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ORIGINAL RESEARCH

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BACKGROUND AND PURPOSE: With advances in neuroimaging, unruptured cerebral aneurysms are being diagnosed more frequently. Until 1995, surgical clipping of the aneurysm was the only treatment available. Since then, a less invasive endovascular technique has been found effective in a trial of ruptured aneurysms. No efficacy studies comparing the 2 procedures for unruptured aneurysms exist to guide clinical decisions. The objective of this study was to assess effectiveness and outcomes of endovascular versus neurosurgical treatment for unruptured intracranial aneurysms.

METHODS: This was a retrospective cohort study, using data collected over a 1-year time interval (between 1998 and 2000), from 429 hospitals, in 18 states, and representing 58% of the US population. A total of 2535 treated, unruptured cerebral aneurysm cases were evaluated. The measurements used were effectiveness as measured by hospital discharge outcomes: 1) mortality (in-hospital death), 2) adverse outcomes (death or discharge to a rehabilitation or nursing facility), 3) length of stay, and 4) hospital charges. Univariate analyses compared endovascular versus neurosurgical discharge outcomes. Multivariable models were adjusted for age, sex, region, Medicaid insurance status, year, hospital case volume, comorbidity score, and admission source.

RESULTS: Endovascular treatment was associated with fewer adverse outcomes (6.6% versus 13.2%), decreased mortality (0.9% versus 2.5%), shorter lengths of stay (4.5 versus 7.4 days), and lower hospital charges ($42,044 versus $47,567) compared with neurosurgical treatment ($P < .05$). After multivariable adjustment, neurosurgical cases had 70% greater odds of an adverse outcome, 30% increased hospital charges, and 80% longer length of stay compared with endovascular cases ($P < .05$).

CONCLUSIONS: The current analysis indicates that endovascular therapy is associated with significantly less morbidity, less mortality, and decreased hospital resource use at discharge, compared with conventional neurosurgical treatment for all unruptured aneurysms. Endovascular therapy, as a treatment alternative to surgical clipping, should be offered as a viable therapeutic option for all patients considering treatment of an unruptured cerebral aneurysm.

Intracranial aneurysms are fairly common in the general population. It is estimated that between 0.4% and 6% of people may harbor a cerebral aneurysm.[1-4] Although most intracranial aneurysms go undetected, acute rupture resulting in subarachnoid hemorrhage can be a devastating consequence associated with 30%–67% mortality and 15%–30% morbidity.[2,5,6] Recent advances in noninvasive imaging including CT, MR imaging, CT angiography (CTA), and MR angiography (MRA) have increased clinicians' ability to diagnose patients with this condition.

Clinical management of unruptured aneurysm patients is a current topic of debate.[7] Preventative treatment for unruptured aneurysms, such as neurosurgical clipping or endovascular coiling, may be recommended depending upon the patient's family history, and the aneurysm size, morphology, and location.[8-11] Before 1990, endovascular treatment of aneurysms included use of detachable balloons for parent vessel occlusion, as well as direct balloon occlusion in selected cases. However, with the development of newer detachable coil devices in 1990, and intravascular stents in recent years, the endovascular treatment option has expanded the range of both ruptured and unruptured cerebral aneurysm cases that can now be effectively treated.[2] In 2002, a prospective, multicenter, randomized study (International Subarachnoid Aneurysm Trial) was prematurely halted after concluding that for 2143 patients presenting with a ruptured cerebral aneurysm, those treated by endovascular coiling had a 22.6% relative risk reduction in death or severe disability at 1 year compared with surgical clipping.[12] This study has affected patient treatment patterns, increasing referral to endovascular coiling over surgical clipping if the aneurysm is amenable to treatment by either technique.

No prospective, randomized trial comparing these treatments for unruptured intracranial aneurysms has yet been performed.[7] This article evaluates the effectiveness and assesses outcomes of endovascular coiling versus neurosurgical treatment in a large retrospective cohort of unruptured aneurysm cases.

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Methods

Data Source

A data base was created from publicly available, nonfederal hospital records in 18 states: California, Colorado, Florida, Illinois, Iowa, Maryland, Massachusetts, Nevada, New Hampshire, New Jersey, New York, Oregon, Pennsylvania, Texas, Utah, Vermont, Virginia, and Wisconsin (Health Share, Calif. Office of State Data, Fla. Data and Planning Office). States reflect 1999 hospitalizations, except New Hampshire and New Jersey (1998), and Colorado, Iowa, and Nevada (2000). The assembled data reside with the Health Economics and Outcomes Research Group of Boston Scientific Corporation (B.J.L.) and is available to qualified outcomes researchers for the purposes of methodologic evaluation.

Case Selection

International Classification of Diseases, 9th Rev., Clinical Modification (ICD-9-CM) diagnosis and procedure codes, which have been validated in other studies, were used to select discharge records.[13] A principal diagnosis code 437.3 (unruptured cerebral aneurysm) combined with a treatment procedure code identified study cases. Procedure codes 39.52 (other repair of aneurysm) or 38.81 (other surgical occlusion of intracranial vessels) defined an endovascular case. Previously reported methods were used to confirm endovascular procedural coding.[14] Neurosurgical cases were defined by procedure codes 39.51 (clipping of aneurysm), 38.31 (suture of artery), 38.61 (other excision of intracranial vessels), or 01.24 (other craniotomy).

To evaluate distinct treatment outcomes, records identifying both neurosurgical and endovascular procedures during the same admission were excluded. Ruptured aneurysms (ICD-9-CM 430.0) were also excluded, to eliminate potential confounding effects on clinical and neurologic outcomes at discharge.[14] Validity of the data handling procedures was confirmed by examination of discharge cases at one of the health centers, Johns Hopkins University Hospital, for the time period under investigation (M.T.T., D.F.H.). As a further check for data base agreement and accuracy of data assembled from multiple state data sources, the number of Medicare cases identified in the study data was compared with the number of cases identified by using the same selection algorithm in a data base of 100% Medicare inpatient hospitalizations (B.J.L.).

Outcome and Variable Definitions

Four main outcome measures were evaluated in this analysis: 1) adverse outcomes, 2) in-hospital death, 3) length of stay (LOS), and 4) hospital charges. The discharge status of "expired" defined an in-hospital death and was evaluated separately as well as part of the adverse outcome definition. Adverse outcome was defined as an in-hospital death, discharge to a rehabilitation center, or discharge to a nursing home for patients not previously admitted from a nursing facility. This definition has been used in other aneurysm studies to indicate probable procedure morbidity. Lengths of stay and total hospital charges were summary fields on each record. All charges were adjusted for inflation to the year 2000 using the Consumer Price Index for Inpatient Hospital Services.[15]

Each patient was assigned a census region based on the treating hospital's address.[16] To allow for a volume adjustment in multivariable models, patients were assigned to statistical quartiles based on their treating institution's aneurysm case volume, defined as total number of treated unruptured aneurysms and all ruptured aneurysm admissions. A race/ethnicity variable was not available in all states and insurance status (Medicaid or other) was used as a proxy for a socioeconomic measure.[17-19]

Study Sample

From the study data base, 2619 unruptured aneurysm cases treated with neurosurgical or endovascular methods were identified. Records with missing values were excluded as follows: admission source ($n = 36$), discharge source ($n = 1$), insurance status ($n = 30$), sex ($n = 5$), hospital name ($n = 12$).

Statistical Analysis

Endovascular and neurosurgical cases were compared with univariate and multivariable analyses using SAS statistical software (SAS Institute, Cary, NC). Categoric variables and dichotomous outcomes were evaluated with either the Pearson χ^2 test or Fisher Exact test, and continuous variables and outcomes were compared using a Student *t* test. Lengths of stay and hospital charges were natural-log transformed to normalize values.

For the purposes of risk adjustment, the Elixhauser Comorbidity Index, which was developed for use with administrative data, identified coexisting conditions present during the treatment admission.[20] A score was calculated for each patient summing the number of coexisting conditions weighted according to their relative effects on the outcome measures. Standard derivation and validation procedures were performed. Codes that could indicate procedural complications, rather than existing conditions, were excluded from the index and evaluated separately.[21] These included: headache (784.0), cranial nerve palsy (378.51–378.52, 378.54), monocular vision loss (369.6–369.8), aphasia (784.3), hemiplegia/hemiparesis (342.0–342.92), hydrocephalus (331.3–331.4), ventriculostomy (02.2), ventriculoperitoneal shunt surgery (02.34), cerebral artery occlusion (434.0–434.91), postoperative neurologic complications (997.00–997.09), postoperative cardiac complications (997.1), tracheostomy (31.1–31.29), endotracheal tube (96.04), mechanical ventilation (96.70–96.72), postoperative respiratory insufficiency (518.5), gastrostomy (43.11–43.19), hematoma complication (998.1–998.13), packed red blood cell transfusion (99.04), physical/occupational therapy (93.01–93.59, 93.75, 93.83), and other surgical complications/postoperative infection (99.72–99.75, 998.2, 998.59, 998.0).

For multivariable analyses, generalized estimating equations (GEE) were used to evaluate the outcome measures with adjustment for age, sex, region, Medicaid status, year of treatment, volume quartile, comorbidity score, and admission source.[22] Compound symmetry, or equal correlation between within-hospital observations, was chosen as the initial covariance structure. The GEE models produced estimates of ratios, confidence intervals, and *P* values for the outcome measures. Odds ratios (ORs) are reported for adverse outcome and in-hospital death. Because natural log values were used to normalize length of stay and hospital charge data, effect measures reported are the ratio of geometric means.

Results

A total of 2535 treated unruptured cerebral aneurysm cases, in 429 hospitals, were identified. Seventy-four percent (1881) were surgically treated. Patients identified in the study were a mean of 54 years of age, predominantly female, and predominantly admitted from home (Table 1). There were more men in the endovascular group compared with the neurosurgical group ($P < .05$). The admission source ($P < .0001$) differed significantly between the treatment groups. Compared with endovascular cases, neurosurgical cases were more likely to be admitted through the emergency department (ED) (12% versus 7%), and less likely to be admitted from home or as a

Table 1: Characteristics of unruptured aneurysm cases				
	Total $n = 2535$	Neurosurgical $n = 1881$	Endovascular $n = 654$	P*
Mean Age (SD), years	53.9 (12.9)	53.8 (12.2)	53.9 (15.0)	.83
Male (%)	26	25	31	<.05
Medicaid (%)	9	8	9	.66
Admission Source (%)				<.0001
Home	84	83	88	
Emergency Department	11	13	6	
Transfer	5	4	6	
Region (%)				<.05
West	22	20	27	
South	33	33	33	
Midwest	11	12	11	
New England	8	8	7	
Mid Atlantic	26	27	22	

* Pearson χ^2 test and t test used to evaluate statistical significance for categoric variables and continuous variables, respectively, comparing neurosurgical and endovascular groups. Significant P values are groups into 4 categories: <.05, <.01, <.001, <.0001.

Table 2: Potential markers of symptoms, related conditions, and procedural complications				
Diagnosis or Procedure Category	Total $n = 2535$	Neurosurgical $n = 1881$	Endovascular $n = 654$	P*
Postop neurological complications	6.8	7.4 (140)	4.7 (31)	<.05†
Cranial nerve palsy (IIIrd, VIth)	6.0	7.0 (132)	2.9 (19)	<.0001
Mechanical ventilation	5.0	5.6 (106)	3.1 (20)	<.01†
Physical or occupational therapy	5.0	6.0 (113)	2.1 (14)	<.0001
Hemiplegia or hemiparesis	4.3	4.0 (76)	5.2 (34)	.21†
Occlusion of cerebral artery	3.8	4.2 (79)	2.8 (18)	.10†
Packed red blood cell transfusion	3.8	4.5 (85)	1.7 (11)	<.01
Other complication/postop infection	3.8	4.5 (85)	1.5 (10)	<.001†
Endotracheal tube	3.5	3.9 (74)	2.3 (15)	<.05†
Ventriculostomy	2.9	3.4 (63)	1.7 (11)	<.05†
Hematoma complication	2.8	2.7 (50)	3.2 (21)	.46
Postop respiratory insufficiency	2.5	2.8 (52)	1.8 (12)	.19†
Aphasia	2.1	2.2 (42)	1.7 (11)	.70
Hydrocephalus	2.1	1.9 (36)	2.5 (16)	0.41†
Gastrostomy	2.0	2.3 (44)	1.1 (7)	<.05
Headache	1.6	1.5 (29)	1.7 (11)	.80
Tracheostomy	1.5	1.6 (30)	1.1 (7)	.34
Postop cardiac complications	0.8	0.9 (16)	0.5 (3)	.32
Monocular vision loss	0.5	0.5 (10)	0.5 (3)	.82
Ventriculoperitoneal shunting	0.5	0.5 (9)	0.5 (3)	.95

Note:—Values are presented as % (n).
* Pearson χ^2 test used to evaluate differences between neurosurgical and endovascular groups. Significant P values are groups into 4 categories: <.05, <.01, <.001, <.0001.
† Conditions significantly (p <0.0001) more likely to occur in death cases compared with nondeaths

transfer case (87% versus 93%). There were also statistical treatment variations based on the treating institution's geographic location ($P < .05$).

The mean comorbidity scores, reflecting existing conditions, for the neurovascular and endovascular groups were not significantly different ($P > .73$) for any study outcome. The most frequent comorbid conditions on discharge records were hypertension (39%), chronic pulmonary disease (11%), and arrhythmia (5.4%). Neurosurgical cases were more likely than endovascular cases to have deficiency anemia (3.6% versus 2.0%, $P < .05$), but this condition was not related to either death or adverse outcome. Conditions associated with adverse outcomes included hypertension, congestive heart failure, peripheral vascular disease, and arrhythmia ($P < .05$). Only coagulopathy was associated with an in-hospital death ($P < .05$).

Diagnoses and procedures excluded from the comorbidity index that could potentially indicate a condition or procedure related to the treatment outcomes are displayed in Table 2. Compared with endovascular cases, neurosurgical cases were significantly ($P < .05$) more likely to have the following procedures or diagnoses: cranial nerve palsy, ventriculostomy, postoperative neurologic complications, endotracheal tube placed, mechanical ventilation, gastrostomy, packed red blood cell transfusion, other surgical complication or postoperative infection, and physical or occupational therapy.

Adverse outcome status was assigned to 11.5% of all treated unruptured aneurysms, including 2.1% procedural mortality at discharge (Table 3). The proportion of adverse outcomes was approximately double for neurosurgical cases compared with the endovascular-treated cases (13.2% versus 6.6%, $P < .0001$). The in-hospital neurosurgical mortality was more than twice the rate of endovascular mortality (2.5% versus 0.9%, $P < .05$). The length of stay for neurosurgical cases was significantly longer than for endovascular cases averaging 7.4 versus 4.5 days ($P < .0001$). Mean hospital charges were $5523 more for neurosurgical treatment than for endovascular treatment

Table 3: Univariate analysis of treatment outcomes	Total $n = 2535$	Neurosurgical $n = 1881$	Endovascular $n = 654$	P*
Overall				
Adverse outcomes (*n*)	11.5% (292)	13.2% (249)	6.6% (43)	<.0001
In-hospital death (*n*)	2.1% (53)	2.5% (47)	0.9% (6)	<.05
Length of stay†‡ (SD)	6.8 (6.2) days	7.4 (5.7) days	4.5 (4.7) days	<.0001
Hospital charges†¶ (SD)	$46,250 (36,470)	$47,567 (35,426)	$42,044 (37,286)	<.0001
Emergency department admissions only	$n = 274$	$n = 234$	$n = 40$	
Adverse outcomes (*n*)	16.8% (46)	18.4% (43)	7.5% (3)	.11§
In-hospital death (*n*)	5.5% (15)	6.4% (15)	0.0% (0)	.14§
Length of stay†‡ (SD)	10.4 (7.3) days	10.4 (6.5) days	10.6 (11.3) days	.07
Hospital charges†¶ (SD)	$60,161 (43,117)	$60,544 (41,687)	$57,840 (51,085)	.24
Non-emergency department admissions	$n = 2261$	$n = 1647$	$n = 614$	
Adverse outcome (*n*)	10.9% (246)	12.5% (206)	6.5% (40)	<.0001
In-hospital death (*n*)	1.7% (38)	1.9 % (32)	1.0% (6)	0.11
Length of stay†‡ (SD)	6.3 (5.7) days	7.0 (5.3) days	4.2 (4.2) days	<.0001
Hospital charges†¶ (SD)	$44,408 (34,842)	$45,554 (33,725)	$41,020 (36,128)	<.0001

* Pearson χ^2 test and Student *t* test used to evaluate statistical significance for categoric and continuous variable, respectively, comparing neurosurgical and endovascular groups, unless otherwise specified. Significant *P* values are grouped into 4 categories: <.05, <.01, <.001, <.0001.
† Natural log transformed variables then converted to original units. Values are mean (SD).
‡ $n = 2530$ due to nonreported length of stay, $n = 2256$ excluding emergency department cases, $n = 274$ ED cases.
§ Two-tailed Fisher Exact test used to compared neurosurgical and endovascular groups
¶ $n = 2109$ due to nonreported charges, $n = 1866$ excluding emergency department cases, $n = 243$ ED cases.

Table 4: Multivariable comparison of treatment outcomes

$n = 2535$	Ratio (95% CI)*	P*	Power (%)
Neurosurgical/Endovascular			
Adverse outcome	1.7 (1.2, 2.5)	<.05	82
In-hospital death	2.3 (0.97, 5.7)	.06	45
Length of stay†	1.8 (1.6, 2.0)	<.0001	100
Hospital charges†	1.3 (1.2, 1.5)	<.0001	97
Emergency department admissions only			
Adverse outcome‡	2.7 (0.8, 8.5)	.10	39
In-hospital death§			
Length of stay†	1.3 (0.9, 1.7)	.12	43
Hospital charges†	1.2 (0.9, 1.7)	.24	19
Excluding emergency department admissions			
Adverse outcome	1.6 (1.1, 2.4)	<.05	71
In-hospital death	2.0 (0.7, 5.8)	.18	26
Length of stay†	1.9 (1.7, 2.0)	<.0001	100
Hospital charges†	1.3 (1.2, 1.5)	<.0001	97

* Results are derived from generalized estimating equations and are adjusted for age, sex, admission source, region, year of treatment, insurance status, comorbidity score, and hospital treatment volume. Odds ratios are reported for dichotomous outcomes. Significant *P* values are grouped into 4 categories: <.05, <.01, <.001, <.0001.
† Natural log values of lengths of stay and hospital charges were used in models; results are ratio of geometric mean days and ratio of geometric mean dollars, respectively.
‡ Results are derived from generalized estimating equations and are adjusted for age, sex, admission source, region, insurance status, and hospital treatment volume.
§ Multivariable model not feasible due to zero deaths in the endovascular group.

($P < .0001$). Similar trends are reported for the group when stratified by ED admissions. When ED admissions were excluded from the analysis, the neurosurgical mortality rate decreased from 2.5% to 1.9%. With the exception of in-hospital death, all differences between the 2 types of treatments remained statistically significant when ED admissions were excluded.

Table 4 reports the adjusted ratios and confidence intervals comparing neurosurgical versus endovascular treatments in multivariable models. Power calculations, which indicate the level of confidence that a correct decision was made to reject the null hypothesis, are also reported. Neurosurgical cases had 70% greater odds of an adverse outcome compared with endovascular cases after adjustment for age, sex, Medicaid status, geographic region, year of treatment, comorbidity score, volume quartile, and admission source (OR = 1.7; 95% confidence interval [CI], 1.2, 2.5). After multivariable adjustment, neurosurgical treatment was associated with 2.3 times the odds of death of endovascular treatment (95% CI, 0.97, 5.7), though small numbers resulted in a low statistical power. The geometric mean length of stay was almost twice as long (OR = 1.8; 95% CI, 1.6, 2.0) and hospital charges were 30% higher (OR = 1.3; 95% CI, 1.2, 1.5) for neurosurgical treatments compared with endovascular treatments. Trends were similar for the analyses stratified by ED for all outcomes. Zero deaths in the endovascular group preclude multivariable comparison on this outcome in the emergency admission group.

Discussion

This is the first nationwide study to assess the effectiveness of endovascular and neurosurgical treatment for unruptured intracranial aneurysms at hospital discharge in a geographically diverse sample of community and academic medical centers. First, it has been shown that endovascular therapy was associated with significantly fewer adverse outcomes at discharge compared with neurosurgical treatment for unruptured cerebral aneurysms. Second, endovascular treated cases were less resource-intensive during the treatment hospitalization than neurosurgical cases, having significantly shorter lengths of stay and lower hospital charges. Third, surgical mortality was more than twice as high as endovascular mortality in multivariable analyses.

Both neurosurgical and endovascular treatment of intracranial aneurysms are associated with procedural risks and complications such as disability or death. The International Study of Unruptured Intracranial Aneurysms, a prospective study of 995 surgically treated patients, reported a 1-year neurosurgical mortality rate of 3.2% and a disability rate of 12%.[23] A meta-analysis of 2460 unruptured aneurysm cases in 61 publications between January 1966 and June 1996 reported a neurosurgical mortality rate of 2.6% and morbidity rate of 10.9%.[6] A more recent study of 3498 unruptured aneurysms treated with neurosurgical clipping from 1996 to 2000 reported in-hospital mortality at 2.1% and death or discharge other than home at 18.3%.[21] Our findings of a 2.5% mortality rate and a 13.2% adverse outcome rate in patients with a neurosurgically treated unruptured aneurysm are consistent with these published reports.

Comparative studies of neurosurgical versus endovascular treatment outcomes for unruptured aneurysms are limited to 2 retrospective cohorts.[14,24] In 2069 California patients treated from 1990 to 1998, there was significantly less morbidity (9.7% versus 25.4%), mortality (0.5% versus 3.5%), and resource use (7.1 versus 11.7 hospital days; \$37,000 versus \$63,000 hospital charges, $P < .01$) for those receiving endovascular coiling versus neurosurgical clipping treatment.[24] Likewise, in 2612 patients treated between 1994 and 1997 at 70 US academic medical centers, there were decreased adverse outcomes (10.6% versus 18.5%), procedural mortality (0.4% versus 2.3%), and hospital resource use (4.6 versus 9.6 hospital days; \$30,000 versus \$43,000 hospital charges) ($P < .04$).[14] Our results for 2535 cases, treated at 429 hospitals in 18 states, over a 1-year period are comparable with these prior studies (Table 3). Procedural mortality in the current study was <1% for endovascular treatment versus 2.5% for neurosurgical treatment.

Procedures and diagnoses related to postoperative complications give insight into the relative safety of these procedures and potential reasons for the differences observed in discharge outcomes. Neurosurgical cases received more surgical interventions, compared with cases treated with endovascular therapy (Table 2). For neurosurgical cases, the greater hospital resource use and more frequent adverse outcomes may be explained by the increased rates of postoperative complications and rehabilitation services. Examination of the secondary diagnoses associated with mortality also suggests the prominent association of postoperative complications with death. Diagnoses significantly ($P < .0001$) associated with the 53 total deaths in the study included postoperative neurologic complications (42%), occlusion of cerebral artery (23%), postoperative infections (23%), postoperative respiratory insufficiency (15%), and hydrocephalus (11%). Postoperative stroke was the most common diagnosis on mortality cases, present on 40% (21/53) of records.

ED admission may also indicate an acute case with confounding physiologic variability. From a clinical standpoint, patients admitted urgently tend to be more symptomatic, presenting with headache, pain, or focal neurologic signs. This study confirmed this observation: ED admissions were diagnosed with headache and cranial nerve palsy at triple the rate of non-ED admissions. These symptoms are more frequent with larger aneurysms adjacent to cranial nerves or eloquent brain regions, which may indicate risk for poorer treatment outcomes. Cases admitted through the ED also had triple the death rate (5.5% versus 1.7%) and 1.5 times the adverse outcome rate (16.8% versus 10.9%) of non-ED admissions. The small sample size for this analysis results in limited power for comparisons; thus, conclusions about which treatment has an advantage for ED admissions can be very limited. Our findings suggest that unruptured aneurysm patients presenting in an emergency room are a unique subgroup at higher risk for poor outcomes with either treatment.

Worldwide, it is estimated that more than 220,000 patients with intracranial aneurysms have now been treated with endovascular coiling techniques, at over 2000 medical centers, with approximately 3500–4000 patients currently treated per month, a figure that has steadily increased since 1990.[25] This study indicates that patients were treated with surgery (74%) in higher proportions than endovascular therapy (26%) during the time interval of this analysis. Patients admitted through the ED were even more frequently (85%) operated upon during the time of this study. However, with the emergence of new evidence that endovascular therapy may have a better overall outcome for patients with an unruptured cerebral aneurysm, a change of current practice patterns may be warranted.[7,12] A multidisciplinary approach to patient care may improve overall clinical outcome and patients should be completely informed about the option of endovascular coiling as a viable treatment option in all cases.[26]

Limitations

Retrospective studies, without the benefit of randomization, are subject to several biases, including selection bias. This study is therefore not as strong statistically as a well-designed, prospective, multicenter, randomized clinical trial, such as the data published from the ISAT study. Only discharge data after each respective treatment was analyzed, and longer term data were not available. It is possible that the more difficult and complex treatment cases were referred for endovascular therapy, or vice versa. ICD-9-CM coding cannot identify the size and location of cerebral aneurysms, and it cannot specify the exact timing of diagnosis during a patient admission. To address this limitation, multivariable models were used to adjust for available patient risk factors, including admission source, age, sex, geographic region, year of treatment, Medicaid insurance status, and comorbidity score.

It was not possible to identify procedural failures potentially related to operator experience, except via postoperative complication coding. Physician case volume was not available in the data base but has been shown to be correlated with hospital volume with similar effects on discharge outcomes.[21] Hospital volume, an institutional risk factor for poor outcomes, was adjusted by multivariable models.[21,27-30] Prospective, randomized trials comparing the 2 treatments may be necessary to evaluate clinical factors related to unruptured aneurysm outcomes that cannot be addressed in discharge data base analyses, such as long-term functional outcomes.

Conclusion

This is the first nationwide effectiveness study to have evaluated the treatment of unruptured intracranial aneurysms in a geographically diverse sample of 429 community and academic medical centers in a 1-year time period. The current analysis indicates that endovascular therapy is associated with significantly less morbidity, less mortality, and decreased hospital resource use at discharge, compared with conventional neurosurgical treatment for all unruptured aneurysms.

Efficacy studies, such as randomized clinical trials are a major factor in adopting a particular procedure or therapy; however, this evidence applies only to patients and hospitals with characteristics comparable with those of the trial participants. In contrast, effectiveness research, similar to the study reported here, has high external validity because it directly samples therapy as practiced in the field. Endovascular therapy, as a treatment alternative to surgical clipping, should be offered as a viable therapeutic option for all patients considering treatment of an unruptured cerebral aneurysm.

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