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

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Abstract

Background—The impact of treatment method (surgical clipping or endovascular coiling) on the cost of care of patients with aneurysmal subarachnoid hemorrhage (SAH) is debated. We investigated the association of treatment method with long-term Medicare expenditures in elderly patients with aneurysmal SAH.

Methods—We performed a cohort study of 100% of Medicare fee-for-service claims data for elderly patients, who underwent treatment for ruptured cerebral aneurysms from 2007 to 2012. In order to control for measured confounding, we used propensity score adjusted multivariable regression analysis with mixed effects to account for clustering at the 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, there were 3,210 patients, who underwent treatment for ruptured cerebral aneurysms, and met the inclusion criteria. Of these, 1,206 (37.6%) had surgical clipping, and 2,004 (62.4%) had endovascular coiling. The median total Medicare expenditures in the first year after admission for SAH were $113,000 (IQR $77,500 to $182,000) for surgical clipping, and $103,000 (IQR $72,900 to $159,000) for endovascular coiling. When we adjusted for unmeasured confounders, using an instrumental variable analysis, clipping was associated with increased 1-year Medicare expenditures by $19,577 (95% CI, $4,492 to $34,663).

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Conflicts of interest
The authors have no conflicts to disclose

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

Keywords

cerebral aneurysms; subarachnoid hemorrhage; cost; clipping; coiling; instrumental variable; Medicare

INTRODUCTION

The treatment of subarachnoid hemorrhage (SAH) has changed dramatically[3,16] since the publication of the International Study for Aneurysm Treatment (ISAT),[30] which highlighted the value of endovascular interventions for ruptured cerebral aneurysms.[3,34] 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 trial[29] confirmed its findings. These results have fueled an explosive growth of coiling in this population.[3] However, as endovascular options are increasingly becoming technologically sophisticated they are associated with a rising device cost. Concerns have been raised that this cost outweighs the cost of clipping, which involves less expensive implants. With healthcare economic sustainability being a national priority,[20] demonstrating the financial viability of new treatment options is crucial.[1,2,11,12,14,15,18,24,26,28,33]

Several studies have analyzed the economic aspects of cerebral aneurysm interventions.[19,22,25,27,37,39] However, the generalizability of their findings is limited due to 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.[7,10,19,22,23,25,39] The investigators of the ISAT study reported no difference in the long-term cost of clipping or coiling among patients participating in the study.[37] 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 in regards to under-represented populations. There is no prior investigation examining the comparative long-term cost of clipping and coiling in the elderly, while appropriately controlling for unmeasured confounders.

We performed a national cohort study of Medicare patients with aneurysmal SAH investigating the association of treatment method and Medicare expenditures for elderly patients in the first year post-SAH. In order to control for unmeasured confounding (mainly the different patient characteristics and the non-random selection of treatments), we used an instrumental variable (IV) approach, simulating pseudo-randomization on the treatment method.

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 aneurysmal SAH. 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, (2) be age 65 or older at the time of index diagnosis, and (3) have no secondary insurance at any point during the study.

Intervention

We used ICD-9-CM (*International Classification of Diseases, Ninth Revision, Current Modification)* codes to identify patients presenting with aneurysmal SAH (ICD-9-CM code 430) who underwent clipping (ICD-9-CM code 39.51) or coiling (ICD-9-CM 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 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) 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.

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 (Supplemental Table I), 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 Region (HRR) in the United States as used by The Dartmouth Atlas of Health Care. An HRR is a region served by a hospital or group of hospitals that offer cardiovascular and neurosurgical procedures, so that each HRR includes at least one tertiary care hospital. All ZIP codes in the United Sates were assigned to 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. In an alternative way to control for measured confounding we employed a linear regression with adjustment (stratification) by quantiles (we chose the number of quantiles to be 20) of 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 sensitivity analysis we repeated all approaches after logarithmic transformation of expenditures. The results were similar and are therefore not reported further.

Patients have different neurologic status 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 non-random selection of patients for either treatment) due to covariates not captured by Medicare we employed an instrumental variable analysis.[21] This analysis 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 before 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).[31,36,38]

Use of coiling varies widely across HRR. Patients tend to seek care for emergencies such as SAH close to their residence. Someone, who lives in an HRR where coiling is primarily offered, is more likely to receive this treatment. The IV approach depends on the assumption that HRR coiling rates affect the outcomes only by promoting the use of coiling in that HRR (exclusion restriction criterion), and on the assumption 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. HRR coiling rates were not correlated with average predicted cost within an HRR, based on covariates controlled for in the regression models presented ($r= 0.01$, $P>0.10$) suggesting case-mix balance between HRRs. A practical rule[35] for employing an instrument is that the F-statistic (or chi-square for a binary exposure) for the association of the instrument and treatment exceeds 10. This value was 125 in our study, 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, using a linear regression model with an IV analysis, in 2-stage least squares approach (2SLS), as previously described in the literature.[6,31,36,38] HRR coiling rate was used as an instrument for coiling, and we additionally adjusted for all other covariates listed above. In sensitivity analysis we excluded patients with less than a year of follow up from our models. The direction of the observed associations did not change and therefore these results are not reported further.

Given that we had 2,004 patients undergoing coiling and 1,206 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 lognormal distribution with mean of $107,000 and IQR of $75,000 to $168,000. 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 3,210 Medicare patients who underwent treatment for ruptured cerebral aneurysms, and met the inclusion criteria for the study. Of these, 1,206 (37.6%) underwent surgical clipping, and 2,004 (62.4%) had endovascular coiling. The respective distribution of exposure variables between the two 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 procedure 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 of treatment method with 7-day expenditures (adjusted difference −$887; 95% CI, −$2,483 to $709) in the unadjusted analysis. This persisted (Table 2) when adjusting for measured confounders with a linear regression model (adjusted difference −$971; 95% CI, −$2,574 to $632), and a propensity adjusted regression model (adjusted difference −$958; 95% CI, −$2,560 to $643). Similarly, when we adjusted for unmeasured confounders, using an instrumental variable analysis, treatment choice was not associated with 7-day Medicare expenditures (adjusted difference −$438; 95% CI, −$4,368 to $3,491).

1 year total Medicare expenditures

The median total Medicare expenditures in the first year after admission for the procedure were $113,000 (IQR $77,500 to $182,000) for surgical clipping, and $103,000 (IQR $72,900 to $159,000) for endovascular coiling.

As demonstrated in Table 2, surgical clipping was associated with increased 1-year expenditures by $11,379 (95% CI, $5,480 to $17,278) in the unadjusted analysis. Adjusting for measured confounders (Table 2) with multiple linear regression (adjusted difference $9,484; 95% CI, $3,363 to $15,605), or a propensity score adjusted regression (adjusted difference $9,937; 95% CI, $3,789 to $16,086) confirmed this association. When we controlled for unmeasured confounders, using an instrumental variable analysis, clipping was associated with increased 1-year Medicare expenditures by $19,577 (95% CI, $4,492 to $34,663).

DISCUSSION

Among Medicare patients undergoing treatment for ruptured cerebral aneurysms, we identified an association of surgical clipping with increased Medicare expenditures at 1-year after the day of admission for SAH, in comparison to endovascular coiling. 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 of patients undergoing these interventions remains an issue of debate.

Prior long-term economic analyses of these groups have limited generalization. Wolstenholme et al[37] in a post-hoc analysis of the ISAT trial were not able to demonstrate a difference in the 1-year cost of care of patients undergoing clipping or coiling. However, the results of this trial are limited to Europe, with different financial environments in each country, and reflect prices and technologies that are now over 10 years old. In the last decade endovascular interventions have seen a dramatic increase in effectiveness, but also cost, enhancing this debate. More recently, other investigators[27] utilized a commercial database in order to assess the cost-effectiveness of clipping and coiling in the setting of SAH. However, the cost calculations in this study were based on assumptions and extrapolation of data from other investigations, and do 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 two interventions. In addition, participation in this 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,[19,22,25,39] a retrospective analysis of the Nationwide Inpatient Sample[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 methodologic limitations. First, we created a cohort of almost all elderly patients in the United States, 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 neurologic status and characteristics) will undoubtedly bias the outcomes and therefore the comparative cost of the two procedures. We utilized an instrumental variable analysis to account for such bias. This approach simulates the effect of randomization on treatment by controlling for unknown confounders (i.e. neurologic status at presentation, aneurysm size, and 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 reintervention in some patients, or the cost of long-term care in patients experiencing complications. Lastly, our cost calculations are based on exact Medicare expenditures for each patient longitudinally overtime. This provides an accurate reflection of the true financial impact of those procedures, contrary to prior investigations focusing on charges or estimates.

This analysis provides insight in the economic aspects of the available treatments for aneurysmal SAH. It addresses a common misconception that endovascular interventions are more costly. The care of individual patients should be directed based on 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 being introduced. It is likely that the increased expenditures associated with clipping are secondary to the higher percentage of such patients being 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 by the creation of large, long-term registries, with such efforts currently being underway.[32] These 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, this is an observational study. 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 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,[35] 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 postoperative neurologic status of the patients (i.e. modified Rankin score), chronic pain, or quality of life. Therefore we cannot analyze the difference of clipping and coiling, in regards 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 insurance. 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. Lastly, causal inference is hard to establish based on observational data, even when using an IV analysis.[21]

Conclusions

The cost difference between the two treatment options (surgical clipping and endovascular coiling) for ruptured cerebral aneurysms remains an issue of debate. We investigated the association of 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 in comparison to endovascular coiling.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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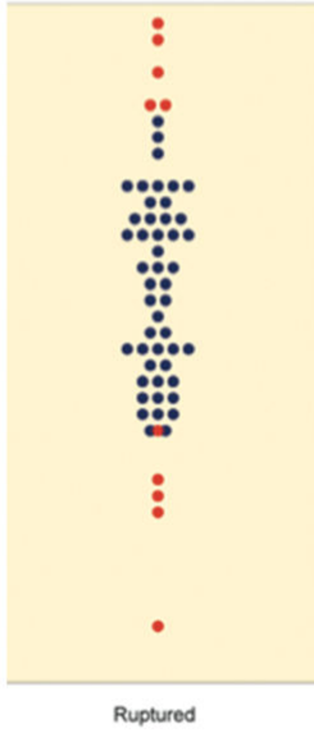

Ruptured	
Fort Lauderdale, FL	98.8%
Nashville, TN	96.6%
Providence, RI	93.2%
Camden, NJ	88.9%
Honolulu, HI	88.8%
Chicago, IL	55.3%
Dallas, TX	51.4%
San Antonio, TX	48.7%
Phoenix, AZ	48.3%
Atlanta, GA	36.3%

Figure 1.
Percent of Medicare beneficiaries treated for ruptured cerebral aneurysms using coiling (2007–2012). Each blue dot represents the percent of Medicare beneficiaries who were treated for ruptured cerebral aneurysms with coiling in one of 306 hospital referral regions in the U.S. Red dots indicate the regions with the 5 lowest and 5 highest rates. The names of the latter can be found on the right. (Bekelis K, Goodney RP, Dzebisashvili N, Goodman DC, Bronner KK. *Variation in the Care of Surgical Conditions: Cerebral Aneurysms.* Lebanon, NH, 2014, reproduced with permission)

Table 1

Patient characteristics

	Clipping	**Coiling**	**Z-value**
Age, mean (SD)	73.5 (6.2)	75.3 (6.8)	7.4
Male gender	275 (22.8%)	533 (26.6%)	−2.4
African-Americans	135 (11.2%)	208 (10.4%)	0.7
Income *	$44,800 (17,900)	$45,700(17,700)	−1.4
Poverty *	137 (11.4%)	210 (10.5%)	3.1
Comorbidities ¶			
Hypertension	421 (34.9%)	859 (42.9%)	−4.5
Hyperlipidemia	166 (13.7%)	294 (14.7%)	−0.7
Chronic obstructive pulmonary disease	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	Ø	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	Ø	Ø	0.5
Alcohol abuse	Ø	Ø	−0.8
Dementia	Ø	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

Output represents crude numbers and percentages in parentheses

* 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

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

Table 2

Correlation of clipping with outcome measures

Models	1-year 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

95% CI: 95% Confidence Interval

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

¶ HRR coiling rate (fraction of coiling of total procedures performed) was used as an instrument of choice of treatment

Analyses based on linear regression