Using Small Area Variations in Procedure Rates to Identify Effects of Revascularization Among the Elderly

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Abstract

Among elderly Medicare patients with acute coronary syndromes, the regional ratio of surgical treatmnts (percutaneous angioplasty with stenting versus coronary artery bypass graft) based on the location of a beneficiary's residence may affect the choice of treatment in a way that is conceptually and empirically distinguishable from the revascularization provider's volume (skill or experience) effect on outcome. This study uses Medicare claims data for Medicare beneficiaris admitted to the hospital for ACS from July 2003 until October 2004 to assess the choice of initial revascularization treatment and differences in subsequent health outcomes (post-discharge mortality and repeat revascularizations). The analysis uses small area variations in procedure rates by hospital referral region to identify the choice of procedure. The analysis of treatment effect on outcome (repeat revascularization or death within one year following initial revascularization) controls for hospital-specific productivity/volume effects on quality. The analysis provides two important contributions. First, it adds to our understanding of the effect of small area variations on treatment choice. Second, the analysis will demonstrate whether small area variations over time in procedure rates can help identify the effects of different treatment strategies.

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Introduction

The diffusion experiences of the two main types of revascularization commonly used to treat elderly patients diagnosed with coronary disease, percutaneous angioplasty with stenting (PCIS) and coronary artery bypass graft (CABG), have differed substantially over the last two decades. Figure 1 uses data from the Hospital Cost and Utilization Project to show that from 1997 through 2005, the rate of PCI (with or without stenting) for persons aged 65-84 increased 31% (from 847 to 1,110 per 100,000 elderly), while the rate of CABG declined by 48% (from 717 to 375 per 100,000 elderly) (Sheridan, Stearns, Massing et al. 2008). For persons aged 85 or older, PCI rates increased by 100%, and CABG rates declined somewhat, though the magnitudes of changes for this age group are affected by the baseline (1977) rates which were smaller for both procedures. Considerations such as the less invasive nature of PCI relative to CABG and approval by the Food and Drug Administration of drug-eluting stents for PCI in April 2003 help explain the different diffusion experience of these two procedures. Yet the dramatic decline in CABG rates is surprising since a number of studies indicate better outcomes (lower rates of repeat revascularization and mortality) from CABG (Serruys, Ong, van Herwerden et al. 2005; Bravata, McDonald, Gienger et al. 2007; Hannan, Wu, Walford et al. 2008) as well as greater cost-effectiveness (Yock, Boothroyd, Owens et al. 2003). Furthermore, the documented compression of morbidity over the last two decades means a greater proportion of the elderly may be good candidates for revascularization including CABG.

A central issue of interest, therefore, becomes the relative effectiveness of these two revascularization procedures in the elderly population. Many of the randomized trials to date have only had limited numbers of elderly subjects, yet using observational data to analyze differences in outcomes is problematic because of the underlying patient selection that may occur in determining which procedure candidates for revascularization receive. Some patients are clear candidates for one technique or another; for example, CABG is usually preferred for patients with left main coronary artery disease or triple-vessel disease with reduced left ventricular function, while PCIS is usually preferred for patients with single-vessel disease (Bravata, McDonald et al. 2007). Yet a middle range between these extremes consists of patients who arguably could be well-served by either PCIS or CABG. The problem is compounded by the fact that patients with heart disease are often seen first by cardiologists who may be inclined to favor PCIS over referral of patients to cardiothoracic surgeons for evaluation; even without considering the highly debated argument of provider-induced demand, many patients may indicate a preference for PCIS to their cardiologists because of the less invasive nature and more immediate pain relief provided by the procedure (vanDomburg, Daemen, Pedersen et al. 2008). Finally, the value of using resource-intensive revascularization techniques in extremely old but healthy individuals may be questioned on broader grounds given high competing mortality risks, though factors such as reluctance by physicians to proceed with revascularizations in patients with a life expectancy of less than one year could help ensure that sufficient returns are achieved to warrant intervention.

Instrumental variable techniques have been used to address the underlying problem of selection in treatment choice in seminal analyses of the effect of cardiac catheterization (McClellan, McNeil and Newhouse 1994). More recently, Chandra and Staiger (2007) used differential distance as an instrument in an analysis of the productivity spillovers in the treatment of heart attacks, specifically the use and effects of cardiac catheterization. These authors argue that the lack of empirical association between surgical volume and outcomes across different areas may be better explained by productivity spillovers that improve surgical outcomes in high volume areas among patients most appropriate for surgery and negatively affects outcomes among patients least appropriate for surgery. Their results reject the notion of flat-of-the-curve medicine as an explanation of the empirical observation that on average high rates of surgery are not positively associated with overall outcomes in an area. Their work implies that small area variations cannot be used as an instrument to identify treatment choice because variation in treatment volume across geographic areas is not only related to variation in treatment choice for an individual patient but is also intrinsically related to the outcome experience by patients (e.g., through productivity spillovers or volume/experience effects).

In this paper, we propose that small area variations in treatment rates according to where a patient lives may affect the choice of treatment in a way that is conceptually and empirically distinguishable from a volume productivity (skill or experience) effect on outcome that likely holds for the provider actually providing the revascularization treatment. So while we endorse the basic premise of Chandra and Staiger (2007), we believe that small area variations can be used for identification in specific applications such as the choice of revascularization treatment.

This study uses Medicare claims data for persons admitted to the hospital for acute coronary syndromes (ACS) from July 2003 until October 2004 to assess the choice of initial revascularization treatment and differences in subsequent health outcomes including post-discharge mortality and repeat revascularizations. The analysis uses small area variations in procedure rates by hospital referral region (HRR) to identify the choice of procedure. The analysis of treatment effect on outcome (repeat revascularization or death within one year following initial revascularization) controls for provider-specific productivity/volume effects on quality. The analysis provides two important contributions. First, it adds to our understanding of the effect of small area variations on treatment choice. Second, the analysis will demonstrate whether small area variations over time in procedure rates can help identify the effects of different treatment strategies.

Background

The idea that higher surgical volumes are associated with improved outcomes has been supported by a number of studies, though the evidence with respect to cardiac procedures such as angioplasty is mixed (Ho 2002). More recent discussion of volume effects has focused on the issue that area-specific procedure rates may affect not only the likelihood of getting a certain procedure but may also affect outcomes, thereby precluding the use of small area variations in procedure rates to identify a treatment effect. Specifically, Chandra and Staiger (2007) show that although area rates are unrelated to outcomes on average, they are related to outcomes for certain types of patients. For example, a patient who is "most appropriate" for a CABG and gets a CABG in an HRR with high CABG rate will have good outcomes, while a patient who is "least appropriate" for a CABG (i.e., "most appropriate for a PCIS") and gets a CABG in an HRR with a high CABG will have poor outcomes. In an analysis of inpatient hospital mortality after cardiac procedures, Sfekas (2008) claimed to deal with bias from selection while controlling for volume effects in his outcome equation, but his approach was only identified by functional form and does not therefore provide a useful alternative to Chandra and Staiger's concerns.

We argue that three considerations are relevant to the treatment choice for a patient needing revascularization: (1) the geographic area in which a patient lives; (2) the location of the provider (physician or hospital) where a patient presents with ACS (which in most cases will be relatively close to the patient's home); and (3) the provider who actually performs the revascularization. An important distinction exists between the effect of small area variations in procedure rates in which the beneficiary lives (which will affect the likelihood of getting a procedure) and the provider-specific volume of that procedure (which will affect procedure outcome). While these two rates are undoubtedly correlated, the fact that they are conceptually different means that the validity of using small area variations in procedure rates to identify treatment effects (separate from provider-specific volume/experience effects) becomes an empirical question.

HRRs are a good candidate for defining the small area relevant for the volume measure for the geographic area in which a beneficiary lives. HRRs are defined in the *Dartmouth Atlas* (Wennberg and Cooper 1999) by determining where Medicare patients were referred for major cardiovascular surgical procedures and for neurosurgery. The *Dartmouth Atlas* aggregates 3,436 hospital service areas into 306 HRRs, and each HRR has at least one city where both major cardiovascular surgical procedures and neurosurgery were performed. Figure 2 provides an example of HRRs for the south Atlantic region; as shown in this figure, patients being referred for cardiovascular surgery may travel over 100 miles from the southern portion of North Carolina for treatment in the Durham HRR area. The rate at which PCIS are done in the HRR (relative to the rate of CABG) likely affects the choice of revascularization treatment for the patient. Once the patient is referred to a specific hospital, however, the outcome from surgery is likely affected by the revascularization provider's volume of revascularization.

Methods

Our goal is to determine the effect of PCIS (as opposed to CABG) on first year outcomes (repeat revascularization or death) for Medicare beneficiaries age 65 and older who have not had a prior revascularization but are admitted to a hospital with symptoms of ACS and receive revascularization within 28 days of the initial admission. Treatment choice will be modeled as a function of patient characteristics and the area-specific procedures rates. Variations in the area-specific procedure rates allow identification of the endogenous treatment effect of PCIS relative to CABG. We will estimate the effect of PCIS, compared to CABG, on selected outcomes in an instrumental variables approach (IV) assuming that patients whose probability of receiving PCIS is determined largely by where they live. The outcome analyses will use two important sets of control variables for the hospital providing the initial revascularization: procedure volume measures to control for experience, and hospital fixed effects to control for unobserved time-invariant hospital characteristics that might affect outcomes.

Specifically, we propose the following IV model for Medicare patients conditional upon their receiving some type of revascularization:

$$(1)\ PCIS_{it} = \alpha_0 + \alpha_1 PAT_{it} + \alpha_2 IV_{it} + \alpha_3 TFE_t + e_{1it}$$

$$(2)\ REVAS2_{it} = \beta_0 + \beta_1 PAT_{it} + \beta_2 PCIS\_HAT_{it} + \beta_3 VOLUME_{it} + \beta_4 HFE_i + \beta_5 TFE_t + e_{2it}$$

We will estimate the model with one observation per patient constructed from the hospital MedPAR record in which the patient received their initial revascularization (which may or may not have been the "onset admission with an ACS diagnosis" used to select them into the sample, as defined in the data section below). In the model above, $PCIS_{it}$ is a dummy indicating the i^{th} patient got a stent (rather than a CABG) within 30 days of their "onset admission," PAT_{it} is a vector of patient characteristics at the time of the revascularization admission (age, comorbidities), IV_{it} represents instrumental variables for identification (discussed below), and TFE_t represents time fixed effects measured as the revascularization month and year. The dummy dependent variable in the second equation, $REVAS2_{it}$, indicates whether the patient received a repeat (second) revascularization or died within one year of the initial revascularization, $PCIS\_HAT_{it}$ is a prediction of whether the patient received PCIS as the initial revascularization, $VOLUME_{it}$ represents a vector of indicators of average PCIS and CABG Medicare volumes over the last six months at the hospital where the initial revascularization was performed, HFE_t represents hospital fixed effects corresponding to the hospital performing the initial revascularization, and TFE_t represents time fixed effects measured as the revascularization month and year.

The instrumental variables in the first equation are critical for identifying the effect of receiving PCIS rather than CABG in the second equation. To construct our instruments, we use rates of PCIS and CABG corresponding to the HRR in which the beneficiary lives. The *Dartmouth Atlas* defines the annual rates for the 306 HRRs as:

$$\text{PCIS (or CABG) rate} = \frac{\text{number of PCIS (or CABGs) in Medicare Beneficiaries in HRR}_j}{\text{1,000 of Medicare Beneficiaries in HRR}_j}$$

We consider two sets of instruments in the first equation. First, we consider a single instrument of the PCIS rate divided by the CABG rate to account for the relative procedure rate in the HRR in which the beneficiary lives. We believe that this measure is the most important exogenous predictor of treatment choice that is not correlated with outcome; people who live in areas where more PCIS are done relative to CABG should simply be more likely to get a PCIS. To strengthen our model, however, it is desirable to have more than one instrument so that the model will be overidentified. We hypothesize that the ratio of PCIS to CABG may be non-linearly related to the likelihood someone receives a PCIS. Instead of including the single ratio, we use two splines that allow the effect of the ratio to be different above and below a ratio of two (where a value of two corresponds to roughly the 25^{th} percentile of the distribution of the ratio in the analysis sample). We test both models for exogeneity of the PCIS indicator used in the second equation, and we test for overidentification in the model that includes the splined instruments.

Given how successful the idea of "differential distance" has been in identifying the effects of cardiac catheterization in past analyses (McClellan, McNeil et al. 1994; Chandra and Staiger 2007), we plan to consider in future work whether an additional instrumental variable of the differential distance to a "high PCIS volume" provider could be developed. However, since many ACS patients are transferred after being stabilized from the original admitting hospital to other hospitals for catheterization and subsequent revascularization (approximately 18% of our analysis sample), the idea of differential distance may not work as well in a model to detect the effect of PCIS versus CABG on outcomes. We still expect that geographic proximity has some value for patients, so that whether or not the "revascularization hospital" closest to where the beneficiary lives is performing PCIS at a relatively higher rate than the next closest revascularization hospital may have some impact on the likelihood a patient gets a PCIS. For example, we could try to develop a measure of the differential distance between the closest revascularization hospital and the next closest revascularization hospital; the measure could be equal to zero if the closest hospital has a higher PCIS rate than the next closest revascularization hospital.

Since our PCIS and CABG ratio variable(s) are defined according to the HRR corresponding to the beneficiary's zip code, measurement error may arise for cases such as so-called "snowbirds" who live in the Midwest or Northeast but spend part of the year in the warmer south (e.g., Arizona or Florida). In future work, we will adjust for this possibility and see whether the results are changed substantially by dropping observations where the beneficiary zipcode is more than some specified distance from the hospital where the patient received the initial revascularization.

Data

To identify our sample, we first selected one million Medicare beneficiaries age 65 and older who had an acute care hospital discharge (MedPAR record) from January 2003 through mid-October 2004 with an ACS diagnosis and no diagnosis indicating prior revascularization or valve disease. We called this stay the "onset admission" and then obtained all MedPAR records for these individuals from 2002 through 2006. We used the MedPAR records prior to the onset admission to further exclude patients who had hospital stays with selected diagnoses or procedures indicating revascularizations or other exclusion conditions (e.g., valve disease, heart transplant) prior to the onset admission.

We then used the onset admission record and subsequent MedPAR records to identify all patients who had PCIS (DRG codes 516, 517, 555, 556 for bare-metal stents or codes 526, 527, 557, 558 for drug-eluting stents) or CABG (DRG codes 106, 107, 109, 547, 548, 549, or 550) within 28 days at any hospital (not necessarily the onset admission hospital). Because we needed six months of data to calculate our revascularization volume measures for the hospitals performing revascularations, we kept all beneficiaries whose onset admission date was after July 1, 2003 for the final analysis sample, merged these records with Medicare denominator file records, and used the MedPAR records to determine repeat revascularizations through December 2006.[1] This process resulted in an analysis sample of 164,091 records for unique beneficiaries with information for the onset admission, revascularization admission (if different from the onset

[1] An important limitation of this hospital volume measure is that we currently are only able to construct is using the MedPAR records for the 1 million beneficiaries with ACS who were part of our original data request rather than all Medicare beneficiaries.

admission), and time to repeat revascularization or death. We used coding from the Agency for Healthcare Quality and Research (AHRQ) to construct comorbidity measures.[2]

For the volume measure in the second equation, we use the six month moving average of PCIS or CABG done by the revascularization hospital in our patient sample. AHRQ has developed inpatient quality measures that recommend threshold quality volumes (Level 1) of 100 procedures per year for CABG and 200 procedures per year for PCIS (AHQR 2008).

For this preliminary analysis, linear probability models (LPM) were used to estimate both equations 1 and 2. Standard errors in equation 2 have not yet been corrected for the use of predicted PCIS,[3] but the large sample size means that standard errors should be approximately correct.

Results

Figure 3 shows the pattern of initial revascularizations (by type of revascularization) in our analysis sample over time. Although Figure 1 showed declines in CABG and increases in PCIS over a longer time period, the overall rates of PCIS and CABG are fairly stable. Drug-eluting stents, which were approved for use in April 2003, are increasingly used in lieu of bare-metal stents. (In future work we will model outcomes separately for bare–metal versus drug-eluting stents. We posit that the availability of drug-eluting stents did not substantially shift the threshold for decisions to conduct PCIS in lieu of medical management of ACS, though the

[2] See www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp for the coding algorithm we used. For future analyses, we plan to add additional measures we didn't have time to construct for this analysis, including race, ethnicity, and other aspects of heart disease including prior AMI, unstable angina, and smoking.

[3] Stata has a command xtivreg that will correct the standard errors automatically, but the need to include provider fixed effects in only the second equation required separate LPM estimation of each equation.

availability of drug-eluting stents most likely changed the threshold for the choice between PCIS and CABG.)

Figure 4 shows the distribution of initial revascularization by patient age group and type of revascularization (PCIS versus CABG). The frequency of revascularizations is highest for beneficiaries who are between 70 and 74 years of age, and only a small number of Medicare beneficiaries get an initial revascularization beyond age 90. Beneficiaries are approximately twice as likely to get a PCIS rather than a CABG as their initial revascularization regardless of age (except that only very few CABGs are done beyond age 90).

Table 1 provides descriptive statistics for the analysis sample, in total and by whether the beneficiary's initial revascularization was PCIS. Among the 164,091 sample members, 65% received PCIS as their initial revascularization. Within one year of the initial revascularization, 4.81 percent were revascularized and 9.38 percent died, resulting in 14.3% of the sample either being revascularized ***or*** dying within one year. Persons who received PCIS for their initial revascularization were more than twice as likely to be revascularized or die within one year (18% versus 7%). The ratio of the HRR rates of PCIS to CABG, which is the main IV, ranges from 1.00 to 9.26 PCIS per CABG, with a sample average of 2.38.[4] We assessed correlations between the HRR ratio and the revascularization hospital PCIS and CABG volume measures. The correlations were small (less than 0.2). Roughly 74% of the sample is age 65 to 79; persons receiving PCIS as their initial revascularization are slightly less likely to be under age 80 and slightly more likely to be over age 80 than persons receiving CABG. Approximately 64% of patients lived in a urban area.[5] Except for the presence of hypertension (63%), diabetes without

[4] The HRR rate of PCIS per 1,000 Medicare beneficiaries ranges from 3.6 to 43.7, with a sample average of 11.4; the HRR rate of CABG per 1,000 Medicare beneficiaries ranges from 1.8 to 9.9, with a sample average of 6.45.
[5] In these preliminary models, we only controlled for urbanicity of the patient's residence in the PCIS choice equation based on the reasoning that the hospital fixed effects would control for urbanicity of revascularization

complex complications (23%), and chronic pulmonary disease (17%), the rates of other comorbidities are relatively low, which is consistent with the idea that people with fewer comorbidities in general are referred to surgical revascularization relative to other Medicare beneficiaries with ACS who may be treated medically. Rates of comorbidities are slightly higher for most of the disease indicators for persons receiving CABG, which is consistent with the idea that CABG patients generally have more severe case mix.

Table 2 provides regression results for all models. Column 1 provides an unadjusted estimate of the difference in the outcome of having a repeat revascularization or death within one year of the initial revascularization (an effect of 11.0 percentage points); the estimate in Column 2 which adjusts for patient characteristics and revascularization hospital fixed effects is virtually unchanged. Columns 3 & 4 provide the results from the instrumental variables two equation estimate; the HRR PCIS to CABG ratio is statistically significant in predicting who gets a PCIS (p=0.000), and a test of exogeneity indicated that PCIS is endogenous in equation 2. The estimated effect of having a PCIS versus a CABG on the "repeat revasc or die" outcome is slightly less at 10.1 percentage points. The hospital PCIS and CABG volume measures in equation 2 (column 4) are not statistically significant, possibly because these measures are likely highly correlated with the hospital fixed effects. We explored this possibility by estimating the IV model without hospital fixed effects in the outcome equation (column 5); while the volume measures become statistically significant (with the expected positive coefficient on the PCIS volume measure), the estimated effect of PCIS on outcomes becomes unbelievably large at 31.4%, most likely because of substantial bias from not controlling for hospital fixed effects that

hospital. In future models, however, we will include urbanicity of patient's residence in the outcome equations also. Urbanicity is defined using Rural-Urban Commuting Area Codes from the University of Washington Rural Health Research Center (http://depts.washington.edu/uwruca/approx.html).

control for time-invariant hospital characteristics that likely have a substantial effects on outcomes.

Because overidentification is always preferred, we estimate a second IV model in which we include two ratio measure splines that allow the effect of the ratio on the choice of PCIS to vary for beneficiaries living in a low ratio area (ratio less than two) versus a high ratio area (ratio greater or equal to 2). Column 6 shows that both measures are significantly and positively related to PCIS choice, with a greater marginal effect at low levels of the ratio. The F test strongly supported the strength of the instruments, and a test of exogeneity showed that PCIS is endogenous. However, the estimated effect of PCIS on outcome only changed by a small amount, and the test of overidentification failed to support the two instruments jointly. As a result, the model with the single ratio entered may be best even though the identification of the model cannot be tested.

Discussion

This analysis provides a preliminary estimation of the effect of PCIS on first year outcomes using an IV approach to adjust for the selection bias that is often inherent when using observational data to analyze treatment choice. The use of the HRR ratio of PCIS to CABG as an instrument did reduce the effect of PCIS on outcomes by about 1 percentage point; this estimate is modest relative to the adjustment that happens in some IV estimations, though the change represents approximately a 10% decrease in the estimated effect, which may be clinically significant. We did find greater effects in some estimations not shown,[6] and further data

[6] We found a coefficient of about 8 percentage points using a model that included absolute PCI volume as an instrument in addition to the ratio and excluded the urban indicator (which was not available for all patients), but because of the lack of a conceptual justification for the absolute volume measure and the need to clean the data further to attribute the urban measure to all observations, we chose not to present that model in this paper.

cleaning and manipulation needs to be done before finalizing the models. Yet the use of the HRR ratio may provide a promising way to use small area variations to try to identify the effects of surgical treatments while still allowing hospital-specific surgical volume to have an effect on patient outcomes.

Figure 1: CABG and PCI Procedure Rates and Diffusion By Age Group 1997 to 2005
(Sources: principal procedures from www.hcupnet.ahrq.gov and population data from www.census.gov/popest/estimates.php)

Figure 1a. Procedures per 100,000 persons aged 65-84.

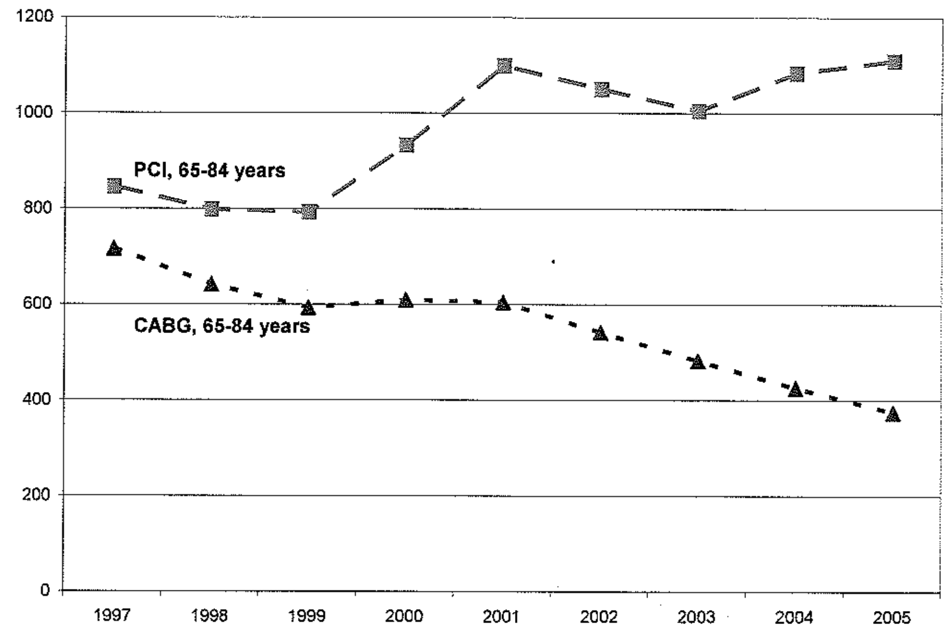

Figure 1b. Procedures per 100,000 persons aged 85+.

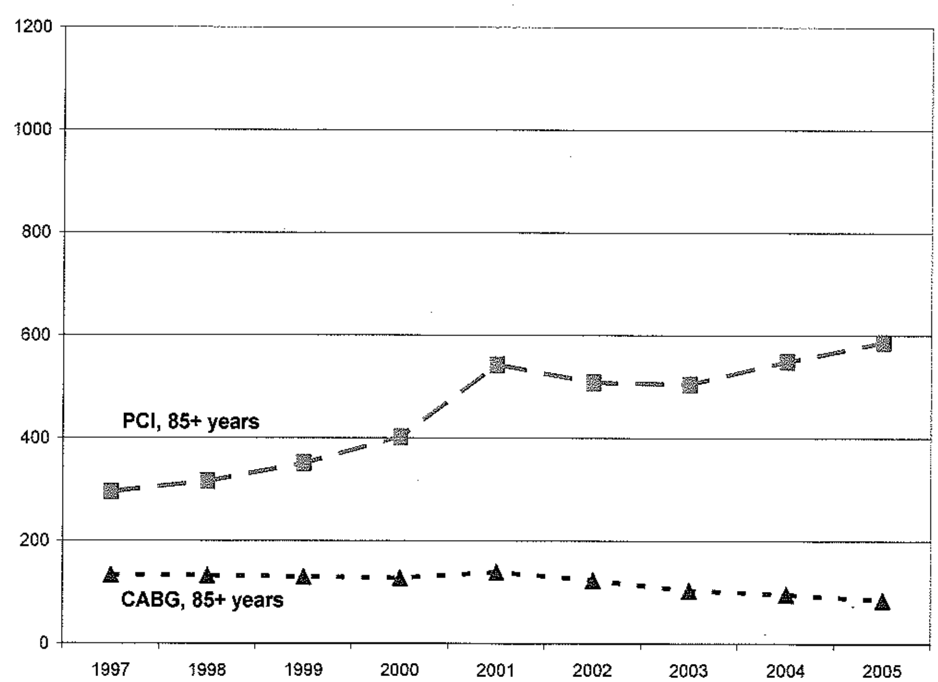

Figure 2: Example of Hospital Referral Regions (Map of South Atlantic HRR) (Source: Appendix on the Geography of Healthcare in the US, p. 299 http://www.dartmouthatlas.org/faq/geogappdx.pdf)

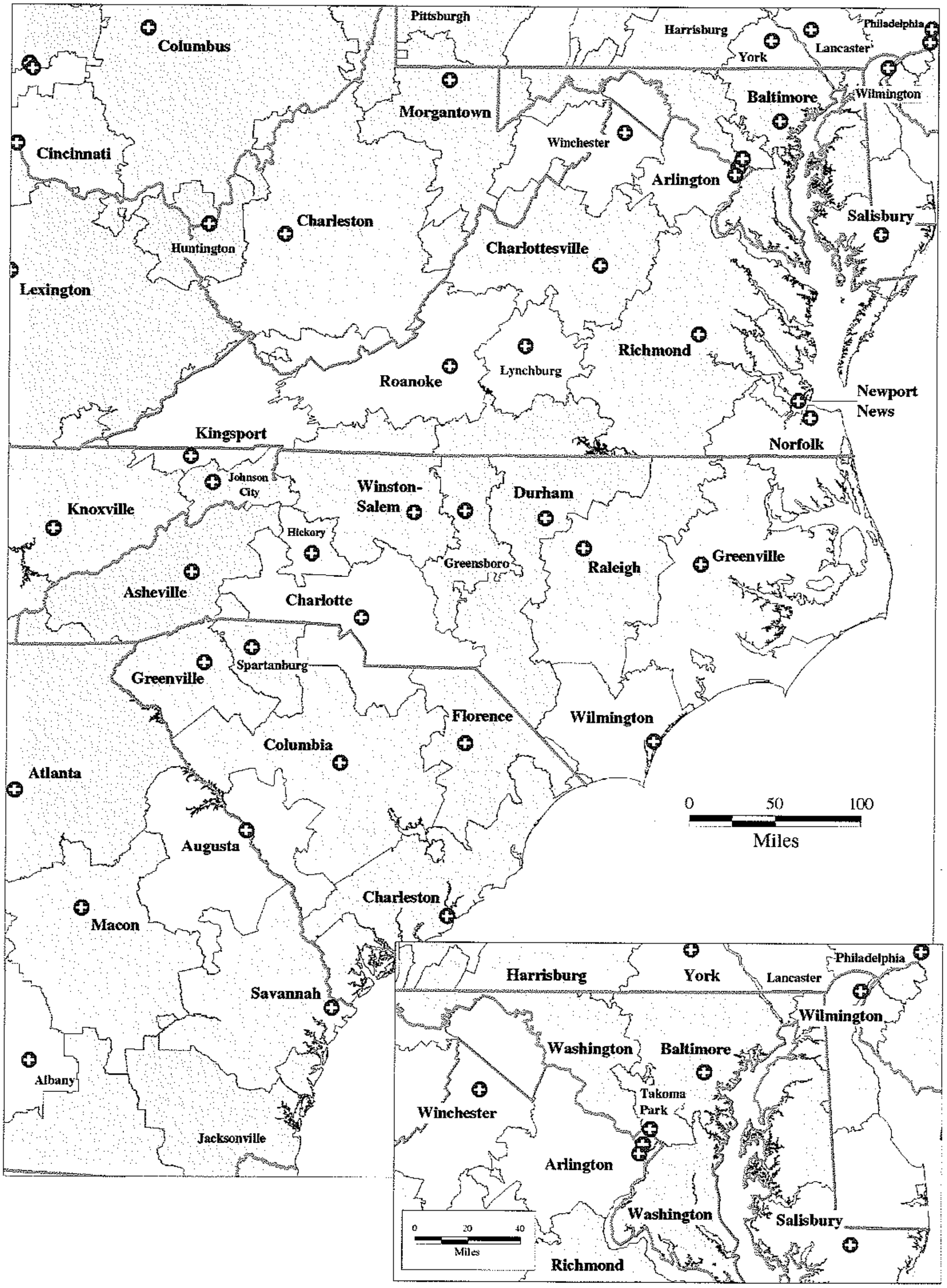

Figure 3: Analysis Sample Initial Revascularizations over Time

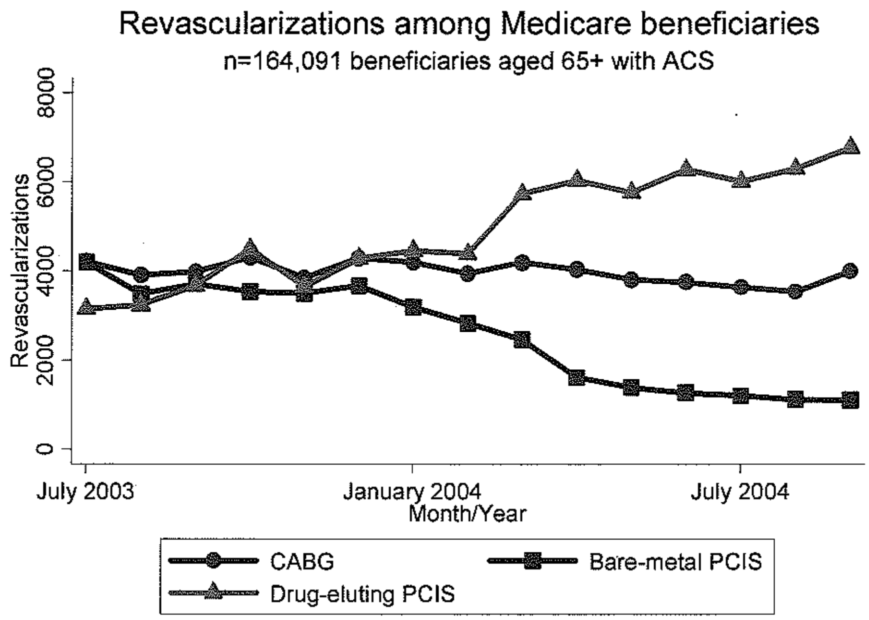

Figure 4: Analysis Sample Initial Revascularizations by Patient Age

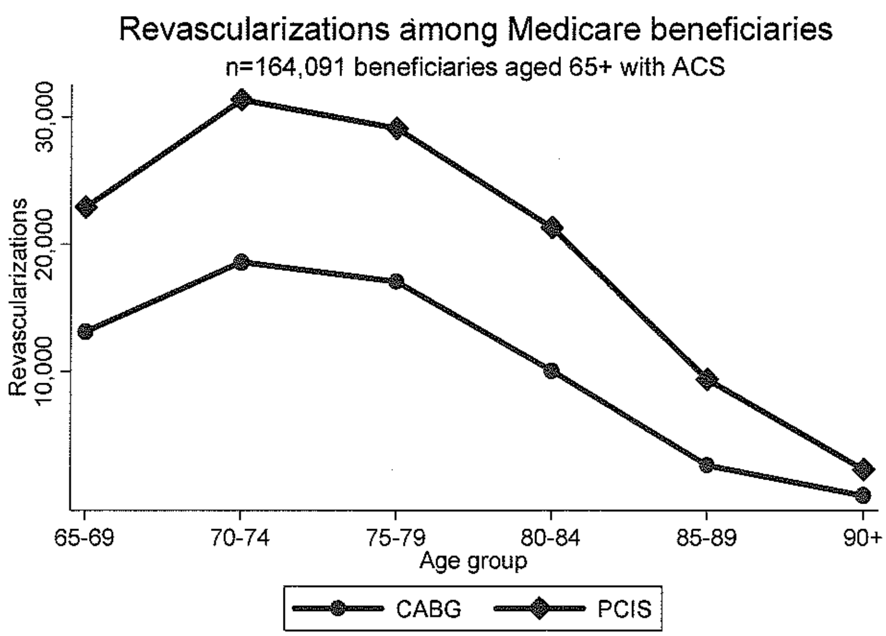

Table 1: Descriptive Statistics (n=164,091)
(All variables except the HRR PCIS to CABG ratio are dichotomous variables)

VARIABLES	Total n=164,091	CABG n=57,171	PCIS n=106,920
Dependent Variables			
PCIS for Initial Revascularization	0.65	0.00	1.00
Repeat Revascularization or Death within One Year	0.14	0.07	0.18
PCIS Choice Equation 1 Instruments (HRR Procedure Rates)			
HRR Ratio of PCIS to CABG	2.38	2.29	2.43
Outcome Equation 2 Revasc Hospital Surgical Volumes (monthly moving average over prior 6 months)			
Revasc Hospital PCIS Volume			
Revasc Hospital CABG Volume			
Beneficiary Characteristics			
Age 65-69	0.20	0.22	0.20
Age 70-74	0.28	0.30	0.27
Age 75-79	0.26	0.27	0.25
Age 80-84	0.17	0.16	0.18
Age 85-89	0.07	0.04	0.08
Age 90+	0.01	0.00	0.02
Male	0.56	0.65	0.51
Urban Residence	0.64	0.62	0.65
Comorbidities			
Other conditions	0.03	0.03	0.02
Peripheral vascular disease	0.10	0.11	0.09
Hypertension	0.63	0.63	0.64
Other neurological disorders	0.02	0.02	0.03
Chronic pulmonary disease	0.17	0.20	0.16
Diabetes w/o chronic complications	0.23	0.25	0.22
Diabetes w/ chronic complications	0.02	0.03	0.02

VARIABLES	Total n=164,091	CABG n=57,171	PCIS n=106,920
Hypothyroidism	0.09	0.07	0.09
Renal Failure	0.02	0.03	0.02
Solid tumor w/out metastasis	0.01	0.01	0.01
Rehumoatoid arthritis/collagen vas	0.02	0.01	0.02
Coagulopthy	0.03	0.07	0.02
Obesity	0.06	0.06	0.05
Fluid and electrolyte disorders	0.09	0.14	0.06
Deficiency Anemias	0.07	0.09	0.06
Alcohol Abuse	0.01	0.01	0.01
Psychoses	0.01	0.01	0.01
Depression	0.02	0.02	0.03

Table 2: Linear Probability Model Estimation Results

VARIABLES	(1) Outcome Simple OLS	(2) Outcome Naïve OLS Hospital FE	(3) PCIS Choice One IV	(4) Outcome One IV Hospital FE	(5) Outcome One IV, No FE	(6) PCIS Choice Two IV	(7) Outcome Two IV Hospital FE
Outcome Equation 2: Effect of PCIS versus CABG							
PCIS for Initial Revascularization	0.110***	0.111***					
	(0.002)	(0.002)					
Predicted PCIS (1 IV)				0.101***	0.314***		
				(0.034)	(0.020)		
Predicted PCIS (Low & High IVs)							0.103***
							(0.033)
PCI Choice Equation 1: Instruments (HRR Procedure Rates)							
HRR Ratio of PCIS to CABG			0.069***				
			(0.002)				
Low HRR PCIS to CABG Ratio (Ratio <2)						0.154***	
						(0.007)	
High HRR PCIS to CABG Ratio (Ratio >=2)						0.053***	
						(0.002)	
Outcome Equation 2: Revasc Hospital Surgical Volumes (monthly moving average over prior 6 months)							
Revasc Hospital PCIS Volume		-0.000		-0.001	0.001***		-0.001
		(0.001)		(0.001)	(0.000)		(0.001)
Revasc Hospital CABG Volume		-0.000		0.001	-0.003***		0.001
		(0.001)		(0.001)	(0.000)		(0.001)
Beneficiary Characteristics (Splines)							
Age 65-69		0.002	-0.003*	0.001	0.002*	-0.003*	0.001
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age 70-74		0.001**	-0.003***	0.001**	0.002***	-0.003***	0.001**

VARIABLES	(1) Outcome Simple OLS	(2) Outcome Naïve OLS Hospital FE	(3) PCIS Choice One IV	(4) Outcome One IV Hospital FE	(5) Outcome One IV, No FE	(6) PCIS Choice Two IV	(7) Outcome Two IV Hospital FE
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age 75-79		0.001	0.005***	0.001	0.000	0.005***	0.001
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age 80-84		0.003***	0.014***	0.003***	0.001	0.014***	0.003***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age 85-89		0.001	0.026***	0.001	-0.004**	0.026***	0.001
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age 90+		0.007**	0.010**	0.007**	0.005	0.010**	0.007**
		(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)
Male		0.010***	-0.121***	0.009**	0.033***	-0.121***	0.009**
		(0.002)	(0.002)	(0.004)	(0.003)	(0.002)	(0.004)
Urban Residence			0.015***			0.014***	
			(0.002)			(0.002)	
Comorbidities							
Other conditions		0.072***	-0.056***	0.071***	0.082***	-0.056***	0.071***
		(0.005)	(0.007)	(0.005)	(0.005)	(0.007)	(0.005)
Peripheral vascular disease		0.019***	-0.054***	0.019***	0.031***	-0.054***	0.019***
		(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)
Hypertension		-0.010***	-0.014***	-0.010***	-0.007***	-0.014***	-0.010***
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Other neurological disorders		0.014***	0.044***	0.014**	0.006	0.044***	0.014**
		(0.005)	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)
Chronic pulmonary disease		0.031***	-0.058***	0.031***	0.044***	-0.058***	0.031***
		(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Diabetes w/o chronic complications		0.019***	-0.039***	0.019***	0.028***	-0.039***	0.019***
		(0.002)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
Diabetes w/ chronic complications		0.041***	-0.125***	0.040***	0.066***	-0.125***	0.040***
		(0.006)	(0.008)	(0.007)	(0.006)	(0.008)	(0.007)
Hypothyroidism		-0.004	0.004	-0.004	-0.005	0.004	-0.004
		(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)
Renal Failure		0.061***	-0.048***	0.061***	0.071***	-0.047***	0.061***

VARIABLES	(1) Outcome Simple OLS	(2) Outcome Naïve OLS Hospital FE	(3) PCIS Choice One IV	(4) Outcome One IV Hospital FE	(5) Outcome One IV, No FE	(6) PCIS Choice Two IV	(7) Outcome Two IV Hospital FE
		(0.006)	(0.008)	(0.006)	(0.006)	(0.008)	(0.006)
Solid tumor w/out metastasis		0.068***	0.025**	0.068***	0.063***	0.026**	0.068***
		(0.008)	(0.010)	(0.008)	(0.008)	(0.010)	(0.008)
Rehumoatoid arthritis/collagen vas		0.014**	0.035***	0.015**	0.004	0.036***	0.015**
		(0.007)	(0.009)	(0.007)	(0.007)	(0.009)	(0.007)
Coagulopthy		0.013***	-0.328***	0.011	0.080***	-0.329***	0.011
		(0.005)	(0.006)	(0.012)	(0.008)	(0.006)	(0.012)
Obesity		-0.006*	-0.050***	-0.006	0.003	-0.049***	-0.006
		(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)
Fluid and electrolyte disorders		0.019***	-0.231***	0.017**	0.066***	-0.231***	0.017**
		(0.003)	(0.004)	(0.008)	(0.005)	(0.004)	(0.008)
Deficiency Anemias		0.012***	-0.095***	0.011**	0.032***	-0.095***	0.011**
		(0.003)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)
Alcohol Abuse		0.008	-0.042***	0.008	0.017*	-0.042***	0.008
		(0.010)	(0.013)	(0.010)	(0.010)	(0.013)	(0.010)
Psychoses		0.007	-0.061***	0.007	0.020*	-0.061***	0.007
		(0.011)	(0.015)	(0.011)	(0.011)	(0.015)	(0.011)
Depression		0.016***	0.031***	0.016***	0.006	0.031***	0.016***
		(0.005)	(0.007)	(0.006)	(0.005)	(0.007)	(0.006)
Time Fixed Effects (Omitted: July 2003)							
August 2003		-0.005	-0.001	-0.005	-0.005	-0.001	-0.005
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Sept 2003		-0.003	0.015**	-0.002	-0.006	0.015**	-0.002
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Oct 2003		0.002	0.017***	0.002	-0.003	0.017***	0.002
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Nov 2003		0.008*	0.020***	0.009*	0.003	0.019***	0.009*
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Dec 2003		0.017***	0.019***	0.017***	0.010**	0.018***	0.017***
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Jan 2004		0.022***	-0.004	0.023***	0.018***	-0.005	0.023***

VARIABLES	(1) Outcome Simple OLS	(2) Outcome Naïve OLS Hospital FE	(3) PCIS Choice One IV	(4) Outcome One IV Hospital FE	(5) Outcome One IV, No FE	(6) PCIS Choice Two IV	(7) Outcome Two IV Hospital FE
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Feb 2004		-0.005	0.002	-0.004	-0.010**	0.001	-0.004
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
March 2004		-0.012**	0.012*	-0.011**	-0.020***	0.011*	-0.011**
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
April 2004		-0.007	0.002	-0.006	-0.014***	0.001	-0.006
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
May 2004		-0.003	0.002	-0.002	-0.009*	0.001	-0.002
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
June 2004		-0.012**	0.018***	-0.011**	-0.021***	0.017***	-0.011**
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
July 2004		-0.009*	0.017***	-0.008	-0.018***	0.016***	-0.008*
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
August 2004		-0.013***	0.026***	-0.012**	-0.024***	0.025***	-0.012**
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Sept 2004		-0.006	0.013**	-0.005	-0.015***	0.012*	-0.005
		(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Oct 2004		-0.011*	-0.002	-0.010	-0.017***	-0.003	-0.010
		(0.006)	(0.008)	(0.006)	(0.006)	(0.008)	(0.006)
Constant	0.066***	-0.064	0.790***	-0.057	-0.251***	0.638***	-0.059
	(0.001)	(0.074)	(0.099)	(0.081)	(0.077)	(0.099)	(0.081)
R-squared for Equation 1			0.087			0.088	

All models use 164,091 patients who received initial revascularization at 1,597 hospitals
*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Standard errors in parentheses

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