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The impact of hybrid neurosurgeons on the outcomes of endovascular coiling for unruptured cerebral aneurysms

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Abstract

Background—The impact of combined practices on the outcomes of unruptured cerebral aneurysm coiling remains an issue of debate. We investigated the association of combined open and endovascular expertise with the outcomes of unruptured cerebral aneurysm coiling.

Methods—We performed a cohort study of 100% of Medicare fee-for-service claims data for elderly patients who underwent endovascular coiling for unruptured cerebral aneurysms from 2007 to 2012. In order to control for confounding we used propensity score conditioning, with mixed effects to account for clustering at the HRR level.

Results—During the study period, there were 11,716 patients, who underwent endovascular coiling for unruptured cerebral aneurysms, and met the inclusion criteria. Of these, 1,186 (10.1%) underwent treatment by hybrid neurosurgeons, and 10,530 (89.9%) by proceduralists who performed only endovascular coiling. Multivariable regression analysis with propensity score adjustment demonstrated lack of association of combined practice with 1-year postoperative mortality (OR, 0.84; 95% CI, 0.58–1.23), discharge to rehabilitation (OR, 1.0; 95% CI, 0.66–1.51), 30-day readmission rate (OR, 1.07; 95% CI, 0.83–1.38) and length of stay (LOS) (adjusted difference, 0.41; 95% CI, −0.26 to 1.09). Higher procedural volume was independently associated with improved outcomes.

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Conflicts of interest
The authors have no conflicts to disclose

Conclusions—In a cohort of Medicare patients, we did not demonstrate a difference in mortality, discharge to rehabilitation, readmission rate, and LOS between hybrid neurosurgeons, and proceduralists only performing endovascular coiling.

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Keywords

cerebral aneurysms; endovascular surgery; elderly; hybrid neurosurgeons; Medicare

INTRODUCTION

Cerebral aneurysm rupture is a devastating event.[1,4] There are two distinct treatment options for unruptured aneurysms to prevent this outcome.[1,11] 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 endovascular surgical approach achieving aneurysm obliteration from within the blood vessel.[1,4] Although neurosurgeons in the United States performed clipping almost exclusively, the training paradigm has changed dramatically in recent years, with a growing number of hybrid neurosurgeons performing both clipping and coiling.[1] Endovascular coiling is also performed by radiologists, or other proceduralists, who solely focus on this approach for the treatment of cerebral aneurysms. It is often questioned whether hybrid neurosurgeons can perform endovascular surgery as successfully and safely as providers focusing only on coiling.

However, limited literature exists attempting to answer this question. De Vries and Boogaarts published a single-center series[6] on the outcomes of coiling of ruptured cerebral aneurysms by two hybrid neurosurgeons. 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 on endovascular coiling. No prior study has investigated the association of combined open and endovascular expertise on the outcomes of unruptured cerebral aneurysm coiling in a national comprehensive cohort of elderly patients.

We performed a cohort study of Medicare patients with unruptured cerebral aneurysms, investigating the association of combined open and endovascular expertise on the outcomes of endovascular coiling. 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 scores.

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) 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. 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 (based on Medicare data) consisting of the secondary approach.

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.

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 hybrid neurosurgeons and physician performing only endovascular coiling (clipping or coiling) therapies we used several methods to address measured confounding, one of which was based on propensities. Initially, to compare death at 1 year postoperatively, 30-day readmission and discharge to rehabilitation between hybrid neurosurgeons and proceduralists focusing on endovascular coiling, we employed a multivariable logistic regression, including all the covariates listed above, the proceduralist's case volume, and the proceduralist's specialty (neurosurgery, radiology, and other). To account for clustering of observations within physicians 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 physicians 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 (based on Medicare data). We repeated all the above analyses considering as hybrid neurosurgeons, those with at least one secondary procedure (e.g. if a neurosurgeon was performing mainly coiling, he was considered as a hybrid if he had performed 1 clipping), and those with more than 5 secondary procedures. Additionally, we applied these 3 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 set the smoothing parameter (i.e. effective degrees of freedom) at 3.0. Lastly, in pre-specified subgroup analyses we examined the differences in outcomes among various specialties (neurosurgeons, radiologists, other), controlling for all covariates listed previously, including case volume. Age and pretreatment comorbidity burden (as reflected by the Charlson Comorbidity Score) were integrated in the initial regressions, and also used for additional stratified analysis. Our results were robust in all these additional analyses.

Given that we had 11,716 patients from 3,246 combined practitioners, and approximately 10% were hybrid practitioners, we had an 80% power to detect a difference in mortality as small as 2.5% among patients treated by hybrid and non-hybrid neurosurgeons, e.g. 4.5% vs 7.0% 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 11,716 Medicare patients who underwent endovascular coiling for unruptured cerebral aneurysms, and met the inclusion criteria for the study. From these patients, 1,186 (10.1%) underwent treatment by a hybrid neurosurgeon, whereas 10,530 (89.9%) underwent treatment by physicians performing exclusively endovascular coiling. The respective distribution of exposure variables between the two types of proceduralists can be found in Table 1.

Mortality

Among patients undergoing endovascular coiling, 93 (4.9%) deaths were recorded (Table 2) in the first year after treatment by a combined proceduralist, and 684 (6.5%) after treatment by interventionalists who only performed coiling. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with increased 1-year mortality (OR, 0.78; 95% CI, 0.54–1.12) 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, 0.77; 95% CI, 0.49–1.22), which persisted after propensity score adjustment (OR, 0.84; 95% CI, 0.58–1.23). (Table 3)

Higher procedural volume was associated with lower mortality, regardless of the focus of the proceduralist's practice. Performing 10–20 (OR, 0.55; 95% CI, 0.41–0.75), 20–50 (OR, 0.52; 95% CI, 0.38–0.71), or more than 50 procedures per year (OR, 0.42; 95% CI, 0.27–0.65) was associated with decreased mortality in comparison to low volume proceduralists (less than 10 coiling procedures per year). Figure 1 demonstrates a graphic representation of the association of proceduralist's case volume with 1-year mortality of patients undergoing endovascular coiling for unruptured cerebral aneurysms.

When controlling for case volume the specialty of the proceduralist had no association with mortality. There was no difference of neurosurgeons from radiologists (OR, 0.85; 95% CI, 0.59–1.22), or other proceduralists (OR, 0.86; 95% CI, 0.53–1.39) performing the operation.

Length-of-stay (LOS)

Among patients undergoing endovascular coiling, the average LOS was 3.1 (SD 4.5) after treatment by a combined proceduralist (Table 2), and 3.5 (SD 5.1) after treatment by interventionalists who only performed coiling. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with increased LOS (adjusted difference, 0.31; 95% CI, −0.38 to 0.99) 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 LOS (adjusted difference, 0.42; 95% CI, −0.24 to 1.08), which persisted after propensity score adjustment (adjusted difference, 0.41; 95% CI, −0.26 to 1.09). (Table 3)

Discharge to a rehabilitation facility

Among patients undergoing endovascular coiling, 90 (4.8%) patients were discharged to rehabilitation (Table 2) after treatment by a combined proceduralist, and 525 (4.9%) after treatment by interventionalists who only performed coiling. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with increased rate of discharge to rehabilitation (OR, 0.97; 95% CI, 0.64–1.46) 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 rate of discharge to rehabilitation (OR, 0.95; 95% CI, 0.57–1.58), which persisted after propensity score adjustment (OR, 1.00; 95% CI, 0.66–1.51). (Table 3)

30-day readmission

Among patients undergoing endovascular coiling, 271 (14.4%) were readmitted within 30 days of discharge (Table 2) after treatment by a combined proceduralist, and 1489 (14.1%) after treatment by interventionalists who only performed coiling. As demonstrated in Table 3, being treated by a combined proceduralist was not associated with higher rate of 30-day readmission (OR, 1.04; 95% CI, 0.81–1.35) 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, 1.03; 95% CI, 0.75–1.42), which persisted after propensity score adjustment (OR, 1.07; 95% CI, 0.83–1.38). (Table 3)

DISCUSSION

In a cohort of elderly patients undergoing endovascular surgical treatment of 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. Proceduralists with higher case volume had improved outcomes, regardless of the focus of their practice, or their specialty. These results were consistent when using propensity score adjustment and controlling for clustering at the physician level. Regional coiling rates are highly variable, ranging from 35% in Modesto, CA, to 98.6% in Tacoma, WA,[1] secondary to the varying expertise and training of the respective providers. Radiologists, neurosurgeons, and other proceduralists perform endovascular coiling. From these, dually trained neurosurgeons, using both open and endovascular techniques, is the fastest growing group.[1]

However, some argue that these skillsets are not compatible, and therefore proceduralists performing only endovascular coiling have superior outcomes. They claim that hybrid neurosurgeons have a diffuse practice and never become experts in this procedure. On the contrary, others believe that dually trained neurosurgeons provide an unbiased and well-considered assessment of which therapy would be indicated in a given patient. De Vries and Boogaarts, both hybrid neurosurgeons, demonstrated low periprocedural complications in their personal series.[6] They treated 80% of their patients with endovascular means. These interventions were associated with combined in-hospital morbidity and mortality of 1.4%. However, the lack of a comparison group of only endovascular proceduralists 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 in this age group. Our analysis for the first time considers the real-world representation of open neurosurgeons, endovascular neurosurgeons, hybrid neurosurgeons, radiologists, and other endovascular specialists 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, supporting the validity of the observed associations.

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 series[5,7] and international investigations[8] have supported that surgeon volume did not correlate with outcomes. However, national studies in the United States have demonstrated evidence to the contrary.[2,10] Barker et al in an cohort of patients undergoing coiling for unruptured aneurysms from the Nationwide Inpatient Sample, demonstrated that higher hospital and surgeon volume were associated with decreased morbidity, but had no significant effect on mortality.[9] In an analysis of a New York State cohort of similar patients, Zacharia et al[13] demonstrated that higher hospital volume was associated with a lower chance of being discharged to rehabilitation.

In our cohort, we consistently found an incremental association of proceduralist volume with lower morbidity and mortality for endovascular coiling of unruptured aneurysms. This effect plateaued at 20 procedures a year. 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 coiling appear to have similar results to their counterparts focusing on this procedure. In addition, when controlling for case volume we did not observe any differences in outcomes between neurosurgeons, radiologists, or other proceduralists performing endovascular coiling. These results highlight that the debate should not focus on the specialty of the physicians performing these procedures, but on their case volume, given the increasing trend of endovascular coiling by low-volume, inexperienced proceduralists.[3]

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, HRR random effects,), 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.[12] 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. Our definition of combined practice is only based on Medicare data, and therefore does not reflect practice patterns among younger patients. However, it is less likely that a surgeon would perform only one approach (i.e. endovascular) for all his Medicare patients in the span of 6 years of the study, and follow a different practice pattern in their younger patients. Fifth, we cannot analyze any potential selection biases on aneurysms treated by open or endovascular means. However, the present analysis focuses only on endovascular approaches. Additionally, 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. Sixth, we could not analyze, based on the available data, the percentage of non-aneurysmal cases for proceduralists performing only endovascular approaches. Lastly, causal inference is hard to establish based on observational data, even when using advanced observational techniques.

Conclusions

The impact of combined practices on the outcomes of unruptured cerebral aneurysm coiling remains an issue of debate. In a cohort of elderly patients undergoing endovascular surgical treatment of 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. Proceduralists with higher case volume had improved outcomes, regardless of the focus of their practice, or their specialty. Future comparative effectiveness studies will likely need to be based on prospective registries, using quality outcome metrics, when determining which approach is best.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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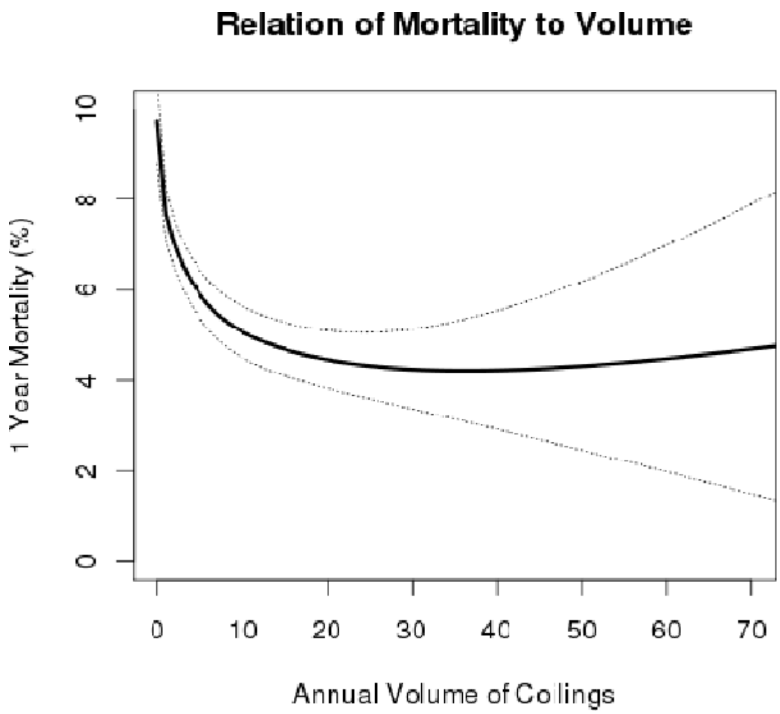

Figure 1.

LOWESS (Locally Weighted Scatterplot Smoothing) graph demonstrating the relationship of annual endovascular coiling volume of the proceduralist with 1-year postoperative mortality

Table 1

Patient characteristics

	Treatment by non-hybrid neurosurgeons	Treatment by hybrid neurosurgeons	Z-value
Age, mean (SD)	72.4 (5.2)	72.2 (5.1)	−1.5
Male gender	2,506 (23.9%)	386 (20.5%)	−3.2
African-Americans	734 (7.0%)	132 (7.0%)	0.1
Income *	$46,700 (16,900)	$48,268 (17,626)	3.5
Poverty *	952 (9.4%)	162 (9.0%)	−2.4
Comorbidities ¶			
Hypertension	5,529 (52.5%)	1,008 (53.4%)	0.8
Hyperlipidemia	2,383 (22.6%)	473 (25.1%)	2.3
Chronic obstructive pulmonary disease	267 (2.5%)	49 (2.6%)	0.2
Myocardial infarction	1,533 (14.6%)	220 (11.7%)	−3.3
Cardiac arrhythmia	804 (7.6%)	123 (6.5%)	−1.7
Coagulopathy	102 (1.0%)	12 (0.6%)	−1.4
Renal insufficiency	381 (3.6%)	57 (3.0%)	−1.3
Congestive heart failure	461 (4.4%)	64 (3.4%)	−2.0
Pulmonary disease §	261 (2.5%)	53 (2.8%)	0.8
Obesity	83 (0.8%)	18 (1.0%)	0.7
Alcohol abuse	33 (0.3%)	∅	
Dementia	138 (1.3%)	13 (0.7%)	−2.3
Ischemic stroke	1,260 (12.0%)	224 (11.9%)	−0.1
Diabetes	1,529 (14.5%)	273 (14.5%)	−0.1
Peripheral vascular disease	1,357 (12.9%)	277 (14.7%)	2.1
Malignancy	805 (7.6%)	121 (6.4%)	−1.9

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

∅ 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	684 (6.5%)	93 (4.9%)	0.683
30-day readmission	1,489 (14.1%)	271 (14.4%)	0.282
Discharge to rehabilitation	525 (5.0%)	90 (4.8%)	0.351
Length-of-stay (SD)	3.5 (5.1)	3.1 (4.5)	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

Model	Crude		Multivariable Regression Adjusted*		Propensity Score Controlled*	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
1-year mortality⌘	0.78 (0.54–1.12)	0.167	0.77 (0.49–1.22)	0.062	0.84 (0.58–1.23)	0.364
Discharge to rehabilitation⌘	0.97 (0.64–1.46)	0.866	0.95 (0.57–1.58)	0.853	1.00 (0.66–1.51)	0.996
30-day readmission⌘	1.04 (0.81–1.35)	0.746	1.03 (0.75–1.42)	0.857	1.07 (0.83–1.38)	0.597
	Difference (95% CI)	P-value	Difference (95% CI)	P-value	Difference (95% CI)	P-value
Length-of-Stay°	0.31 (−0.38 – 0.99)	0.370	1.03 (0.75–1.42)	0.857	1.07 (0.83–1.38)	0.597

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

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

⌘Analyses based on logistic regression

°Analyses based on linear regression; point estimates are beta coefficients