore, endovascular intervention is now the major driving force behind the increasing overall national charges. Given the current healthcare climate, the impact of these trends warrants discussion and debate. (Stroke. 2011;42:1730-1735.)

Key Words: aneurysms ■ endovascular ■ healthcare ■ Nationwide Inpatient Sample

Subarachnoid hemorrhage (SAH) from aneurysmal rupture accounts for 2% to 5% of all new strokes in the United States, affecting up to 33 000 people each year.1-3 Despite advancements in diagnostic modalities, neurocritical care, surgical, and endovascular treatments, aneurysmal SAH remains a devastating disease with mortality rates ranging from 32% to 57%.4-6 Nearly half of the survivors may have long-term physical and cognitive sequelae.1,2,5 Aneurysmal SAH is associated with significant financial burdens on the healthcare system, because it demands intense use of both hospital and long-term care resources.3

There is great impetus to treat unruptured incidental aneurysms (UIA) to prevent the devastating outcomes and to reduce the immense consumption of healthcare resources associated with SAH. However, there remains great variability in the management of UIAs. Microsurgical clipping is associated with excellent obliteration outcomes but carries procedural morbidity and mortality rates of up to 15.7%.7,8 Endovascular treatment using coil and/or stent devices deployed under fluoroscopic visualization is less invasive and is associated with lower procedural complications, shorter hospital stays, and potentially lower costs.9 However, few studies have examined the financial impact of UIA treatment on a national level.10,11 The goal of the current study is to assess trends in the treatment of UIAs and the associated economic burden in the United States with particular emphasis on differences between endovascular and open surgical treatment modalities.

Methods
Clinical data were extracted from the Nationwide Inpatient Sample (NIS) for the years 1997 through 2006. The NIS, which is maintained by the Agency for Healthcare Research and Quality, contains discharge data from 5 to 8 million hospital stays from approximately 1000 short-term, nonfederal, general hospitals. These hospitals represent different ownerships, bed sizes, teaching status, and urban/
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A total of 100,650 records associated with UIAs were retrieved from the NIS database during the study period (Table 1). From 1997 to 2006, there was a 75% increase in the number of hospitalizations per 100,000 in the United States. The mean age was 55.4 years, which remained consistent across the 10-year period. The average female-to-male ratio was 2.7 to 1 without significant variations. From 2001 to 2006, the most common secondary diagnosis was hypertension (47.8%). Other associated diagnoses included tobacco use (26.5%), hypercholesterolemia (15.2%), diabetes mellitus (7.7%), convulsions (7.3%), coronary artery disease (5.5%), and headache (4.5%). The great majority of these aneurysms were treated in teaching hospitals. There was a trend of increasing concentration of the management of UIAs in teaching hospitals over the 10-year period.

### Intervention

To compare surgical clipping versus endovascular treatment, available online data (from 2003 through 2006) were abstracted and analyzed (Table 2). On average, treatment with either endovascular or clipping techniques was associated with 66% of the hospitalizations related to UIA. From 2003 to 2006, although there was a 22.3% increase in the total number of hospitalizations related to UIA, there was a >100% increase in the absolute number of reported endovascular treatments (Figure 1). In 2003, endovascular treatments accounted for only 25.4% of the hospitalizations for UIA and was less common than surgical clipping ($P<0.001$). By 2006, endovascular had surpassed surgical treatments as the more common technique, accounting for 42.4% of the hospitalizations ($P<0.001$). Concurrently, there was an 11.2% decrease in the number of hospitalizations associated with clipping of aneurysms.

### Outcome

The in-hospital mortality for hospitalizations associated with UIA declined from a rate of 2.3% in 1997 to 1.1% in 2006, representing a 53.9% improvement (Table 1). Mortality data for individual treatment modalities were suppressed by the NIS database due to unacceptable rates of error. The mean LOS decreased by 37.3% from 6.7 days to 4.2 days during the 10-year study period (Table 1). In the period from 2003 to 2006, the mean LOS decreased by 19.2% overall. This was secondary to a 10% decrease in mean LOS in hospitalizations associated with clipping of UIA remained constant at 7 days (Table 3). The LOS associated with endovascular treatment was significantly lower ($P<0.001$) than the LOS for surgical clipping for each year between 2003 and 2006.

Routine discharge rates after hospitalization associated with UIA increased by 5%, whereas discharges to another

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**Table 1. Total Number of Hospitalizations Associated With Unruptured Aneurysms From 1997 to 2006**

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<tbody>
<tr>
<td>Total no.</td>
<td>7566</td>
<td>7974</td>
<td>9586</td>
<td>9395</td>
<td>8692</td>
<td>8448</td>
<td>12092</td>
<td>11225</td>
<td>10879</td>
<td>14793</td>
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<tr>
<td>Per 100,000 US population</td>
<td>2.8</td>
<td>3.0</td>
<td>3.5</td>
<td>3.3</td>
<td>3.0</td>
<td>2.9</td>
<td>4.1</td>
<td>3.8</td>
<td>3.7</td>
<td>4.9</td>
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<td>Mean age, years</td>
<td>56.2</td>
<td>54.8</td>
<td>55.3</td>
<td>55.0</td>
<td>55.4</td>
<td>54.7</td>
<td>55.8</td>
<td>55.3</td>
<td>55.3</td>
<td>55.7</td>
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<tr>
<td>Male (%)</td>
<td>2091 (27.6)</td>
<td>2261 (28.4)</td>
<td>2711 (28.3)</td>
<td>2482 (26.4)</td>
<td>2468 (28.4)</td>
<td>2327 (27.6)</td>
<td>3128 (27.6)</td>
<td>3128 (27.6)</td>
<td>2985 (28.6)</td>
<td>2916 (26.8)</td>
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<tr>
<td>Female (%)</td>
<td>5475 (72.4)</td>
<td>5713 (71.6)</td>
<td>6875 (71.7)</td>
<td>6909 (73.5)</td>
<td>6224 (71.6)</td>
<td>6120 (72.5)</td>
<td>8896 (73.6)</td>
<td>8229 (73.3)</td>
<td>7848 (72.1)</td>
<td>10952 (74.0)</td>
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<td>Hospital setting</td>
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<td>Teaching (%)</td>
<td>5814 (76.8)</td>
<td>6277 (78.7)</td>
<td>7947 (82.9)</td>
<td>7260 (77.3)</td>
<td>7062 (81.2)</td>
<td>6563 (77.7)</td>
<td>9559 (79.1)</td>
<td>9655 (86.0)</td>
<td>8598 (79.0)</td>
<td>13136 (88.8)</td>
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<td>Nonteaching (%)</td>
<td>1752 (23.2)</td>
<td>1660 (20.8)</td>
<td>1639 (17.1)</td>
<td>2135 (22.7)</td>
<td>1630 (18.8)</td>
<td>1884 (22.3)</td>
<td>2533 (21.0)</td>
<td>1570 (14.0)</td>
<td>2282 (21.0)</td>
<td>1657 (11.2)</td>
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<td>Outcome</td>
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<td>In-hospital deaths, %</td>
<td>2.3</td>
<td>2.6</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>1.5</td>
<td>1.6</td>
<td>1.4</td>
<td>1.2</td>
<td>0.9</td>
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<td>Hospitalizations</td>
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institution such as nursing home or rehabilitation facility fell by 19.4% overall. Analysis of discharge status based on intervention found a 12.1% decrease in discharge to institution in hospitalizations associated with endovascular treatment compared with a 2.8% decrease when treated with clipping (Table 3). Between 2003 and 2006, the percentage of patients with a routine discharge (a surrogate marker for good outcome) was significantly higher for those undergoing endovascular treatment compared with those undergoing surgical clipping ($P<0.001$).

### Charges

Between 1997 and 2006, the inflation adjusted per hospitalization charge associated with UIA increased by 60%, from $29,362 to $46,950, whereas the national bill increased by >200%, from $222 million to $695 million (Figure 2). When considered by type of intervention, there was a greater increase in the mean charge per hospitalization when comparing surgery with endovascular treatment (32.3% versus 26.1%) between 2003 and 2006. However, the rise in the aggregate national bill secondary to endovascular treatment was significantly greater than that of surgery (156.8% versus 32.3%; Table 2; Figure 3). Although surgical clipping was associated with higher charges per admission, overall national charges were significantly higher with endovascular treatment due to the high volume of these cases.

### Discussion

Analysis of the NIS database revealed a 75% increase in the number of hospitalizations associated with UIA between 1996 and 2007. There was a concurrent surge of hospital charges by 60% and of the total national bill by 200%. The rising number of hospitalizations and total national charges related to inpatient treatment of UIAs were significantly associated with endovascular treatment rather than surgical clipping.

There have been tremendous efforts to understand the prevalence and the natural history of aneurysms. Autopsy and angiographic studies estimated the prevalence of intracranial aneurysms in the general population to range from 0.4% to 6.0% with higher rates in patients with autosomal-dominant polycystic kidney disease, familial history of SAH, connective tissue disease, or atherosclerosis. MRI of the brain in adult volunteers from the population-based Rotterdam Study demonstrated that aneurysms were the second most common incidental finding. The great majority of incidentally identified aneurysms were located in the anterior circulation and <6 mm.

Early historical case series described significant risks of enlargement or hemorrhage from UIAs. With reported hem-
orrhage rates up to 8.3% annually, surgeons advocated for obliteration of UIAs, especially in younger patients.14–18 Modern results from the Scandinavian series and International Study of Unruptured Intracranial Aneurysms (ISUIA) studies, however, suggested that UIAs have much lower annual hemorrhage rates per patient year studied, ranging from 0.3% to 1.4%.7,8,19–22 Small aneurysms (<10 mm), especially, were found to have extremely low annual rates of rupture.7 In a recent meta-analysis by Wermer et al, the overall risk of rupture of UIAs in patients with <10 years of follow-up was 1.3%.22 Aneurysmal size, location in the posterior circulation, symptoms other than SAH, age >60 years, and female gender were identified as risk factors for aneurysmal rupture.22

The American Heart Association recommended conservative management of small asymptomatic aneurysms, especially in elderly patients with medical comorbidities.23 Given the majority of UIAs are small, it would seem that treatment, whether microsurgical clipping or endovascular coiling, should be reserved for a small portion of UIAs. Paradoxically, we found that after a modest decline in the number of hospitalizations for UIAs from 1999 to 2002, there was a dramatic increase from 2003 to 2006. Overall, there was a 75% increase in the number of hospitalizations per 100 000 in the United States between 1997 and 2006. This was despite publications during this period demonstrating lower than previously reported rupture rates. This increase in hospitalizations associated with UIA appeared to be driven by a greater number of patients undergoing endovascular treatment. Although there was an 11.2% decrease in the number of hospitalizations for surgical clipping of UIAs between

| Table 3. Length of Stay and Discharge Status After Hospitalization for Unruptured Aneurysms From 2003 to 2006 |
|--------------------------------------------------|------------------|-------------|-------------|-------------|-------------|----------------|
| Mean length of stay                             | 2003            | 2004        | 2005        | 2006        | Average     | Percent Change |
| Overall (SE)                                    | 5.2 (0.2)       | 4.6 (0.2)   | 4.3 (0.2)   | 4.2 (0.2)   | 4.6         | 19.2          |
| Endovascular treatment (SE)                     | 3.0 (0.2)       | 3.0 (0.2)   | 2.9 (0.2)   | 2.7 (0.2)   | 2.9         | 10.0          |
| Surgical clipping (SE)                         | 7.0 (0.2)       | 6.6 (0.5)   | 6.5 (0.4)   | 7.0 (0.4)   | 6.8         | 0.0           |
| P                                               | <0.001          | <0.001      | <0.001      | <0.001      |             |               |
| Routine discharge                               |                 |             |             |             |             |               |
| Overall (%)                                     | 9528 (78.8)     | 8824 (78.6) | 8734 (80.3) | 12 241 (82.8) | 9831.8 (80.1) | 5.0          |
| Endovascular treatment (%)                      | 2785 (90.7)     | 3397 (91.7) | 3875 (91.5) | 5844 (93.1) | 3975.3 (91.7) | 2.6          |
| Surgical clipping (%)                           | 3444 (76.9)     | 2663 (73.8) | 2356 (78.3) | 3115 (78.4) | 2894.5 (76.9) | 1.9          |
| P                                               | <0.001          | <0.001      | <0.001      | <0.001      |             |               |
| Discharge to another institution (nursing home, rehabilitation) |                 |             |             |             |             |               |
| Overall (%)                                     | 1178 (9.7)      | 970 (8.7)   | 1022 (9.4)  | 1161 (7.9)  | 1082.8 (8.9) | 19.4          |
| Endovascular treatment (%)                      | 132 (4.3)       | 148 (4.0)   | 189 (4.5)   | 238 (3.8)   | 176.8 (4.1)  | 12.1          |
| Surgical clipping (%)                           | 583 (13.0)      | 512 (14.2)  | 457 (15.2)  | 503 (12.7)  | 513.8 (13.8) | 2.8           |
| P                                               | <0.001          | <0.001      | <0.001      | <0.001      |             |               |

Figure 2. Trends in inflation-adjusted hospital charges per admission and aggregated national bill associated with unruptured aneurysms from 1997 to 2006. Whereas the per-hospitalization charge associated with unruptured aneurysms increased by 60%, the national bill increased by >200%.

Figure 3. Trends in aggregate hospital charges for endovascular and surgical treatment of unruptured aneurysms from 2003 to 2006. Aggregated charges for surgical treatment increased by 32.3%, whereas charges secondary to endovascular treatment increased by 156.8%.
2003 and 2006, the number of endovascular treatments increased by 104.5%. Coiling surpassed clipping as the more popular treatment modality in 2004.

Corresponding to this rise in admissions for treatment of UIAs, the national annual aggregate charge associated with UIAs increased by 33.4% from 2003 to 2006. Despite costing less per hospitalization, endovascular treatment generated a larger aggregate charge than surgical clipping due to a greater number of admissions. The total charges generated by endovascular procedures increased by 156.8% during the study period. Therefore, although endovascular treatment was less costly than surgical clipping on a per-hospitalization basis, its use in an increasingly larger population of patients was responsible for the increasing national charges for UIA treatment.

Previous studies of the economics of aneurysm treatment have focused on comparison of charges associated with clipping versus coiling on a per-case basis.2–11,24–27 Several analyses of UIAs treatments found surgical clipping to be more economically favorable despite significantly longer hospitalizations. The higher procedural costs of endovascular clipping overshadowed savings associated with shorter hospitalizations.24,25 Our findings of higher hospitalization charges associated with clipping for UIAs were consistent with results from Andaluz et al and Hoh et al in their analyses of NIS data. However, by examining the national aggregate charges, we found that despite having lower mean charges, coiling was responsible for a greater proportion of the national economic burden associated with UIA treatment.

Our analysis confirmed the relative safety of endovascular treatment compared with microsurgical clipping of UIA. Patients hospitalized for endovascular procedures had shorter LOS and higher rates of routine discharges than their surgical counterparts. However, procedural selection may not be the only reason for this apparent improvement. Without detailed clinical information, other contributing factors cannot be elucidated. Overall, the rates of in-hospital mortality steadily decreased during the study period. These rates were not adjusted for LOS or other potentially confounding factors, and no long-term outcome data were available. Likewise, the durability of endovascular treatment versus microsurgical clipping was not addressed.

The limitations of the NIS and similar databases have been addressed previously.28–30 Although the NIS database provided a robust repository of admitting diagnoses and immediate discharge status, reporting inconsistencies and lack of sophisticated demographic and clinical details were significant drawbacks. Secondary diagnoses were identified by crossreference with additional International Classification of Diseases, 9th Revision codes, but this only suggested associations and did not establish causations. The specifics of aneurysmal anatomy, location, and other risk factors were absent and the reasons for admission could not be ascertained. The NIS database may be queried geographically, but it was insufficient to study the regionalization and concentration of specialty care in detail.

These shortcomings of the NIS were balanced by advantages of using large-scale databases such as avoiding selection bias and studying trends on a national level. Although the NIS database could not elucidate the particular causes in the rise of UIA treatment, it brought to focus the national effects of current treatment strategies. In the current healthcare climate, the understanding of the socioeconomic impact of various treatment modalities is imperative, if not advantageous, for the practicing neurosurgeon.

Conclusions

Despite recent studies suggesting a low risk of rupture of UIAs, data from this study suggest an increasing trend of treatment for UIAs in the United States. Furthermore, endovascular intervention is now the major driving force behind the increasing overall national charges. The socioeconomic impact of these trends warrants discussion and debate.

Disclosures

None.

References

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