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Unruptured cerebral aneurysm clipping: the association of combined open and endovascular expertise with outcomes

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Abstract

Background—It is often questioned if one physician can conduct both open and endovascular techniques successfully and safely. We investigated the association of combined open and endovascular expertise with the outcomes of unruptured cerebral aneurysm clipping.

Methods—We performed a cohort study of 100% of Medicare fee-for-service claims data for elderly patients who underwent surgical clipping for unruptured cerebral aneurysms from 2007 to 2012. In order to control for confounding we used propensity score conditioning, and controlled for clustering at the physician level.

Results—During the study period, there were 3,247 patients, who underwent clipping for unruptured cerebral aneurysms, and met the inclusion criteria. Of these, 766 (23.6%) underwent treatment by hybrid neurosurgeons, and 2,481 (76.4%) by proceduralists who performed only clipping. Multivariable regression analysis with propensity score adjustment demonstrated lack of association of combined practice with 1-year postoperative mortality (OR, 0.81; 95% CI, 0.51–

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KB-conception and design, drafting the manuscript, study supervision

DG-data collection and analysis, revised manuscript

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1.28), discharge to rehabilitation (OR, 0.95; 95% CI, 0.72–1.25), LOS (adjusted difference 0.85 days; 95% CI, –0.31 to 2.00), or 30-day readmission rate (OR, 1.05; 95% CI, 0.80–1.39). Higher procedural volume was independently associated with improved outcomes.

Conclusions—In a cohort of Medicare patients with unruptured aneurysms, we did not demonstrate a difference in mortality, discharge to rehabilitation, or readmission rate between hybrid neurosurgeons and surgeons only performing clipping.

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Keywords

cerebral aneurysms; clipping; hybrid neurosurgeons; Medicare

INTRODUCTION

Cerebral aneurysms are a common cause of intracranial hemorrhage, stroke, and death.¹² Two treatment options are utilized in current practice.¹³ Surgical clipping involves a craniotomy and placement of a clip on the blood vessel to exclude the weakened area, whereas endovascular coiling is a minimally invasive angiographic technique achieving aneurysm obliteration from within the blood vessel.¹² Although initially endovascular coiling was performed almost exclusively by radiologists, there has been a growing trend of neurosurgeons undergoing training in both open and endovascular techniques.¹ This changing landscape is reflected in highly variable regional coiling rates, ranging from 35% in Modesto, CA, to 98.6% in Tacoma, WA,¹ secondary to the varying expertise and training of the respective providers. It is often questioned if one physician would be able to conduct both open and endovascular techniques successfully and safely. These considerations can affect referral patterns and patient choices.

However, limited literature exists on the impact of combined practices on the outcomes of cerebral aneurysm treatment. De Vries and Boogaarts published their personal retrospective series⁴ on the outcomes of clipping of ruptured cerebral aneurysms by two neurosurgeons, who performed both open and endovascular procedures. In their single center study, they did not use a comparison group, and did not employ multivariable techniques to control for confounding. Therefore their results cannot be generalized, or compared to those of proceduralists with expertise only in surgical clipping. No prior study has investigated the comparative effectiveness of the focus of a surgeons practice on the outcomes of unruptured cerebral aneurysm clipping.

We performed a cohort study of Medicare patients with unruptured cerebral aneurysms, investigating the association of combined open and endovascular expertise with the outcomes of surgical clipping in comparison to surgeons performing only clipping. The outcomes examined were 1-year mortality, 30-day readmission, length of stay, and discharge to a rehabilitation facility. We utilized a battery of approaches to control for confounding,

including regression adjustment, and propensity score adjustment, while controlling for clustering at the physician level.

METHODS

Data and cohort creation

This study was approved by the Dartmouth Committee for Protection of Human Subjects. The data was anonymized and de-identified prior to use and therefore no informed consent was required. We used 100% of Medicare Denominator file and corresponding Medicare inpatient and outpatient claims, Parts A and B, 2007–2012 (MedPAR, Carrier and Outpatient files) to select patients with unruptured cerebral aneurysm diagnosis. Aneurysm patients were identified based on one or more inpatient or outpatient diagnoses (*International Classification of Diseases, Ninth Revision* (ICD-9) diagnosis code 437.3) between 2007 and 2012. For cohort inclusion, patients were required to be (1) continuously enrolled in fee-for-service (FFS) Medicare Parts A, and B for 12 months before index diagnosis, and (2) be age 65 or older at the time of index diagnosis.

Intervention

We used ICD-9-CM codes to identify patients with unruptured cerebral aneurysms (ICD-9-CM code 437.3) who underwent clipping (ICD-9-CM code 39.51) between 2007 and 2012. For patients with multiple interventions, only the first one was included in the final cohort. A neurosurgeon was considered to have a dual practice (open and endovascular), when he practiced both approaches, with more than 10% of his total case volume consisting of the secondary approach (either clipping or coiling). Procedural coding definitions can be found in Table S1.

Outcome variables

The primary outcome was 1-year post-procedure mortality. Secondary outcomes were: length of stay (LOS) during the initial hospitalization, rate of discharge to a rehabilitation facility, and rate of 30-day post-discharge readmission.

Covariates

Sex-age categories (65–69, 70–74, 75–79, 80–84, 85–99) were created, as well as five ethnicity and race categories (Asian, Black, Hispanic, Native American, and other, with white being the excluded variable). The enrollee's ZIP code was used to match to 2010 Census data on income and poverty. We included the ZIP-level poverty rate separately, from the income variable, to reflect the differing distribution of income within the ZIP code. The neurosurgeon's case volume was calculated as the average annual number of surgical clipping cases performed by the surgeon.

Comorbidities, diagnosed (in more than 2 outpatient and/or 1 inpatient encounters) at any time in the 12-month look-back (before the intervention), for which outcomes were adjusted (Table S1), included: hypertension, myocardial infarction, cardiac arrhythmia, congestive heart failure, hyperlipidemia, coagulopathy, hypertension, ischemic stroke, peripheral

vascular disease, chronic obstructive pulmonary disease (COPD), other pulmonary disease, diabetes, obesity, alcohol abuse, malignancy, and dementia.

Statistical analysis

To compare outcomes between combined proceduralists and neurosurgeons performing only clipping we used several methods to address measured confounding. Initially, to compare death at 1 year postoperatively, 30-day readmission and discharge to rehabilitation between hybrid and non-hybrid neurosurgeons, we employed a multivariable logistic regression, including all the covariates listed above, and the surgeon's case volume. To account for clustering of observations within neurosurgeons we employed a sandwich variance based on an exchangeable correlation matrix. For length of stay we employed the corresponding versions of multiple linear regression models. In sensitivity analysis we repeated this approach after logarithmic transformation of LOS. The results were similar and are therefore not reported further.

To further control for confounding we used regression models with adjustment (stratification) by quantiles (we chose the number of quantiles to be 20) of propensity score. To derive the propensity of undergoing treatment by a hybrid neurosurgeon we developed a prediction model using logistic regression, based on the covariates described above. To account for clustering of observations within neurosurgeons we employed a sandwich variance based on an exchangeable correlation matrix.

Additionally, in sensitivity analysis, we examined the effect of various other definitions of hybrid neurosurgeons (in our primary analysis those were defined as neurosurgeons with more than 10% of their practice consisting of the secondary procedure) on outcomes. We repeated all the above analyses considering as hybrid neurosurgeons, those with at least 5 secondary procedure (e.g. if a neurosurgeon was performing mainly coiling, he was considered as a hybrid if he had performed 5 clippings). Additionally, we applied these two definitions only for the surgeon's case volume in the year prior to the intervention in question and repeated the pre-specified analyses. Our results were remarkably robust to all these sensitivity analyses. The direction of the observed associations was identical in these different iterations, and therefore these results are not reported further. The relationship of annual case volume and 1-year mortality was additionally examined with the use of a LOWESS (Locally Weighted Scatterplot Smoothing) graph. We specified the effective degrees of freedom for this to be 3.0.

This study of 3400 patients had sufficient power (80%) to detect a difference in 1-year mortality of 3% among patients treated by hybrid and non-hybrid neurosurgeons, at an α -level of 0.05. Patients with missing data (3% of poverty and income) were excluded from further analysis. All probability values were the result of two sided tests. SAS version 9.4 (SAS Institute, Cary, NC), and the 64-bit version of R.2.12.2 (R Foundation for Statistical Computing) were used for statistical analysis.

RESULTS

Patient characteristics

From 2007–2012, there were 3,247 Medicare patients who underwent surgical clipping for unruptured cerebral aneurysms, and met the inclusion criteria for the study. From these patients, 766 (23.6%) underwent treatment by a hybrid neurosurgeon, whereas 2,481 (76.4%) underwent treatment by physicians performing exclusively surgical clipping during the study period. The respective distribution of exposure variables between the two types of proceduralists can be found in Table 1.

Mortality

39 (5.0%) deaths were recorded (Table 2) in the first year after treatment by a combined proceduralist, and 140 (6.4%) after treatment by neurosurgeons who only performed clipping. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with increased 1-year mortality (OR, 0.90; 95% CI, 0.55–1.49) in the unadjusted analysis. Similarly, adjusting for confounders with a multivariable logistic regression model (Table 3) demonstrated a lack of association of combined practice with 1-year mortality (OR, 0.87; 95% CI, 0.52–1.47), which persisted after propensity score adjustment (OR, 0.81; 95% CI, 0.51–1.28).

Higher procedural volume was associated with lower mortality, regardless of the focus of the surgeon's practice. Performing 10–20 procedures per year (OR, 0.32; 95% CI, 0.17–0.62), or more than 20 procedures per year (OR, 0.48; 95% CI, 0.24–0.97) was associated with decreased mortality in comparison to low volume neurosurgeons (less than 10 clipping procedures per year). Figure 1 demonstrates a graphic representation of the association of surgeon's case volume with 1-year mortality of patients undergoing clipping for unruptured cerebral aneurysms.

Length-of-stay (LOS)

Among patients undergoing clipping, the average LOS was 7.4 (SD 7.2) after treatment by a combined proceduralist (Table 2), and 7.8 (SD 7.5) after treatment by neurosurgeons who only performed clipping. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with longer LOS (adjusted difference 0.91 days; 95% CI, –0.25 to 2.06) in the unadjusted analysis. Similarly, adjusting for confounders with a multiple linear regression model (Table 3) demonstrated a lack of association of combined practice with LOS (adjusted difference 0.90 days; 95% CI, –0.26 to 2.05), which persisted after propensity score adjustment (adjusted difference 0.85 days; 95% CI, –0.31 to 2.00).

Discharge to a rehabilitation facility

157 (20.2%) patients were discharged to a rehabilitation facility (Table 2) after treatment by a combined proceduralist, and 547 (20.7%) after treatment by neurosurgeons who only performed clipping. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with increased rate of discharge to rehabilitation (OR, 1.15; 95% CI, 0.86–1.54) in the unadjusted analysis. Similarly, adjusting for confounders with a multivariable logistic regression model (Table 3) demonstrated a lack of association of

combined practice with the rate of discharge to rehabilitation (OR, 1.09; 95% CI, 0.81–1.48), which persisted after propensity score adjustment (OR, 0.95; 95% CI, 0.72–1.25).

30-day readmission

120 (15.4%) patients were readmitted within 30-days of discharge (Table 2) after treatment by a combined proceduralist, and 409 (15.5%) after treatment by neurosurgeons who only performed clipping. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with higher rate of 30-day readmission (OR, 1.13; 95% CI, 0.84–1.52) in the unadjusted analysis. Similarly, adjusting for confounders with a multivariable logistic regression model (Table 3) demonstrated a lack of association of combined practice with 30-day readmission (OR, 1.14; 95% CI, 0.84–1.54), which persisted after propensity score adjustment (OR, 1.05; 95% CI, 0.80–1.39).

DISCUSSION

Among Medicare patients undergoing surgical clipping for unruptured cerebral aneurysms, we did not identify an association of treatment by hybrid neurosurgeons with 1-year mortality, LOS, discharge to rehabilitation, or 30-day readmission, although there was a trend for superior outcomes for this group of neurosurgeons. Neurosurgeons with higher case volume had decreased mortality, regardless of the focus of their practice. These results were consistent when using propensity score adjustment, controlling for clustering at the physician level, and in multiple sensitivity analyses. In recent years, the pendulum has swung dramatically in the United States in favor of dually trained neurosurgeons, using both open and endovascular techniques for the treatment of unruptured cerebral aneurysms.¹

However, the rapidly increasing number of these hybrid neurosurgeons has fueled a debate about the compatibility of their skillsets. Proponents of this treatment paradigm support that dually trained neurosurgeons provide an unbiased and well-considered assessment of which therapy would be indicated in a given patient. On the contrary, critics claim that hybrid neurosurgeons have a diffuse practice and never become experts in either procedure, with a negative impact on outcomes. De Vries and Boogaarts published their experience of treating ruptured cerebral aneurysms, as hybrid neurosurgeons, in a single European center.⁴ Surgical clipping in their practice was associated with combined morbidity and mortality of 2.1%. However, the lack of a comparison group of neurosurgeons, whose practices focus on clipping, is making these results difficult to generalize.

In our study of unruptured aneurysms we intentionally addressed these limitations. First, we created a cohort of almost all elderly patients in the United States, giving a true picture of national practice. Our analysis for the first time considers the real-world representation of open and hybrid neurosurgeons to address this question. Second, we used advanced observational techniques to control for confounding. Propensity score stratification was employed to adjust our analyses for known confounders. The possibility of clustering, which can bias the results of multi-center national studies, was accounted for at the physician level. Results were consistent across techniques and definitions, supporting the robustness of the observed correlations. The observed associations could reflect complex patient selection as dictated by provider comfort in the setting of constantly evolving referral patterns.

Treatment of unruptured aneurysms, particularly in the elderly is usually only undertaken when there is a favorable risk/benefit profile. If an aneurysm is evaluated by a neurosurgeon who only performs microsurgery and the lesion is best treated with endovascular coiling, it is the standard of care to refer that patient to an endovascular specialist. On the other hand, as many simple aneurysms can be treated with both clipping and coiling, the trend towards favoring coiling has resulted in centralization of complex aneurysms to expert neurosurgeons for clipping.⁵

The association between practice patterns and outcomes can be confounded by proceduralist case volume. Prior data on the association of case volume and outcomes of cerebral aneurysm treatment have been conflicting. Single center series⁶⁷ and international investigations⁸ have supported that surgeon volume did not correlate with outcomes. However, national studies in the United States have found evidence to the contrary.⁹¹⁰ Barker et al,¹¹ in an unruptured aneurysm cohort from the Nationwide Inpatient Sample, demonstrated that higher hospital and surgeon volume were associated with decreased in-hospital morbidity, but had no significant effect on mortality. In an analysis of a New York State cohort of similar patients, Zacharia et al¹² demonstrated that higher hospital volume was associated with a lower chance of being discharged to a rehabilitation facility.

In our cohort, we consistently found an incremental association of proceduralist volume with lower morbidity and mortality for clipping of unruptured cerebral aneurysms. In contrast to all prior studies, which lacked long-term survival results, we modeled our primary outcome as 1-year mortality. Hybrid neurosurgeons maintaining a high volume of both clipping and coiling appear to have similar results to their counterparts focusing on either procedure. The beneficial effect of volume on outcomes seemed to plateau for over 20 cases of clipping per year. In this context the observed shift¹³ of aneurysm treatment to low volume centers should alert referring providers and regulators.

This study has several limitations common to administrative databases. First, this is an observational investigation, and there is still a possibility of residual confounding. We used multiple techniques (propensity score stratification, controlled for clustering) yielding consistent results to account for confounders. Second, coding inaccuracies can affect our estimates. However, coding for procedures is rarely inaccurate, given that it is a revenue generator, and is under scrutiny by payers.

Third, claims data do not provide metrics on the postoperative neurologic status of the patients (i.e. modified Rankin score), chronic pain, or quality of life. Therefore we cannot analyze the difference of surgeon expertise, in regards to these measures. Alternatively, this question can be answered by the creation of large, long-term registries, with such efforts currently being underway.¹⁴ Quality of life outcome measures, or patient satisfaction metrics could be used instead in future prospective investigations. Fourth, findings among this older, American population may not be generalizable to younger or otherwise dissimilar populations. Fifth, we have no information on aneurysm size and location, which can affect surgical outcomes. However, we expect that surgeons would treat similar aneurysms with clipping (mostly anterior circulation) or coiling (mostly posterior circulation) regardless of

whether they have a combined practice. Lastly, causal inference is hard to establish based on observational data, even when using advanced observational techniques.¹⁵

Conclusions

It is often questioned if one physician can conduct both open and endovascular techniques successfully and safely. We investigated the association of combined open and endovascular expertise with the outcomes of unruptured cerebral aneurysm clipping. We did not identify an association of treatment by hybrid neurosurgeons with 1-year mortality, discharge to rehabilitation, LOS, or 30-day readmission. Neurosurgeons with higher case volume had improved mortality, regardless of the focus of their practice. Future comparative effectiveness studies will likely need to be based on prospective registries, using quality outcome metrics, when determining which treatment option is best.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. LOWESS (Locally Weighted Scatterplot Smoothing) graph demonstrating the relationship of annual surgeon clipping volume with 1-year postoperative mortality

Table 1

Patient characteristics

	Treatment by non-hybrid neurosurgeons	Treatment by hybrid neurosurgeons	Z-value
Age, mean (SD)	70.5 (4.1)	70.4 (4.0)	-0.8
Male gender	578 (23.3%)	174 (22.7%)	-0.4
African-Americans	160 (6.0%)	70 (9.0%)	2.9
Income *	\$45,600 (16,900)	\$47,100 (17,800)	2.3
Poverty *	256 (10.1%)	73 (9.6%)	-1.2
Comorbidities[¶]			
Hypertension	1387 (52.4%)	428 (54.9%)	1.3
Hyperlipidemia	532 (20.1%)	180 (23.1%)	1.8
Chronic obstructive pulmonary disease	89 (3.4%)	25 (3.2%)	-0.2
Myocardial infarction	325 (12.3%)	92 (11.8%)	-0.3
Cardiac arrhythmia	127 (4.8%)	61 (7.8%)	3.3
Coagulopathy	22 (0.8%)	Ø	-0.5
Renal insufficiency	62 (2.3%)	14 (1.8%)	-0.9
Congestive heart failure	80 (3.0%)	19 (2.4%)	-0.9
Pulmonary disease [§]	89 (23.4%)	19 (2.4%)	-1.3
Obesity	20 (0.7%)	Ø	-1.1
Alcohol abuse	Ø	Ø	1.3
Dementia	20 (0.8%)	Ø	-0.3
Ischemic stroke	278 (10.5%)	77 (9.9%)	-0.5
Diabetes	331 (12.5%)	103 (13.2%)	0.5
Peripheral vascular disease	280 (10.6%)	89 (11.4%)	0.7
Malignancy	186 (7.0%)	36 (4.6%)	-2.4

SD: Standard Deviation

Output represents crude numbers and percentages in parentheses, unless otherwise indicated

* The enrollee's ZIP code was used to match to 2010 Census data on income and poverty.

[¶]Based on 12-month look-back before the date of the procedure[§]Non COPD

Ø Output suppressed to comply with the reporting rules of Medicare, which do not allow printing of output involving less than 11 patients

Table 2**Outcomes**

	Treatment by non-hybrid neurosurgeons	Treatment by hybrid neurosurgeons	P-value
1-year mortality	140 (6.4%)	39 (5.0%)	0.683
30-day readmission	409 (15.5%)	120 (15.4%)	0.282
Discharge to rehabilitation	547 (20.7%)	157 (20.2%)	0.351
Length-of-stay (SD)	7.4 (7.2)	7.8 (7.5)	0.172

SD: Standard Deviation

Output represents crude numbers and percentages in parentheses, unless otherwise indicated Length-of-stay is measured in days. The mean value and SD are displayed

Table 3
Association of receiving treatment by a hybrid neurosurgeon with outcome measures

Models	1-year mortality ^{##}		Length-of-stay (days) [*]		Discharge to rehabilitation ^{##}	
	OR (95% CI)	P-value	Adjusted difference (95% CI)	P-value	OR (95% CI)	P-value
Crude	0.90 (0.55–1.49)	0.683	0.91 (–0.25 to 2.06)	0.413	1.15 (0.86–1.54)	0.351
Multivariable regression [*]	0.87 (0.52–1.47)	0.602	0.90 (–0.26 to 2.05)	0.322	1.09 (0.81–1.48)	0.567
Propensity score adjustment [*]	0.81 (0.51–1.28)	0.353	0.85 (–0.31 to 2.00)	0.141	0.95 (0.72–1.25)	0.717
30-day readmissions^{##}						
Crude	OR (95% CI)	P-value				
	1.13 (0.84–1.52)	0.282				
	1.14 (0.84–1.54)	0.166				
Propensity score adjustment [*]	1.05 (0.80–1.39)	0.830				

OR: Odds Ratio; 95% CI: 95% Confidence Interval

^{*} Mixed effects; Includes patient's HRR as a random effect variable

^{##} Analyses based on logistic regression

^o Analyses based on linear regression; point estimates are beta coefficients