Medicare expenditures for elderly patients undergoing surgical clipping or endovascular intervention for subarachnoid hemorrhage

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OBJECTIVE The impact of treatment method—surgical clipping or endovascular coiling—on the cost of care for patients with aneurysmal subarachnoid hemorrhage (SAH) is debated. Here, the authors investigated the association between treatment method and long-term Medicare expenditures in elderly patients with aneurysmal SAH.

METHODS The authors performed a cohort study of 100% of the Medicare fee-for-service claims data for elderly patients who had undergone treatment for ruptured cerebral aneurysms in the period from 2007 to 2012. To control for measured confounding, the authors used propensity score–adjusted multivariable regression analysis with mixed effects to account for clustering at the hospital referral region (HRR) level. An instrumental variable (regional rates of coiling) analysis was used to control for unmeasured confounding by creating pseudo-randomization on the treatment method.

RESULTS During the study period, 3210 patients underwent treatment for ruptured cerebral aneurysms and met the inclusion criteria. Of these patients, 1206 (37.6%) had surgical clipping and 2004 (62.4%) had endovascular coiling. The median total Medicare expenditures in the 1st year after admission for SAH were \$113,000 (IQR \$77,500–\$182,000) for surgical clipping and \$103,000 (IQR \$72,900–\$159,000) for endovascular coiling. When the authors adjusted for unmeasured confounders by using an instrumental variable analysis, clipping was associated with increased 1-year Medicare expenditures by \$19,577 (95% CI \$4492–\$34,663).

CONCLUSIONS In a cohort of Medicare patients with aneurysmal SAH, after controlling for unmeasured confounding, surgical clipping was associated with increased 1-year expenditures in comparison with endovascular coiling.

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KEY WORDS cerebral aneurysms; subarachnoid hemorrhage; cost; clipping; coiling; instrumental variable; Medicare; vascular disorders

THE treatment of subarachnoid hemorrhage (SAH) has changed dramatically^{3,16} since the publication of the International Subarachnoid Aneurysm Trial (ISAT),³⁰ which highlighted the value of endovascular interventions for ruptured cerebral aneurysms.^{3,33} Despite initial criticism about the study's design and limited focus, further national investigations^{4,5,8,9,13,17,22} and a North American trial²⁹ confirmed its findings. These results have fueled an explosive growth of coiling in the SAH population.³ However, as endovascular options are increasingly becoming technologically sophisticated, they are associated with rising device costs. Concerns have been raised that this cost outweighs the cost of clipping,

which involves less expensive implants. With health care economic sustainability a national priority,²⁰ demonstrating the financial viability of new treatment options is crucial.^{1,2,11,12,14,15,18,24,26,28,32}

Several studies have analyzed the economic aspects of cerebral aneurysm interventions.^{19,22,25,27,36,38} However, the generalizability of their findings is limited given the lack of adjustment for unmeasured confounding. In addition, most investigators have focused only on hospitalization cost, which does not take into account the cost of possible future reintervention in endovascularly treated patients or the cost of long-term care in patients experiencing complications.^{7,10,19,22,23,25,38} The investigators of the ISAT reported

ABBREVIATIONS COPD = chronic obstructive pulmonary disease; HRR = hospital referral region; ISAT = International Subarachnoid Aneurysm Trial; IV = instrumental variable; NIS = Nationwide Inpatient Sample; SAH = subarachnoid hemorrhage; ZIP = Zone Improvement Program.

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no difference in the long-term cost of clipping or coiling among patients participating in the study.³⁶ However, this study was conducted in Europe more than 10 years ago and does not reflect the current financial realities of North America. In addition, extrapolating the results of highly selective, well-controlled randomized trials to the real world should be done with caution, especially as regards underrepresented populations. There has been no prior investigation into the comparative long-term cost of clipping and coiling in elderly patients while appropriately controlling for unmeasured confounders.

Thus, we performed a national cohort study of Medicare patients with aneurysmal SAH, investigating the association between treatment method and Medicare expenditures for elderly patients in the 1st year post-SAH. To control for unmeasured confounding (mainly the different patient characteristics and the nonrandom selection of treatments), we used an instrumental variable (IV) approach, simulating pseudo-randomization on the treatment method.

Methods

Data and Cohort Creation

The Dartmouth Committee for the Protection of Human Subjects approved this study. The data were anonymized and de-identified prior to use; therefore, no informed consent was required. We used 100% of the Medicare Denominator File and corresponding Medicare inpatient and outpatient claims, Parts A and B, for 2007–2012 (Medicare Provider Analysis and Review [MEDPAR], Carrier and Outpatient Claims) to select patients with aneurysmal SAH. For cohort inclusion, patients were required 1) to be continuously enrolled in fee-for-service Medicare Parts A and B for 12 months before the index diagnosis, 2) to be an age of 65 years or older at the time of the index diagnosis, and 3) to have no secondary insurance at any point during the study.

Intervention

We used ICD-9-CM codes to identify patients presenting with aneurysmal SAH (ICD-9-CM code 430) who underwent clipping (code 39.51) or coiling (code 39.52 [should also have a code 88.41 and no 39.51 during the same hospitalization], 39.72, 39.75, 39.76, 39.79) between 2007 and 2012.

Outcome Variables

The primary outcome was the 1-year total Medicare expenditures, starting on the admission day for the SAH. Secondary outcome was 7-day total Medicare expenditures, starting on the admission day for the SAH. These calculations included the exact amount paid for all billing claims generated. Expenditures were inflation adjusted to reflect 2012 US dollar values.

Covariates

Age categories (65–69, 70–74, 75–79, 80–84, 85–99 years) were created, as well as 5 ethnicity and race categories (Asian, black, Hispanic, Native American, and other, with white being the excluded variable). The enrollee's

Zone Improvement Plan (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.

Comorbidities diagnosed (in more than 2 outpatient and/or 1 inpatient encounter) at any time in the 12-month look back (before the intervention), for which outcomes were adjusted (Supplemental Table 1), 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.

Each facility was identified with one of the 306 hospital referral regions (HRRs) in the US as used by The Dartmouth Atlas of Health Care. An HRR is a region served by a hospital or group of hospitals that offers cardiovascular and neurosurgical procedures so that each HRR includes at least 1 tertiary care hospital. All ZIP codes in the US were assigned to an HRR on the basis of the migration patterns of hospital use among the elderly population. The coiling rate in each HRR was calculated by dividing the number of coiling procedures in an HRR by the number of total interventions for ruptured cerebral aneurysms in the same location and time period.

Statistical Analysis

To compare total Medicare expenditures between coiling and clipping therapies, we initially used multiple linear regression, adjusting for all the covariates listed above to address known confounders. As an alternative way to control for measured confounding, we employed a linear regression with adjustment (stratification) by quantiles (we chose the number of quantiles as 20) of the propensity score. To derive the propensity of clipping versus coiling, we developed a prediction model using logistic regression based on all the covariates described above. All these models included a random intercept for HRR. In a sensitivity analysis, we repeated all approaches after logarithmic transformation of expenditures. The results were similar and are therefore not reported further.

Patients have different neurological statuses and baseline characteristics and have already been selected for clipping or coiling, which can affect the outcomes as well as the cost of these interventions. To overcome this confounding (the nonrandom selection of patients for either treatment) due to covariates not captured by Medicare, we employed an IV analysis,²¹ which uses the differences in practice patterns across regions to simulate the structure of a randomized trial in an observational setting. This advanced observational technique has been used by clinical researchers to answer comparative effectiveness questions for different interventions. The goal is to simulate randomization, especially when the baseline functional characteristics of the patients are unknown (similar to our application).^{31,35,37}

The use of coiling varies widely across HRRs. Patients tend to seek care for emergencies such as SAH close to their residence. Someone who lives in an HRR in which coiling is primarily offered is more likely to receive this

treatment. The IV approach depends on the assumptions that HRR coiling rates affect outcomes only by promoting the use of coiling in that HRR (exclusion restriction criterion) and that there are no variables that affect both the regional coiling rate and costs (no instrument-outcome confounders) besides those adjusted for, as in the linear regression models above. Hospital referral region coiling rates were not correlated with the average predicted cost within an HRR, based on covariates controlled for in the regression models presented ($r = 0.01$, $p > 0.10$), suggesting a case mix balance between HRRs. A practical rule³⁴ for employing an instrument is that the F-statistic (or chi-square for a binary exposure) for the association between the instrument and the treatment exceeds 10. In our study, this value was 125 when using HRR coiling rates as an instrument for coiling.

We subsequently calculated the causal estimate of the differences in total Medicare expenditures between clipping and coiling by using a linear regression model with an IV analysis in a 2-stage least squares approach, as described in the literature.^{6,31,35,37} The HRR coiling rate was used as an instrument for coiling, and we also adjusted for all other covariates listed above. In sensitivity analysis we excluded patients with less than 1 year of follow-up from our models. The direction of the observed associations did not change; therefore, these results are not reported further.

Given that 2004 patients underwent coiling and 1206 underwent clipping, we had an 80% power to detect a difference in cost as small as 4.0% at an α -level of 0.05, assuming a log-normal distribution with a mean of \$107,000 and an IQR of \$75,000–\$168,000. All probability values were the result of 2-sided tests. The SAS version 9.4 (SAS Institute Inc.) 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 to 2012, 3210 Medicare patients underwent treatment for ruptured cerebral aneurysms and met the inclusion criteria for this study. Of these patients, 1206 (37.6%) had surgical clipping and 2004 (62.4%) had endovascular coiling. The respective distribution of exposure variables between the 2 methods of treatment can be found in Table 1. Figure 1 demonstrates the distribution of coiling rates per HRR.

7-Day Total Medicare Expenditures

The median total Medicare expenditures in the first 7 days after admission for the SAH were \$38,400 (IQR \$29,200 to \$50,100) for surgical clipping and \$38,400 (IQR \$29,600 to \$52,200) for endovascular coiling. As demonstrated in Table 2, there was no association between treatment method and 7-day expenditures (adjusted difference $-\$887$, 95% CI $-\$2483$ to $\$709$) in the unadjusted analysis. This finding persisted when adjusting for measured confounders with a linear regression model (adjusted difference $-\$971$, 95% CI $-\$2574$ to $\$632$) and a propensity-adjusted regression model (adjusted difference $-\$958$, 95% CI $-\$2560$ to $\$643$). Similarly, when we adjusted for

TABLE 1. Summary of patient characteristics*

Characteristic	Clipping	Coiling	Z Value
No. of patients	1206	2004	
Mean age in yrs (SD)	73.5 (6.2)	75.3 (6.8)	7.4
Male sex	275 (22.8%)	533 (26.6%)	-2.4
African American race	135 (11.2%)	208 (10.4%)	0.7
Income in 2012 US\$ (SD)†	\$44,800 (\$17,900)	\$45,700 (\$17,700)	-1.4
Poverty‡	137 (11.4%)	210 (10.5%)	3.1
Comorbidity‡			
Hypertension	421 (34.9%)	859 (42.9%)	-4.5
Hyperlipidemia	166 (13.7%)	294 (14.7%)	-0.7
COPD	20 (1.7%)	33 (1.6%)	0.02
Myocardial infarction	97 (8.0%)	223 (11.1%)	-2.8
Cardiac arrhythmia	51 (4.2%)	135 (6.7%)	-3.0
Coagulopathy	§	17 (0.8%)	-1.2
Renal insufficiency	42 (3.5%)	67 (3.3%)	0.2
Congestive heart failure	27 (2.2%)	82 (4.1%)	-2.8
Pulmonary disease¶	25 (2.1%)	47 (2.3%)	-0.5
Obesity	§	§	0.5
Alcohol abuse	§	§	-0.8
Dementia	§	31 (1.5%)	-2.0
Ischemic stroke	39 (3.2%)	89 (4.4%)	-1.7
Diabetes	123 (10.2%)	241 (12.0%)	-1.6
Peripheral vascular disease	51 (4.2%)	142 (7.1%)	-3.3
Malignancy	58 (4.8%)	132 (6.6%)	-2.1

SD = standard deviation.

* Values represent crude numbers.

† 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.

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

¶ Non-COPD.

unmeasured confounders by using an IV analysis, treatment choice was not associated with 7-day Medicare expenditures (adjusted difference $-\$438$, 95% CI $-\$4368$ to $\$3491$).

1-Year Total Medicare Expenditures

The median total Medicare expenditures in the 1st year after admission for the SAH were \$113,000 (IQR \$77,500–\$182,000) for surgical clipping and \$103,000 (IQR \$72,900–\$159,000) for endovascular coiling. As demonstrated in Table 2, surgical clipping was associated with increased 1-year expenditures by \$11,379 (95% CI \$5480–\$17,278) in the unadjusted analysis. Adjusting for measured confounders with multiple linear regression (adjusted difference \$9484, 95% CI \$3363–\$15,605) or a propensity score-adjusted regression (adjusted difference \$9937, 95% CI \$3789–\$16,086) confirmed this association. When we controlled for unmeasured confounders by using an IV analysis, clipping was associated with in-

FIG. 1. Percent of Medicare beneficiaries treated for ruptured cerebral aneurysms using coiling (2007–2012). Each dot represents 1 HRR; the higher the dot, the higher the percentage. Each blue dot represents the percentage of Medicare beneficiaries treated for ruptured cerebral aneurysms with coiling in 1 of 306 HRRs in the US. Red dots indicate the regions with the 5 lowest and 5 highest rates, whose names are listed to the right. Reproduced from Bekelis K. *Variation in the Care of Surgical Conditions: A Dartmouth Atlas of Health Care Series*. Lebanon, NH, 2014. Published with permission. Figure is available in color online only.

creased 1-year Medicare expenditures by \$19,577 (95% CI \$4492–\$34,663).

Discussion

Among Medicare patients undergoing treatment for ruptured cerebral aneurysms, we identified an association between surgical clipping and increased Medicare expenditures at 1 year after the day of admission for SAH. There was no difference in expenditures in the first 7 days after admission. In recent years, the pendulum has swung dramatically in favor of endovascular interventions for aneurysmal SAH. However, the comparative cost of long-term care in patients undergoing these interventions remains an issue of debate.

Prior long-term economic analyses of these groups have limited generalization. Wolstenholme et al.,³⁶ in a post hoc analysis of the ISAT, were unable to demonstrate a difference in the 1-year cost of care in patients undergoing

clipping or coiling. However, the results of this trial were limited to Europe, with its different financial environments in each country, and reflect prices and technologies that are now more than 10 years old. In the last decade endovascular interventions have seen a dramatic increase in effectiveness but also in cost, enhancing this debate. More recently, other investigators²⁷ used a commercial database to assess the cost-effectiveness of clipping and coiling in the setting of SAH. However, the cost calculations in that study were based on assumptions and extrapolation of data from other investigations and did not represent the exact costs incurred during the procedures. Therefore, it is questionable whether these findings give a true picture of the economic impact of the 2 interventions. In addition, participation in the database was voluntary, and it is likely that hospitals incentivized to achieve higher quality standards would be overrepresented. This self-selection introduces significant unmeasured confounding, which the authors did not account for.

Other studies focusing on the hospitalization cost of cerebral aneurysm treatment have demonstrated conflicting results. Although single-center investigations have shown a lower hospitalization cost for coiling,^{19,22,25,38} a retrospective analysis of the Nationwide Inpatient Sample (NIS)²³ showed that clipping was associated with higher hospitalization charges for both ruptured and unruptured aneurysms. Utilizing the same national database, Bekelis et al.^{7,10} developed a predictive model of hospitalization cost for these patients. However, cost calculations based on the NIS are crude and mostly derived from charges and therefore do not reflect true cost. In addition, the available data refer to the acute hospitalization only and do not allow the study of the long-term financial impact of these procedures. Lastly, the lack of adjustment for clustering and rigorous control for unmeasured confounders significantly limits the interpretation of the results of these prior analyses.

Our study addresses many of these methodological limitations. First, we created a cohort of almost all elderly patients in the US, giving a true picture of national practice in this age group. Second, we used advanced observational techniques to control for confounding. The prior selection of patients for either procedure (based on their different neurological statuses and characteristics) will undoubtedly bias the outcomes and thus the comparative cost of the 2 procedures. We used an IV analysis to account for such bias. This approach simulates the effect of randomization on treatment by controlling for unknown confounders (that is, neurological status at presentation, aneurysm size, and

TABLE 2. Correlation between clipping and outcome measures

Model	1-Yr Expenditures*		7-Day Expenditures*	
	Adjusted Difference (95% CI)	p Value	Adjusted Difference (95% CI)	p Value
Crude	\$11,379 (\$5,480 to \$17,278)	<0.001	–\$887 (–\$2,483 to \$709)	0.276
Multivariable regression†	\$9,484 (\$3,363 to \$15,605)	<0.001	–\$971 (–\$2,574 to \$632)	0.235
Propensity-adjusted regression†	\$9,937 (\$3,789 to \$16,086)	<0.001	–\$958 (–\$2,560 to \$643)	0.241
Instrumental variable analysis‡	\$19,577 (\$4,492 to \$34,663)	<0.001	–\$438 (–\$4,368 to \$3,491)	0.827

* Analyses based on linear regression.

† Mixed effects; includes patient's HRR as a random effect variable.

‡ Hospital referral region coiling rate (fraction of coiling of total procedures performed) was used as an instrument of choice of treatment.

location). In contrast to some prior studies, which lacked long-term cost analysis, we modeled our primary outcome as 1-year expenditures to account for possible future re-intervention in some patients or the cost of long-term care in patients experiencing complications. Third, our cost calculations were based on exact Medicare expenditures for each patient over time. This accurately reflected the true financial impact of those procedures, contrary to prior investigations focusing on charges or estimates.

Our analysis provides insight into the economic aspects of available treatments for aneurysmal SAH. It addresses a common misconception that endovascular interventions are more costly. The care of individual patients should be directed according to their specific characteristics and not by the cost of the respective procedures. However, our data provide an additional argument in favor of the economic sustainability of endovascular options, which can be used in the debate with policy makers, payers, and administrators as new treatments that can benefit neurosurgical patients are introduced. It is likely that the increased expenditures associated with clipping are secondary to the higher percentage of patients discharged to rehabilitation facilities,^{4,5} resulting in increased spending. However, we are lacking the granularity to identify the exact components contributing to the total yearly cost of either procedure. More detailed analyses can be performed with the creation of large, long-term registries, and such efforts are underway (<http://www.neuropoint.org/NPA%20N2QOD.aspx>). These registries can integrate quality of life outcome measures (such as the modified Rankin Scale) or patient satisfaction metrics to reach meaningful conclusions about cost-effectiveness.

Our study has several limitations common to administrative databases. First, the study is observational. We used multiple techniques (multivariable regression, HRR random effects, propensity score adjustment, IV analysis) to account for known and unknown confounders. To the extent that the HRR coiling rate is a good instrument, the possibility of residual confounding is small. Our first stage F-statistic was consistent with a strong instrument,³⁴ and it is unlikely that the regional rate of coiling will be associated with costs in any other way than the choice of treatment. 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 post-operative neurological status of patients (that is, modified Rankin Scale score), chronic pain, or quality of life; therefore, we cannot analyze the difference between clipping and coiling in regard to these measures. Fourth, findings among this older American population may not be generalizable to younger or otherwise dissimilar populations. Although our results accurately reflect the cost of cerebral aneurysm treatment for Medicare, we cannot generalize these results for other payers or private insurers. Fifth, we have no information on aneurysm size, location, and details of treatment, which can affect expenditures. However, the use of an IV analysis is expected to simulate a randomized trial and control for such unknown confounders. Sixth, causal inference is hard to establish based on observational data, even when using an IV analysis.²¹

Conclusions

The cost difference between the 2 treatment options of surgical clipping and endovascular coiling for ruptured cerebral aneurysms remains an issue of debate. We investigated the association between treatment method and Medicare expenditures in elderly patients with aneurysmal SAH. In a cohort of Medicare patients, after controlling for unmeasured confounding, we demonstrated that surgical clipping of ruptured cerebral aneurysms was associated with increased 1-year expenditures.

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Disclosures

Dr. Lanzino is a consultant for Covidien/Medtronic. The funders had no role in the design or execution of the study.

Author Contributions

Conception and design: Bekelis. Acquisition of data: Bekelis, Gottlieb, Su, MacKenzie. Analysis and interpretation of data: all authors. Drafting the article: Bekelis. Critically revising the article: Gottlieb, Lanzino, Lawton, MacKenzie. Reviewed submitted version of manuscript: Bekelis. Approved the final version of the manuscript on behalf of all authors: Bekelis. Statistical analysis: Bekelis, Gottlieb, Su, MacKenzie. Administrative/technical/material support: Bekelis. Study supervision: Bekelis.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Table 1. <http://thejns.org/doi/suppl/10.3171/2016.2.JNS152994>.

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