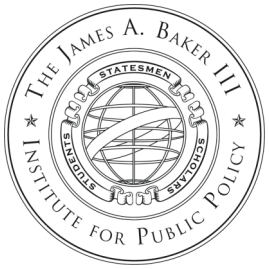

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Physician Supply, Treatment, and Amputation Rates for Peripheral Arterial Disease

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ABSTRACT

Objective: To test whether availability of vascular surgeons and cardiologists in a region affects revascularization and amputation rates for patients with peripheral arterial disease (PAD).

Design and Subjects: We identified all patients with PAD in the Medicare claims data in 1994 and tracked their claims through 1999. We aggregated risk-adjusted data on the 143,202 patients who survived through 1999 by Hospital Referral Region and merged this data with information on local physician supply and other regional characteristics. Instrumental variables analysis was used to account for unobserved illness severity.

Main Outcome Measures: Risk-adjusted rates of lower extremity bypass surgery, angioplasty, and amputation by region.

Results: Increasing vascular surgeon supply in a region by approximately one standard deviation (.30 per 10,000 Medicare beneficiaries) is associated with a 1.0 percentage point increase in bypass surgery rates and a 1.4 percentage point reduction in amputation rates. We find no evidence that greater availability of cardiologists increases angioplasty rates and weak evidence that greater cardiologist supply reduces amputation rates. Factors reflecting regional attractiveness, such as the rating of a region based on climate, recreation, crime, and other attributes, were strong independent predictors of the number of vascular surgeons and cardiologists in an area.

Conclusions: Availability of vascular surgeons affects outcomes for PAD patients. Regional variability in specialists who treat PAD is influenced by factors other than regional medical needs. Policies aimed at increasing the supply of vascular surgeons and their provision of bypass

surgery in underserved areas may help to reduce regional disparities in amputation.

INTRODUCTION

Amputations resulting in limb loss vary more than ten-fold among Medicare beneficiaries, from 0.37 per 1,000 Medicare enrollees in Grand Junction, Colorado to 4.35 in Corpus Christi, Texas.(1) Peripheral Arterial Disease (PAD) accounts for approximately half of all amputations among diabetics and is the major cause of amputation for nondiabetic patients.(2;3) The gold standard for revascularization is bypass surgery, although percutaneous transluminal angioplasty is frequently recommended for patients with localized disease in larger arteries.(4;5) Regional variations in bypass surgery and angioplasty rates also exist.(1)

The likelihood that a patient undergoes revascularization and therefore long-term outcome may depend on access to vascular specialists. We test whether regional differences in amputation rates and revascularization for patients with PAD are determined by the local availability of vascular surgeons (who perform bypass surgery) and cardiologists (who perform angioplasty).

METHODS

We identified all Medicare beneficiaries age 65 and over in the 1994 physician claims files with an ICD-9 diagnosis code for lower extremity atherosclerosis (440.20-440.29). We also selected patients with CPT codes for arteriography of the abdominal vessels or lower extremity arteries (75630 or 75710) and a diagnosis or procedure code consistent with PAD; for example, stricture of artery or gangrene.(4) Altogether 358,050 patients met these criteria.

We then searched the Medicare hospital inpatient and outpatient standard analytic files to identify lower extremity bypass surgery (ICD-9 procedure codes 39.25 or 39.29), angioplasty (39.50), and major lower extremity amputations (84.10, 84.13-84.17) for these patients in the years 1994 through 1999. An angioplasty was not counted if the claim also included an ICD-9 code for occlusion and stenosis of the precerebral arteries (433) or atherosclerosis of the renal artery (440.1). Amputations preserving the heel and therefore the patient=s ability to ambulate were not considered major amputations. We searched the outpatient files for CPT codes for these same procedures using an ICD-9 to CPT Procedural Coding Crosswalk.(5)

The explanatory variables of interest are the number of vascular surgeons and cardiologists in a Hospital Referral Region. Counts of board certified vascular surgeons and cardiologists were available for the year 1996.(1;6) To control for disease severity and focus analysis on patients most likely to benefit from revascularization, the sample was limited to the 143,202 patients who remained alive at the end of 1999. Of these patients, 21.8% received an arteriography in 1994.

The unit of analysis was the bypass surgery, angioplasty, or amputation rate in one of 306 Hospital Referral Regions (HRRs) as defined by the *Dartmouth Atlas of Health Care*.(7) HRRs are naturally occurring tertiary care markets within which Medicare beneficiaries receive

inpatient services.(7;8) Treatment and amputation rates were assigned based on each patient=s residence rather than the region in which patients received care.(2;9)

A small fraction of patients (6.4%) underwent more than one revascularization during the study period. For these patients, we only analyzed the first revascularization. Some patients (1.6%) suffered an amputation prior to reported revascularization. Because these amputations are more likely a marker for disease severity than a result of access to specialists over the sample period, amputations which occurred prior to reported revascularization were excluded from the calculation of regional amputation rates.

All rates were adjusted for illness severity using the method of indirect standardization, which involves multiplying the procedure=s national rate by the ratio of the crude rate to the predicted rate for the HRR.(10) The predicted rate was obtained from a patient-level logistic regression of bypass surgery, angioplasty, or amputation on indicator variables for age (70 to 74, 75 to 79, age 80+), gender, mild to moderate diabetes, diabetes with chronic complications, prior AMI,(4) and amputation during the sample period prior to revascularization. Values for these indicators were based on data in the 1994 claims files. Although 90 percent of patients in the sample reported a PAD diagnosis in 1994, 59 percent of these diagnoses did not report PAD severity; e.g. intermittent claudication, rest pain, ulceration, or gangrene. Given its potential for measurement error, PAD severity was not used in risk adjustment.

Linear regressions were estimated to test whether bypass surgery, angioplasty, and amputation rates are associated with the number of vascular surgeons or cardiologists per Medicare enrollee in an HRR. The regressions include an illness index for each HRR to further control for regional differences in health status. The index is based on mortality rates and rates of five types of hospitalizations, which are proxies for disease incidence: hip fracture, cancer of

the colon or lung treated surgically, gastro-intestinal hemorrhage, acute myocardial infarction, or stroke.(7;11)

More PAD in an area may attract more specialists who can provide treatment. Although risk-adjusted treatment rates and the regional illness index are included in the analyses, any residual differences in regional health status will bias the estimates of the impact of physician availability on treatment and amputation rates. Therefore, we test for the need for an instrumental variables analysis for the number of vascular surgeons and cardiologists and implement this framework where indicated.

Instrumental variables analysis controls for confounding which may be introduced by crude measures of illness severity in administrative data. AInstruments@ are variables which effectively randomize patients to different levels of the explanatory variable of interest.(12) Distance from a hospital providing cardiac catheterization has been used as an instrument to explain whether or not AMI patients receive catheterization.(13) We use variables which measure the general attractiveness of an HRR as instruments for the region=s number of vascular surgeons and cardiologists. Most specialists work in cities where they did not grow up; often migrating to areas with greater social amenities. Thus, the livability of an area should affect the availability of specialists who treat PAD, but it is unlikely to be correlated with residual PAD severity. Variations in the availability of vascular surgeons and cardiologists due to differences in the attractiveness of each region provide an estimate of the effect of specialist availability on revascularization and amputation rates, which is unaffected by unmeasured illness severity.

The variables characterizing regional attractiveness are the mean score in the *Places Rated Almanac*, the average July temperature in an HRR, and the number of accountants per capita. The 1997 *Almanac* assigned 351 metropolitan areas a mean score based on: costs of

living, job outlook, transportation, education, health care, crime, the arts, recreation, and climate.(14) The Area Resource File reported July temperatures by county. The number of accountants per 10,000 residents by county reported in the 1997 Bureau of Labor Statistics survey on Covered Employment and Wages proxies for regional attractiveness to another relatively mobile profession. These variables were crosswalked to HRRs using city names for each region in the *Atlas* and county-zipcode crosswalks.(15)

Three regional attractiveness measures were required for use as instruments for the number of vascular surgeons and cardiologists; and to conduct diagnostic tests to determine the validity of these variables to serve as instruments.(16) These diagnostic tests avoid the possibility of reaching illogical conclusions, which occurred in earlier instrumental variables studies.(17) Instrumental variables were used only in regressions where test results indicated it was appropriate.(18) Each treatment and amputation rate was weighted in the regressions according to the number of PAD patients in the sample in that region. Estimation was conducted using Stata 8.0.(19)

RESULTS

We analyzed 143,202 Medicare beneficiaries with PAD in 1994 who survived through 1999, an average of 468 patients per HRR. The mean risk-adjusted bypass surgery rate for all 306 regions was 23.2 percent. Risk-adjusted angioplasty and amputation rates were 7.6 and 6.9 percent respectively.

Table 1 illustrates how regional attractiveness randomizes areas to differing specialist availability. Regions in the lowest third of the *Places Rated Almanac* rating were compared to regions in the top third, which received the most favorable scores. Regions in the highest tertile had more vascular surgeons (0.53 versus 0.35) and more cardiologists (6.71 versus 4.18) per 10,000 Medicare beneficiaries than lower tertile regions. Regions in the highest tertile also experienced lower amputation rates (5.6 versus 7.7 percent), suggesting that greater availability of vascular surgeons and cardiologists leads to lower amputation rates.

Regions in the *Almanac=s* highest tertile had patients who were slightly older and more likely to have suffered a previous myocardial infarction. Low tertile regions had slightly higher shares of diabetic patients and prior amputation rates. The absence of large or systematic differences by tertile in health characteristics provides some validation that the *Almanac* score randomizes areas to differing specialist availability. However, this observation is best confirmed in a regression framework.

Contrary to our hypothesis, more attractive HRRs displayed lower bypass surgery and angioplasty rates. These regions had larger supplies of both vascular surgeons and cardiologists, who may substitute for each other in performing revascularization. More vascular surgeons may lower angioplasty rates, and more cardiologists may lower bypass rates. Therefore, the independent supply effect for each of these specialties is best assessed with regressions.

Endogeneity tests indicated that instrumental variables analysis was not necessary to control for unobserved patient severity in regressions explaining bypass surgery and angioplasty rates (p=0.20 and p=0.39 respectively). Therefore, Table 2 presents weighted least squares estimates of the relationship between specialist availability and risk-adjusted treatment rates. Column 1 suggests a positive association between the number of vascular surgeons per 10,000 Medicare beneficiaries in an HRR and bypass surgery rates for PAD patients (coefficient=0.033, p=0.02). To provide perspective, a one standard deviation difference in the number of vascular surgeons in a region equals approximately .30 surgeons per 10,000 Medicare beneficiaries. The regression estimates suggest that a 0.30 increase in the number of vascular surgeons per 10,000 Medicare beneficiaries is associated with a 1.0 percentage point increase in bypass surgery rates.

Correspondingly, higher numbers of cardiologists per capita in a region is associated with a decrease in risk-adjusted bypass surgery rates (coefficient = -0.011, p<.001). Increasing the number of cardiologists in an HRR by 0.30 per 10,000 Medicare beneficiaries is associated with a 0.3 percentage point reduction in bypass surgery rates.

Column 2 reports factors explaining angioplasty rates. Both increases in the number of vascular surgeons and cardiologists per 10,000 Medicare beneficiaries are associated with decreases in risk-adjusted angioplasty rates. The effect sizes are smaller than those observed in Column 1. Increasing by 0.30 the number of vascular surgeons per 10,000 Medicare beneficiaries is associated with a 0.6 percentage point decrease in angioplasty rates. Increasing by 0.30 the number of cardiologists per 10,000 Medicare beneficiaries is predicted to reduce risk-adjusted angioplasty rates by 0.1 percentage point.

Table 3 presents regression estimates of the impact of regional attractiveness on specialist availability in each HRR. A higher score in the *Places Rated Almanac* is associated with both

more vascular surgeons and cardiologists per capita (p#.01 in each case). A city ranked in the 10th percentile of the *Almanac* for overall attractiveness had a score of 37.57, and a city in the 90th percentile received a score of 71.11. The coefficients in Table 3 suggest that the predicted increase in the number of specialists associated with this ratings differential is 0.13 vascular surgeons (0.004*33.54) and 2.62 cardiologists (0.078*33.54) per 10,000 Medicare beneficiaries. Likewise, an increase in a region=s July temperature reduces the number of vascular surgeons per capita (p<.001), and the number of cardiologists (p=0.05). More accountants in each region is also associated with more vascular surgeons and cardiologists (p#.03 in each case). F-tests for the joint significance of the regional attractiveness measures indicate that the variables do well in explaining variation in both vascular surgeon (F=19.61, p<0.001) and cardiologist (F=73.56, p<.001) availability per 10,000 Medicare beneficiaries, which is a necessary requirement for instrumental variables.(20)

Table 4 presents instrumental variables estimates of the association between the number of specialists per capita and amputation rates across HRRs. An endogeneity test indicated that standard weighted least squares estimation would yield biased coefficient estimates (p=0.01). An overidentification test did not detect a correlation between regional attractiveness measures and unexplained differences in patient severity (p=0.31). Therefore, the instrumental variable estimates are unlikely to be confounded by differences in patient severity when measuring the determinants of regional amputation rates.

Increasing availability of vascular surgeons per 10,000 Medicare beneficiaries is associated with a decrease in regional amputation rates (coefficient=-0.047, p=0.05). The data and regression estimates in Table 3 lead to predicted values of vascular surgeon supply where the 10th percentile and the 90th percentile of the distribution are 0.30 and 0.60 surgeons per 10,000

Medicare beneficiaries respectively. The coefficient estimates in Table 4 suggest that increasing availability of vascular surgeons by this differential amount reduces amputation rates by 1.4 percentage points (-0.047x0.3). Increasing cardiologist supply is also associated with a lower amputation rate, although the effect is less precisely estimated (coefficient=-0.003, p=0.06). Sensitivity analyses indicated that the results were robust to substituting individual components of the *Almanac* ratings (e.g. climate, crime, and jobs), as well as employment counts of other professionals (legal professionals or engineers).

DISCUSSION

Regional variation in amputation rates indicate outcome disparities which cause significant pain and suffering for patients. The results in this paper suggest that greater availability of specialists in an area influences treatment rates and reduces amputations. The distribution of specialists in the United States is strongly correlated with local factors such as climate, transportation, education, and crime. Therefore, variations in regional attractiveness which influence specialist supply have significant implications for treatment and outcomes for PAD patients.

A 0.30 increase in the number of vascular surgeons per 10,000 Medicare beneficiaries leads to an increase in bypass surgery (1.0 percentage point) which is smaller in absolute value than the corresponding reduction in amputations (1.4 percentage points). This finding may seem counterintuitive. However, like cardiologists, vascular surgeons offer medical management of atherosclerosis. Furthermore, vascular surgeons are trained in all aspects of limb salvage, such as wound care, which may in some cases prevent amputation without the need for bypass surgery. We also investigated the association between the availability of vascular surgeons and repeat risk-adjusted bypass surgery rates, excluding the results from the tables for brevity. A 0.30 increase in the number of vascular surgeons per 10,000 Medicare beneficiaries is associated with a 0.4 percentage point increase in repeat bypass surgery rates ($p=0.004$). Increased rates of repeat bypass surgery may further prolong adequate circulation in the lower limbs, reducing the need for amputation.

Contrary to our original hypothesis, increasing the local cardiologist supply is associated with a decrease in angioplasty rates. And although greater availability of cardiologists is associated with lower amputation rates, the effect is imprecisely estimated. Cardiologists may

improve the medical and preventive care of patients with atherosclerosis, which may avoid angioplasty and explain the association with decreased amputation. During the study period 1994 to 1999, cardiologists may have been inclined to treat PAD medically, rather than through invasive techniques. However, with improvement in endovascular technology, cardiologists may become more inclined to use invasive techniques.

Radiologists commonly perform angioplasty for lower extremity revascularization, and general surgeons perform one third of surgical bypass procedures for lower extremity atherosclerosis among Medicare enrollees.(1;8) Furthermore, cardiologists perform angioplasty to varying degrees depending on specific training. Investigating the interaction between invasive and non-invasive specialists (cardiologists, radiologists, and surgeons) requires detailed information on the number of sub-specialists in each area. The *Dartmouth Atlas* series does not publish information on the number of radiologists by HRR. In addition, the instrumental variables method becomes infeasible in an analysis comparing several sub-specialties. The method requires at least as many measures of geographical attractiveness as there are specialities to be compared.

Nevertheless, our data contained information on all bypass surgeries and angioplasties, regardless of which specialty performed the procedure. Because measures of regional attractiveness are likely to influence all specialists in a similar manner, the supply of cardiologists in an HRR is also likely to reflect the local supply of interventional radiologists; and the local supply of vascular surgeons and general surgeons is likely to be positively correlated. If so, then some of the estimated beneficial effects of vascular surgeons may be attributable to general surgeons. In addition, a true potential benefit of interventional radiologists on increased angioplasty and reduced amputations may be masked by effects of

cardiologist supply that are even weaker than those measured in this study. These are possibilities which should be explored in future research. This study provides a useful framework for learning how the local mix of specialists can influence treatment rates in the population. Including a wider range of specialists might reduce the estimated effect of supply of any one specialty on revascularization rates, but overall supply would remain an important determinant of treatment and outcomes.

If greater specialist supply leads to more PAD diagnoses, then our sample may contain less diseased patients in high supply areas. We divided HRRs into thirds based on their supply of vascular surgeons and cardiologists. Rates of diabetes, prior myocardial infarction, and prior amputation were insignificantly different across high and low tertiles of specialist supply. Patients were one half year older ($p=0.01$) in areas with high cardiologist supply. Therefore, it is unlikely that sample selection bias explains our results.

The less precise association between cardiologist supply and amputation rates does not imply that angioplasty is ineffective in treating PAD. Evidence from randomized clinical trials more appropriately tests the effectiveness of bypass surgery and angioplasty in well-defined patient populations.(21) Instead, observational analysis provides information on how specialist availability influences treatment rates and outcomes; and what factors influence regional surgeon and cardiologist supply.

The analysis does not account for mortality which may result from lower-extremity bypass surgery, which was 3.2 percent in the early 1990's.(22) Past studies have identified lower mortality associated with bypass surgery compared to amputation, suggesting that increased lower extremity bypass rates does not increase mortality.(23;24)

Even if vascular surgeon availability improves in underserved areas, noticeable disparities in amputation rates would remain due to disparities in detection of PAD and in outpatient care.(2;25) Increased preventive measures such as foot examinations, smoking cessation, and drug treatment could reduce disparities in amputation rates. Nevertheless, 21.8% of patients in our sample received an arteriography in 1994, which is a marker for advanced disease. For these patients, it is particularly important to consider access to specialists performing revascularization.

Policies which increase cardiovascular specialist supply in underserved areas may help to reduce regional disparities in amputation rates. All aspects of physician recruitment and retention are potential policy levers.(26) Past studies have shown that physician location decisions are responsive to higher reimbursement and greater expected future income.(27;28;28;29) Programs similar to the National Health Service Corps or loan forgiveness provisions for physicians which have been used in the past to encourage physicians to practice in rural areas could be applied.(30) Alternatively, policy makers could consider targeting of Graduate Medical Education financing to encourage increased vascular specialty training in underserved areas.(31) Although these interventions will not eliminate regional disparities in amputation rates, the results in this study suggest that they could improve quality of life for PAD patients in underserved areas.

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REFERENCES

1 Center for the Clinical Evaluative Sciences, Dartmouth Medical School. The Dartmouth atlas of vascular health care. Dartmouth,N.H.: 2000.

2 Wrobel JS, Mayfield JA, Reiber GE. Geographic variation of lower-extremity major amputation in individuals with and without diabetes in the Medicare population. *Diabetes Care* 2001; 24(5):860-864.

3 Pecoraro RE, Reiber GE, Burgess EM. Pathways to diabetic limb amputation. Basis for prevention. *Diabetes Care* 1990; 13(5):513-521.

4 Romano PS, Roos LL, Jollis JG. Adapting a clinical comorbidity index for use with ICD-9-CM administrative data: Differing perspectives. *Journal of Clinical Epidemiology* 1993; 46(10):1075-1079.

5 Ingenix I. Procedural coding crosswalk. 5th Edition ed. Salt Lake City, UT: St. Anthony Publishing, 2002.

6 The Center for the Clinical Evaluative Sciences DMS, The Center for Outcomes Research and Evaluation MMC. The Dartmouth atlas of cardiovascular health care. Chicago, IL: AHA Press, 1999.

7 The Dartmouth Atlas of Health Care 1998. Available at: http://www.dartmouthatlas.org/atlaslinks/98atlas.php.2003. Accessed February 3, 2004.

8 Axelrod DA, Fendrick AM, Birkmeyer JD, Wennberg DE, Siewers AE. Cardiologists performing peripheral angioplasties: impact on utilization. *Eff Clin Pract* 2001; 4(5):191-198.

9 Skinner J, Weinstein JN, Sporer SM, Wennberg JE. Racial, ethnic, and geographic disparities in rates of knee arthroplasty among Medicare patients. *N Engl J Med* 2003; 349(14):1350-1359.

10 Shwartz M, Ash AS, Iezzoni L.I. Comparing outcomes across providers. In: Iezzoni L.I., editor. Risk adjustment for measuring healthcare outcomes. Chicago, IL: Health Administration Press, 1997: 471-516.

11 Wennberg JE, Fisher ES, Skinner JS. Geography and the debate over Medicare Reform, Health Affairs Web Exclusive. http://content.healthaffairs.org/cgi/reprint/hlthaff.w2.96v1? 2-13-2002. Accessed February 3, 2004.

12 Angrist JD, Imbens GW. 2-Stage Least-Squares Estimation of Average Causal Effects in Models with Variable Treatment Intensity. *Journal of the American Statistical Association* 1995; 90(430):431-442.

13 McClellan M, McNeil BJ, Newhouse JP. Does more intensive treatment of acute myocardial infarction in the elderly reduce mortality? Analysis using instrumental variables. *JAMA* 1997; 272(11):859-866.

14 Savageau D, Loftus G. Places rated almanac,Your guide to finding the best places to live in North America. 5th ed. New York: MacMillan, 1997.

15 U.S.Census Bureau. 2002 U.S. Gazetteer. http://www.census.gov/geo/www/gazetteer/places2k.html . 10-20-2003. Accessed October 20,2003.

16 Sargan J. The estimation of economic relationships using instrumental variables. *Econometrica* 1958; 26(3):393-415.

17 Dranove D, Wehner P. Physician-induced demand for childbirths. *Journal of Health Economics* 1994; 13(1):61-73.

18 Hausman J. Specification tests in econometrics. *Econometrica* 1978; 46:1251-1271.

19 Baum CF, Schaffer ME, Stillman S. Instrumental variables and GMM: estimation and testing. *The Stata Journal* 2003; 3(1):1-31.

20 Staiger D, Stock JH. Instrumental variables regression with weak instruments. *Econometrica* 1997; 65(3):557-586.

21 DeWeese JA, Leather R, Porter J. Practice guidelines: Lower extremity revascularization. *Journal of Vascular Surgery* 1993; 18(2):280-294.

22 Manheim LM, Sohn MW, Feinglass J, Ujiki M, Parker MA, Pearce WH. Hospital vascular surgery volume and procedure mortality rates in California, 1982-1994. *Journal of Vascular Surgery* 1998; 28(1):45-56.

23 Hobson RW2, Lynch TG, Jamil Z, Karanfilian RG, Lee BC, Padberg FT Jr, et al. Results of revascularization and amputation in severe lower extremity ischemia; a five-year clinical experience. *Journal of Vascular Surgery* 1985; 2(1):174-185.

24 Ouriel K, Fiore WM, Geary JE. Limb-threatening ischemia in the medically compromised patient: amputation or revascularization? *Surgery* 1988; 104(4):667-672.

25 Guadagnoli E, Ayanian JZ, Gibbons G, McNeil BJ, LoGerfo FW. The influence of race on the use of surgical procedures for treatment of peripheral vascular disease of the lower extremities. *Arch Surg* 1995; 130(4):381-386.

26 Kereiakes DJ, Willerson JT. The United States cardiovascular care deficit. *Circulation* 2004; 109(7):821-823.

27 Langwell KM. Real returns to career decisions: The physician's specialty and location choices. *Journal of Human Resources* 1980; 15(2):278-286.

28 Bolduc D, Fortin B, Fournier M. The effect of incentive policies on the practice location of doctors: A multinomial probit analysis. *Journal of Labor Economics* 1996; 14(4):703-732.

29 Hurley JE. Physicians' choices of specialty, location and mode, A reexamination within an interdependent decision framework. *Journal of Human Resources* 1991; 26(1):47-71.

30 Newhouse JP, Williams AP, Bennett BW, Schwartz WB. Does the geographical distribution of physicians reflect market failure? *The Bell Journal of Economics* 1982; 13(2):493-505.

31 Grumbach K. Fighting hand to hand over physician workforce policy. *Health Aff (Millwood)* 2002; 21(5):13-27.

Table 1. Descriptive Statistics for Hospital Referral Regions by Places Rated Almanac Score[a]

Characteristic	Lowest Tertile (n=102)	Highest Tertile (n=102)
Demographic Characteristics		
Female	54.9	57.3
Mean age 1994, y (SD)	74.5 (1.47)	75.0 (1.40)
Comorbid Disease Characteristics		
Illness index (SD)	1.01 (0.11)	1.00 (0.08)
Mild diabetes	21.6	20.8
Diabetes w/chronic complications	3.6	3.2
Prior myocardial infarction	4.5	5.2
Prior amputation	2.3	2.2
Specialists per 10,000 Medicare Beneficiaries		
Vascular surgeons (SD)	.35 (0.26)	.53 (0.26)
Cardiologists (SD)	4.18 (1.63)	6.71 (2.38)
Revascularization and Amputation Rates		
Bypass surgery	23.2	22.0
Angioplasty	8.4	6.9
Amputation	7.7	5.6

[a]All entries are percentages except for mean age, illness index, and number of specialists.

Table 2. Weighted Least Squares Estimates of Determinants Bypass Surgery and Angioplasty Rates by Hospital Referral Region[a]

Variable	Risk-Adjusted Bypass Surgery Rate[b]		Risk-Adjusted Angioplasty Rate[b]	
Vascular surgeons[c]	0.033	(0.005 B 0.062)[d] bbb	-0.019	(-0.034 B -0.004)
Cardiologists[c]	-0.011	(-0.014 B -0.009)	-0.003	(-0.005 B -0.002)
Illness index	0.167	(0.083 B 0.250)	0.081	(0.038 B 0.124)
Constant	0.057	(-0.025 B 0.139)	0.0005	(-0.042 B 0.043)
R^2	0.19		0.13	
N	306			

[a] Estimates are weighted by number of patients in each Hospital Referral Region.

[b] Rates adjusted by indirect standardization at the patient level using age, gender, diabetes, prior acute myocardial infarction, and prior amputation.

[c] Represents number of physicians per 10,000 Medicare beneficiaries.

[d] 95% confidence intervals in parentheses.

Table 3. Weighted Least Squares Estimates of Determinants of Number of Vascular Surgeons and Cardiologists per 10,000 Medicare Beneficiaries by Hospital Referral Region[a]

Variable	Vascular Surgeons		Cardiologists	
Almanac score	0.004	(0.0009 B 0.007)[b]	0.078	(0.054 B 0.102)
July temperature	-0.017	(-0.023 B -0.011)	-0.052	(-0.103 B -0.001)
Number of accountants	0.003	(0.0004 B 0.006)	0.102	(0.077 B 0.127)
Illness index	0.686	(0.335 B 1.04)	4.958	(1.988 B 7.928)
Constant	0.806	(0.336 B 1.28)	-1.560	(-5.533 B 2.413)
R^2	0.18		0.44	
N	306			

[a]Estimates are weighted by the number of patients in each Hospital Referral Region.

[b]95% confidence intervals in parentheses.

Table 4. Weighted Instrumental Variables Estimates of the Determinants of Amputation Rates by Hospital Referral Region[a]

Variable	Risk-Adjusted Amputation Rate[b]	
Vascular surgeons[c]	-0.047	(-0.093 B -0.0008)[d]
Cardiologists[c]	-0.003	(-0.005 B 0.0002)
Illness index	0.136	(0.098 B 0.174)
Constant	-0.050	(-0.087 B -0.013)
N	306	

[a] Estimates are weighted by the number of patients in each Hospital Referral Region.

[b] Rate is adjusted by indirect standardization at the patient level using age, gender, diabetes, prior acute myocardial infarction, and prior amputation.

[c] Estimates based on instrumental variables models using Almanac score, July temperature, and number of accountants as instruments for number of physicians per 10,000 Medicare beneficiaries.

[d] 95% confidence intervals in parentheses.