Technological Advances in the Management of Unruptured Intracranial Aneurysms Fail to Improve Outcome in New York State

Brad E. Zacharia, MD; Andrew F. Ducruet, MD; Zachary L. Hickman, MD; Bartosz T. Grobelny, MD; Neeraj Badjatia, MD; Stephan A. Mayer, MD; Mitchell F. Berman, MD; Robert A. Solomon, MD; E. Sander Connolly, Jr, MD

Background and Purpose—Unruptured intracranial aneurysms (UIAs) are being identified more frequently and endovascular coil embolization has become an increasingly popular treatment modality. Our study evaluates patient outcomes with changing patterns of treatment of UIA.

Methods—We conducted a retrospective, longitudinal cohort study of 3132 hospital discharges for UIA identified from the New York Statewide Database (SPARCS) in 2005 to 2007 and 2200 discharges from 1995 to 2000. The rates of endovascular coiling and surgical clipping were examined along with hospital variables and discharge outcome. Anatomic specifics of UIA were unavailable for analysis.

Results—The case rate for treatment of UIA doubled from 1.59 (1995 to 2000) to 3.45 per 100 000 (2005 to 2007, P<0.0001) and increased in the case treatment rate for coiling of UIA (0.36 versus 1.98 per 100 000, P<0.0001). Compared with the old epoch, there were more UIAs clipped at high-volume centers (55.8% versus 78.8%, P<0.0001) but fewer coiled at high-volume centers (94.8% versus 84.5%, P<0.0001) in the new epoch. Coiling and increasing hospital UIA treatment volume were associated with good discharge outcome. However, there was no significant improvement in overall good outcome when comparing 1995 to 2000 versus 2005 to 2007 (79% versus 81%, P=0.168) and a worsening of good outcomes for clipping (76.3% versus 71.7%, P=0.0132).

Conclusions—Despite coiling being associated with an increased incidence of good outcome relative to clipping of UIA, the increase in coiling has failed to improve overall patient outcome. The shift in coiling venue from high-volume centers to low-volume centers and decreasing microsurgical volume accompanied by a worsening in microsurgical results contribute to this. This argues for greater centralization of care. (Stroke. 2011;42:2844-2849.)

Key Words: clipping ■ coiling ■ interventional neuroradiology ■ intracranial aneurysm ■ neurosurgery

Unruptured intracranial aneurysms (UIAs) are relatively common lesions, occurring in approximately 2% of the general population, suggesting that >15 million individuals are affected in the United States alone.1–3 With increased use of advanced brain imaging, incidental UIAs are being diagnosed with greater frequency.2 As such, an understanding of evolving treatment paradigms for UIA is critical. In light of 2002, 2005, and 2009 results from the International Subarachnoid Aneurysm Trial (ISAT), a prospective, multicenter, randomized study, major changes in treatment patterns have occurred, favoring endovascular coil over surgical clipping for ruptured aneurysms amenable to both treatment modalities.4–6 Although the ISAT results are not readily extrapolated to patients with UIA and no similar prospective, randomized trial has been performed for UIA, multiple studies demonstrate that an increasing percentage of patients are undergoing endovascular coil embolization for the treatment of UIA.7–16 Many of these studies have also demonstrated improved outcomes in those patients undergoing endovascular versus surgical management. Nevertheless, overall outcome for UIA treatment remains largely unchanged.7

Given our experience at a high-volume cerebrovascular center, we hypothesize that a decentralization of endovascular treatment of cerebral aneurysms to low-volume centers with relatively less procedural experience and lack of comprehensive cerebrovascular programs may account for the lack of improvement in observed outcomes despite an increase in endovascular management. To this end, we examined patient- and hospital-related factors after treatment of UIA using 8 years of New York State hospital discharge data.
Methods

We reviewed data obtained from the New York Statewide Planning And Research Cooperative System (SPARCS). SPARCS is a major management tool assisting hospitals, agencies, and healthcare organizations with decision-making in relation to financial planning and monitoring of inpatient and ambulatory surgery services and costs in New York State. SPARCS currently collects patient-level details for every hospital discharge, ambulatory surgery patient, and emergency department admission in New York State as coded from admission and billing records. This study was approved by the Institutional Review Board of Columbia University Medical Center.

We used 1995 to 2000 and 2005 to 2007 SPARCS data to study treatment trends for UIA and ruptured intracranial aneurysms before and after the 2002 publication of the original ISAT study, although the majority of our study focuses on UIA. The database records diagnoses and procedures according to the International Classification of Diseases, 9th Revision and provides patient demographic and discharge information. Using an accepted search strategy, the following International Classification of Diseases, 9th Revision–Clinical Modification codes were used for data query: 430 (subarachnoid hemorrhage), 437.3 (unruptured cerebral aneurysm), 39.51 (clipping of cerebral aneurysm), and 39.72 (endovascular repair or occlusion of head and neck vessels). We analyzed solely the primary procedure to parallel an intention-to-treat analysis. Temporal differences in discharge coding demanded a slightly altered initial search strategy in the data set from 1995 to 2000, which has been published previously by our group.10 The analysis involved patient demographic variables (gender, race, age, ethnicity) and hospital-specific characteristics, for example, admission source, percent endovascular, and treatment volume. New York State Census data were used to calculate case rates for UIA treatment.

Statistical Analysis

Outcome measures included in-hospital death and discharge outcome. Only discharge to home was considered a good outcome given the predominantly elective nature of surgical treatment and minimal premorbid disability. Mortality in all cases was defined as in-hospital death. For each hospital treating unruptured cerebral aneurysms, we calculated the procedural volume separately for surgical clipping and endovascular therapy of UIA during the respective time period. For univariate analysis, we dichotomized hospitals by case volume with the 10 highest volume hospitals classified as high volume, whereas case volume was used in a continuous manner for multivariate analysis. The hospital-specific propensity to coil was calculated as a percentage of UIA treated by endovascular coiling for each center. Categorical variables and dichotomous outcomes were evaluated with either the Pearson χ² test or Fisher exact test, and continuous variables and outcomes were compared using a Student t test. Wilcoxon rank sum was used for nonparametric data when appropriate. Generalized estimating equations with independent correlation matrix structures, good outcome as the dependent variable, and hospital as the subject variable were used to allow observations to be clustered by hospital. This is a standard statistical technique used when other variables and characteristics of treatment that affect outcome are thought to exist and expected to cluster within prede-termined groups.15

All variables for treated patients from 2005 to 2007 (n = 2004) with P<0.25 in univariate analysis entered into a multiple logistic regression model along with those felt to be clinically relevant, including hospital-related variables, age, gender, and race. Using forward stepwise multiple logistic regression, a final model was constructed leaving only variables achieving a statistical significance of P<0.05. Interactions were tested for all clinically significant variables in the multiple logistic regression model. Similar analysis was performed for the group of patients treated 1995 to 2000, but our study focused on the most recent epoch.

A P value of <0.05 was considered significant for all analyses. Trend data, statistical analyses, and linear regression were performed using commercially available software (JMP, SAS Inc, Version 7).

Results

During the 6-year period from 1995 to 2000, there were 5656 patients and from 2005 to 2007 there were 4056 patients who underwent surgical and or endovascular treatment with a primary diagnosis of either a ruptured or unruptured intracra-nial aneurysm. When corrected for population changes, the case rate for treatment from 1995 to 2000 was 5.04 per 100 000 compared with 7.02 per 100 000 in 2005 to 2007. In the old epoch, 4917 patients underwent surgical clipping versus 1894 in the most recent epoch for case treatment rates of 4.38 and 3.27 per 100 000, respectively. In the old epoch, 739 patients underwent endovascular coiling versus 2162 in the most recent epoch representing an almost 6-fold increase in the case treatment rate from 0.66 to 3.74 per 100 000 (Figure 1A). The per annum rate of overall surgical clipping (ruptured and unruptured) has decreased substantially from 819.5 cases in the old epoch to 631.3 in the new epoch.

When looking specifically at those patients with UIA, we see similar trends in case treatment rates between the 2 epochs with an overall case treatment rate of 1.79 per 100 000 in the old epoch compared with 3.45 per 100 000 in the new epoch (Figure 1B). Of those patients definitively treated for UIA, 57% underwent endovascular coiling in the most recent epoch versus 20.3% in the prior epoch (P<0.0001; Figure 1C). Compared with the old epoch, there were more UIAs being surgically clipped in high-volume centers in the new epoch (55.8% versus 78.8%, P<0.0001) but fewer were undergoing endovascular coiling in high-volume centers (94.8% versus 84.5%, P<0.0001; Figure 2A). This was a trend that continued over the most current years 2005 to 2007 (89.8%, 81.5%, 80.9%, P=0.0006). The percent good outcome after treatment of UIA, however, did not show any substantial improvement between the 2 epochs (79% versus 81%, P=0.168; Figure 2B). When directly comparing clipping, however, we note a decrease in the percent of good outcomes (76.3% versus 71.7%, P=0.0132) between the old and new epoch, whereas the outcome for coiling remained relatively stable (89.7% versus 87.7%, P=nonsignificant; Figure 2B).

We then focused attention on the most recent epoch (2005 to 2007) whose characteristics are shown in Table 1. No significant interactions were found. Those patients undergoing surgical clipping were younger (53.4 versus 56.1 years, P<0.0001), had a greater percentage of adverse outcomes (28.3% versus 12.3%, P<0.0001), and had longer lengths of stay (6.7 versus 3.6 days, P<0.0001) than those undergoing coiling (Table 2). When comparing patients with UIAs treated at high versus low-volume centers, we noted significant differences in mean age (55.4 versus 53.1 day, P=0.0027), percent adverse outcome (17.4% versus 27%, P<0.0001), length of stay (4.6 versus 6.6 days, P<0.0001), and the percent definitively treated through endovascular procedures (59.3% versus 47.5%, P<0.0001; Table 3). We entered all clinically relevant patient and hospital variables into a step-forward multivariate logistic regression model (Table 4). We identified 3 independent predictors of good discharge outcome following treatment of UIA: white race (OR, 1.67; P=0.0007), treatment volume of the hospital (OR, 1.04 per additional 10 cases; P<0.0001), and definitive
treatment by endovascular coiling (OR, 3.94; \(P<0.0001\)). The association of higher treatment volume with good outcome is similar in the old epoch. Older age (OR 0.61 per 10-year increase in age; \(P<0.0001\)) and direct admission from the emergency room (OR, 0.41; \(P=0.0004\)) were associated with a propensity toward worse outcome in our model. Surprisingly, as percent of patients with UIAs treated by endovascular coiling increased at a given center, the risk for poor outcome significantly increased (OR, 0.92 per 10% additional coiling; \(P=0.05\)). Analysis was repeated for clipping and coiling cohorts separately and yielded similar results (Table 4).

Additional analysis is included in the supplemental (http://stroke.ahajournals.org).

**Discussion**

Although Food and Drug Administration-approved since 1995, the use of endovascular coiling truly began to blossom within the past decade after the initial publication of ISAT in 2002 and with population-based data indicating improved outcomes with endovascular management of UIA. Nevertheless, there remains significant clinical debate regarding the ideal treatment modality for individual patients with both aneurysmal subarachnoid hemorrhage and UIA. Specific clinical and aneurysm characteristics may clearly indicate when a patient is best served by a given treatment modality, but often there will be equipoise in benefit between surgical and endovascular treatment. In these instances, treatment decisions are frequently based on operator availability and local expertise. Thus, centers able to offer a comprehensive neurovascular team approach with both surgical and endovascular capabilities are best equipped to make treatment decisions based primarily on patient need.

In the present study, we reviewed all hospital discharges from New York State between 2005 and 2007 involving treatment for UIAs and made comparisons with data from...
Since 1995, there has been a 6-fold increase in the treatment of UIAs driven almost completely by coiling (Figure 1B). Coil embolization of unruptured cerebral aneurysms has been the most significant advancement in the treatment of these lesions since the advent of the operating microscope, yet in the 15 years after its introduction, cumulative procedural morbidity after UIA treatment has remained unchanged (Figure 2B). As the technology driving endovascular coiling has been refined and training programs formalized, we would have expected an improvement in coiling outcomes, yet they have remained stagnant over the past 10 years. Conversely, although one would anticipate stable outcomes for surgical clipping, we have demonstrated a significant decrement in outcome over this time period (Figure 2B).

A possible explanation for the lack of improved outcomes with greater use of coiling and coiling’s technical refinements over time might be the fact that increasing numbers of unruptured aneurysms are being coiled by less experienced teams, thereby negating the advantages of this increasingly sophisticated technology (Figure 2A). Although other studies have investigated the role of regionalization in aneurysm management and demonstrated improved outcomes at higher volume centers for both open and endovascular management.
of cerebral aneurysm treatment,\textsuperscript{10,13,16,18,19} none has shown the inverse regionalization trend that we observe with this new technology. In the authors’ opinion, with the perceived ease of coiling of UIAs and attendant socioeconomic pressures, endovascular technology may continue to spread from major academic centers to smaller community hospitals ill equipped to provide comprehensive cerebrovascular care, which may lead to inferior outcomes not only due to technical shortcomings, but errors in judgment regarding who to treat and how to treat them.

Given the more than doubling of the case rate for treatment of UIAs over the past 10 years, however, the stagnation in patient outcomes may also be, in part, an epiphenomenon of expanding treatment indications. For instance, an increase in the treatment of smaller previously uncoilable aneurysms may be driving the increase in UIA treatment. Expanding indications to lesions where safety is not well established may also result in a wash-out of a possible inherent superiority of endovascular coiling. Furthermore, because a greater percentage of aneurysm cases are being treated endovascularly, the complexity of cases treated by surgical clipping has likely increased substantially, yet case volume and ability to train open cerebrovascular surgeons has suffered. Although endovascular treatment has become increasingly decentralized, surgical management of unruptured aneurysms occurs increasingly at high-volume centers, but these same centers exhibit erosion in their overall treatment volume and expertise (Figure 1A).

All analyses are generated from discharge data recorded solely from New York State hospitals, and as such, the validity of conclusions drawn from this study rests on the accuracy of case-defining diagnostic codes. Numerous studies have pointed out the limitation of classification systems such as the International Classification of Diseases, 9th Revision.\textsuperscript{20,21} For instance, diagnostic codes may not fully encompass the condition under study or the condition may be spread across multiple diagnostic codes. Details about aneurysm size and location that might explain the rationale for treatment or outcome are inherently lost. Only discharge disposition (used as a surrogate for outcome) and in-hospital mortality were available; thus, we were only able to track events occurring up until the time of discharge. Thus, it is possible, as has been previously demonstrated, that endovascular treatment may be associated with an increased risk of recanalization and possibly aneurysmal rupture, an event that would not be accounted for in our study.\textsuperscript{22} Additionally, surgically clipped patients may recover more slowly than patients undergoing endovascular interventions and this would skew the outcome data in favor of coiling. Regardless, although discharge to home does not always indicate a good outcome, discharge status has been shown to correlate well with modified Rankin Scale score\textsuperscript{23} and provides important insight into differences within and between treatment modalities. In addition, it is impossible to control for all confounding variables. Clipped patients and those treated at a higher-volume centers may have more comorbid disease, larger or more complicated aneurysms, or more acute symptoms than those treated endovascularly or vice versa. Additionally, we could not account for number of aneurysms treated by each surgeon per year in each center, which may confound our analysis of high-volume centers. We included all available potential risk factors for poor outcome in our multivariate analysis of high-volume centers. We included all available potential risk factors for poor outcome in our multivariate models, including age, gender, race, ethnicity, and admission source, but a myriad of other factors are not available in the SPARCS data set, namely aneurysm location and morphology.

### Table 4. Multivariate Analysis for Good Outcome After Treatment of UIA From 2005 to 2007

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Clip</th>
<th>Coil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(P)</td>
<td>OR*</td>
<td>(P)</td>
</tr>
<tr>
<td>Age\textsuperscript{†}</td>
<td>(&lt;0.0001)</td>
<td>0.61</td>
<td>(&lt;0.0001)</td>
</tr>
<tr>
<td>Race (white versus all other races)</td>
<td>0.0007</td>
<td>1.67</td>
<td>0.0004</td>
</tr>
<tr>
<td>Treatment volume\textsuperscript{‡}</td>
<td>(&lt;0.0001)</td>
<td>1.04</td>
<td>(&lt;0.0001)</td>
</tr>
<tr>
<td>Coil versus clip</td>
<td>(&lt;0.0001)</td>
<td>3.94</td>
<td>N/A</td>
</tr>
<tr>
<td>Percent endovascular coiling\textsuperscript{§}</td>
<td>0.05</td>
<td>0.92</td>
<td>N/A</td>
</tr>
<tr>
<td>Admission from emergency department</td>
<td>0.0004</td>
<td>0.41</td>
<td>0.0306</td>
</tr>
</tbody>
</table>

UIA indicates unruptured intracranial aneurysm; N/A, not applicable; NS, nonsignificant.

*OR of good discharge outcome.

\(†\) Per 10-y increase in age.

\(‡\) Per additional 10% coiling.

\(§\) Per additional 10% coiling.

Conclusions

Since 1995, in the absence of any published data expanding indications, there has been a doubling the population-adjusted treatment rate for UIA, almost completely driven by a 5-fold increase in the rate of endovascular coiling. Our data, although limited by lack of anatomic specifics of the treated UIA, confirm that endovascular coiling is associated with an increased incidence of good outcome relative to microsurgical clipping and the failure of the evolution in therapeutic practice to improve overall patient outcome. Factors contributing to this failure appear to be the dramatic shift in coiling venue from high-volume centers to low-volume centers where outcomes are inferior, and decreasing microsurgical volume, even in the busiest centers, accompanied by an overall worsening in microsurgical results. Both factors argue for greater centralization of care rather than further technological advances.
Acknowledgments
Emilia Bagiella, PhD, Department of Biostatistics, Mailman School of Public Health, Columbia University, assisted with the statistical analyses and received financial compensation.

Sources of Funding
This study was internally funded by the Columbia University Department of Neurological Surgery.

Disclosures
None.

References
Technological Advances in the Management of Unruptured Intracranial Aneurysms Fail to Improve Outcome in New York State

Stroke. 2011;42:2844-2849; originally published online August 18, 2011;
doi: 10.1161/STROKEAHA.111.619767

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/42/10/2844

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/