Travel Distance and Health Outcomes for Scheduled Surgery

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Background: Changes in the location and availability of surgical services change the distances that patients must travel for surgery. Identifying health effects related to travel distance is therefore crucial to evaluating policies that affect the geographic distribution of these services. We examine the health outcomes of coronary artery bypass graft (CABG) patients in Pennsylvania for evidence that traveling further to a hospital for a one-time, scheduled surgical procedure causes harm.

Methods: We perform instrumental-variable regressions to test for the effect of distance to the admitting hospital on the in-hospital mortality and readmission rates of 102,858 CABG patients in Pennsylvania during 1995–2005, where the instrumental variables are constructed based on the quality of and distance to nearby CABG hospitals.

Results: We found that patients living near a CABG hospital with acceptable quality traveled significantly less and if they were high-risk, had lower in-hospital mortality rates. Readmission rates in general are not affected by patients' travel distance.

Discussion: The positive correlation between travel distance and health outcomes observed by previous studies may reflect the confounding effects of behavioral factors and patient health risks. We found instead that living further from the admitting hospital increases in-hospital mortality for high-risk CABG patients. More research on the possible causes of these effects is necessary to identify optimal policy responses.

Key Words: travel distance, scheduled surgery, hospital quality, outcomes, CABG, regionalization, United States

(*Med Care* 2014;52: 250–257)

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Supported by the Lehigh University College of Business & Economics, the Lehigh University Martindale Center for Private Enterprise, and the Pennsylvania Department of Health (CURE Grant SAP Number 4100054856). This analysis was carried out by S.-Y. C., M.E.D., and S. L. PHC4, its agents and staff, bear no responsibility or liability for the results of the analysis, which are solely the opinion of the authors.

The authors declare no conflict of interest.

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ISSN: 0025-7079/14/5203-0250

Changes in the location and availability of surgical services change the distances that patients must travel for surgery. For example, regionalizing surgical programs or adopting volume-based referral practices so that patients go to higher-volume centers for surgery would increase the distances many travel.[1–3] Conversely, removing regulatory barriers limiting entry of new surgical programs would decrease travel distances if more providers enter the market.[4] Identifying health effects related to travel distance is therefore crucial to evaluating policies that affect the geographic distribution of surgical services, but the causal relationship is difficult to identify because confounding factors such as patients' behavioral patterns and the quality of admitting hospitals are likely correlated with both travel distance and surgical outcomes. In this paper, we use a novel set of instrumental variables to determine whether travel distance affects health outcomes of patients having scheduled coronary artery bypass graft (CABG) surgery in Pennsylvania during the period 1995–2005.

Travel distance may most obviously affect health outcomes if it reduces utilization of preventive care or delays care in emergency conditions.[5,6] However, for one-time, nonemergent surgical patients, greater distances may result in worse health outcomes if they delay preoperative procedures, impair preoperative education of patients and families, reduce the amount of informal care provided by families, or reduce the continuity of postoperative care. Prior literature reveals that preoperative education and family support decrease patients' emotional stress, reduce deterioration of patients' functional and psychological status during the perioperative waiting period, and decrease postoperative complications.[7,8] The benefits of preoperative preparation may be particularly important for high-risk patients: preoperative intensive inspiratory muscle training, for example, can prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery.[9]

However, identifying the causal relationship between travel distance and health outcomes is difficult because unobserved preferences and characteristics of patients may be correlated with both travel distance and health outcomes. For example, patients may travel further because they have a stronger will to live that helps them achieve better outcomes, or they do so to be treated at "centers of excellence" and thus experience better outcomes.[10–13] In contrast, patients traveling further to seek better hospitals may be sicker and, thus, experience worse outcomes.[14] If, as we hypothesize, the true effect of greater travel distance is to cause harm, then regressing outcomes on travel distance results in coefficients that underestimate the true effect in the former case, biasing estimates toward zero, and overestimate the true effect in the latter case, biasing estimates away from zero. Identification is further complicated because travel distance is often measured with error, which will bias estimates toward zero.

We address these identification problems using a novel instrumental-variable approach that controls for potentially confounding factors and for measurement errors.[15] Our instrumental variables are based on the availability and quality of hospitals near a patient's home because of evidence showing that hospital patients strongly prefer to minimize their travel distance but also care about quality.[16–18] As patients value both hospital quality and less travel, the distance that patients actually travel will be correlated with the quality of nearby hospitals, but the quality of nearby hospitals will have no direct effect on patients' outcomes at their admitting hospitals.

We measure the quality of hospitals using report card grades for CABG surgery providers that have been published by Pennsylvania since the early 1990s. Although measures based on the distance to the closest hospital have been used as exogenous variables in a variety of studies,[19–23] this is, to the best of our knowledge, the first use of both the availability and the report card grades of nearby hospitals to create instrumental variables.

METHODS

Data and Sample

Patient data are from the PHC4 inpatient database, which includes patient sex, age, race, insurance type, diagnostic codes, and residential zip code, whether the procedure was scheduled, whether the patient died in the hospital, and an identification number and zip code for the admitting hospital. Each record also contains a patient identifier that allows us to link patient records from quarter to quarter. Our sample is drawn from the set of patients undergoing isolated CABG surgery (CABG surgery with no other major heart surgery during the same admission) in Pennsylvania hospitals during the period 1995–2005. (Our sample ends in 2005 because we only had data through 2006 and needed the last 12 mo to measure one of our outcomes variables.) Distance from a patient's home to a hospital is the straight-line distance from the centroid of a patient's residential zip code to the hospital's location as computed by the Geographic Information System. Hospital longitudes and latitudes are from the American Hospital Association *Annual Survey of Hospitals*.

We eliminated rural patients because almost all the CABG hospitals are located in more densely populated areas; therefore, the distance/quality trade-offs faced by rural patients may be quite different. We further eliminated patients admitted from the emergency room, so as to focus on the health impacts of travel in nonemergency situations. After eliminating observations missing data for any variable, our sample comprised 102,858 patients.

Outcome Equation

Our main specification is:

$$P(\text{Outcome}_{ijkt}) = a + b_1 * \text{Travel Distance}_{ijkt} + b_2 * P_{ijkt} + b_3 * AH_{kt} + H_k + Y_t + \epsilon_{\text{ijkt}} \quad (1)$$

where i is an individual patient residing in zip code j and undergoing s at admitting hospital k in year t, P_{ijkt} and AH_{kt} are vectors of patient and admitting-hospital characteristics, H_k and Y_t are fixed effects for admitting hospital (67 dummies) and year (10 dummies), and ϵ_{ijkt} is the error term.

We estimate the effect of travel distance on 2 different health outcomes, in-hospital mortality and readmission. For mortality, Outcome$_{ijkt}$ is a dummy variable that equals one if the patient died in the hospital, and 0 if not. For readmission, Outcome$_{ijkt}$ is a dummy variable that equals 1 if the patient was readmitted to any hospital during the 12 months following the quarter of their CABG surgery with a diagnosis of ischemic heart disease, congestive heart failure, or post-surgery infection. These conditions capture the most common causes of readmission following CABG surgeries.[24]

Instrumental Variables Estimation

Travel Distance$_{ijkt}$, the distance between the patient's zip code and the admitting hospital, is our proxy for the actual cost of travel in driving distance and time.[25] We instrument for this variable to control for confounding effects using information about the quality and location of a patient's nearby, as opposed to admitting, hospital. The first stage of the IV estimation is specified as:

$$\text{Travel Distance}_{ijkt} = \alpha + \beta_1 * IV_{jt} + \beta_2 * P_{ijkt} + \beta_3 * AH_{kt} + H_k + Y_t + \varepsilon_{ijkt}, \quad (2)$$

where IV_{jt} represents the instrumental variables, and the other variables are as defined in Eq. (1). The instrumental variables are based on the quality of CABG hospitals available near a patient's home, where CABG hospital quality is measured using the grades from *Pennsylvania's Guide to Coronary Artery Bypass Graft Surgery*, published by the Pennsylvania Health Care Cost Containment Council (PHC4).[26] Although these reports are available to patients, we do not assume that patients select hospitals based on the reported grades. Rather, we use these grades as proxies for patients' perceptions of hospital quality, which may be formed by their own experience, recommendations of their referring cardiologist, or word-of-mouth.[27]

In a report, a hospital receives a grade of "Same as expected" if its actual in-hospital mortality rate falls within a 95% confidence interval (CI) around its predicted mortality rate (a grade referred to in this paper as "as expected"). Hospitals with mortality rates that fall outside of a 95% CI around their predicted rate receive a "Lower than expected" grade, if their mortality rate falls below their 95% CI (a grade referred to here as "superior"), or a "Higher than expected" grade if it falls above (a grade referred to here as "poor"). Mortality rates are risk-adjusted, and hospitals must perform at least 30 isolated CABG procedures on adults in a year to receive a grade.

The report cards have been published at irregular intervals since the first was issued in 1992. The second column of Table 1 identifies the date of the most recent report card for each year in our sample (by quarter when there was >1 grade for the year), with the year in which the data for the report card were collected in parentheses. The next 3 columns of Table 1 show the number of hospitals with each type of grade each year, where the grade is the one most recently reported.

Some CABG operations occurred at hospitals that were not graded because <30 surgeries were performed at a hospital when the report card information was being collected or because the hospital started a CABG program after data for the report card were collected. The number of such facilities increased after December 1996, when Pennsylvania ended the Certificate of Need program that had restricted entry of CABG programs. As the new programs grew to the "gradable" threshold, the number of ungraded CABG providers fell, most sharply in 2002, the first year that report cards based on data collected after the CON regulations ended were issued (see columns 6 and 7 of Table 1).

We assign each hospital its most recent CABG report card grade in each period to measure its quality and add information about hospital locations to create 4 instruments. The first 2 IVs are categorical, measuring location by indicating whether or not at least one hospital of acceptable quality is located within a 10-mile radius of the patient, 10 miles being the median travel distance of our sample. IV1 equals one if there is a graded CABG hospital nearby. IV2 includes IV1 plus its interaction with a dummy variable that equals one if the nearby hospital's grade was average or superior. We expect the estimated coefficients to be negative because a patient likely travels less if a CABG hospital of acceptable quality is nearby.

These IVs identify patients who have a nearby hospital of acceptable quality with which they are likely to be familiar and more comfortable. However, our 10-mile radius is essentially arbitrary, so we also use a second set of IVs that measure location as the distance from the patient to the closest CABG hospital of acceptable quality. IV3 is the distance to the closest graded hospital. IV4 includes both the distance to the closest graded hospital and the distance to the closest hospital with an as-expected or superior grade. We expect the estimated coefficients to be positive because research suggests that patients strongly prefer their closest hospital but are willing to travel further for better quality.[16–18]

The equations were estimated using probit or IV probit (Stata, Version 12; StataCorp. College Station, TX). We assess the endogeneity of travel distance using a Durbin-Wu-Hausman test, under the null hypothesis that travel distance is exogenous.

Control Variables

P_{ijkt} in Eqs. (1) and (2) represents a set of patient characteristics that may affect the patient's health outcome, including dummy variables for patient gender (equals one if male), race (equals one if white), and age category, and whether the patient is covered by Medicare. (Virtually, all other patients are privately insured, with a few uninsured or covered by Medicaid.) We control for differences in patients' illness severity using their Elixhauser comorbidities,[28]

TABLE 1. Pennsylvania CABG Report Cards and Hospitals, 1995–2005

	Most Recent Report Card	No. Hospitals With Grades That Were			No. Hospitals That Were		
Year	Most Recent Report (Years of Data Collection)*	Poor	Average	Superior	Graded	Not Graded	No. CABG Patients†
1995	1st Qtr: 1994 (1992); 2nd–4th Qtr: 1995 (1993)	5	29	3	37	5	11,007
1996	1995 (1993)	5	29	3	37	5	11,611
1997	1995 (1993)	5	29	3	37	8	11,466
1998	1st Qtr: 1995 (1993); 2nd–4th Qtr: 1998 (1994–1995)	4	33	3	40	11	10,888
1999	1998 (1994–1995)	4	33	3	40	13	10,468
2000	1998 (1994–1995)	3	32	3	38	15	9875
2001	1998 (1994–1995)	3	32	3	38	19	9185
2002	1st Qtr: 1998 (1994–1995); 2nd–4th Qtr: 2002 (2000)	4	45	3	52	8	8422
2003	2002 (2000)	4	45	3	52	9	7533
2004	2004 (2002)	7	49	2	58	2	6708
2005	2005 (2003)	3	55	1	59	1	5975

*The report card released in the second quarter of 1998 reflects data from 1994 to 1995. Other report cards are based on data from a single year.
†Patients live in nonrural areas and underwent scheduled CABG procedures.

identified from patients' ICD-9 diagnosis codes at the time they were admitted for surgery. We include separate dummy variables for the top 10 comorbidities and summarize all other comorbidities into a single dummy variable that equals one if the patient had at least one of these conditions. We also include dummies to indicate whether 1, 2, 3, or 4 or more vessels were revascularized, and whether the surgery involved a cardiopulmonary bypass. Although we exclude patients admitted from the emergency room from our sample so as to focus on scheduled surgeries, we include 2 dummies to indicate whether those scheduled surgeries were emergent or urgent. Finally, we control for the season of the patient's surgery (3 dummies) and for the region of their residence (8 dummies).

AH_{kt} in equations (1) and (2) represents a set of admitting-hospital characteristics that may affect the patient's health outcome. These variables are: dummies indicating whether, in the most recent report card, the hospital is graded, the grade is as-expected or the grade is superior, the number of CABG surgeries performed at the hospital in the preceding year, the number of CABG surgeries performed by the operating surgeon in the preceding year, and the hospital size category.

RESULTS

Descriptive statistics are shown in Table 2 for the whole sample and by whether a patient lived near a graded hospital. Travel distance was shorter for patients living near a graded hospital, but the mean patient characteristics show no systematic differences, lending support to our assumption that the grade of the nearby hospital is randomly assigned among patients of different age and severity of illness.

The first-stage estimation results are reported in Table 3, with SEs clustered by admitting hospital. Means and SDs for each IV are reported in column (1). Travel distance has been rescaled from miles to hundreds of miles to make

TABLE 2. Descriptive Statistics by Hospital Quality and Location, and for Sample*

	(1) Whole Sample	(2) No Graded Hospital Nearby	(3) Graded Hospital Nearby
Death	0.020	0.022	0.019
One-year readmission†	0.263	0.263	0.262
Distance to admitting hospital (in hundreds of miles)	0.149 (0.160)	0.233 (0.159)	0.088 (0.131)
Patient characteristics‡			
Male	0.709	0.708	0.710
White	0.874	0.873	0.874
Medicare	0.531	0.515	0.542
Age, 50–59 y	0.192	0.200	0.187
Age, 60–69 y	0.317	0.321	0.314
Age, 70–79 y	0.342	0.328	0.353
Age, ≥ 80 y	0.079	0.074	0.082
Hypertension, uncomplicated	0.516	0.511	0.519
Chronic pulmonary disease	0.134	0.136	0.132
Peripheral vascular disorders	0.096	0.090	0.100
Obesity	0.076	0.076	0.076
Fluid and electrolyte disorders	0.073	0.072	0.073
Hypothyroidism	0.056	0.053	0.057
Diabetes, complicated	0.038	0.038	0.038
Diabetes, uncomplicated	0.224	0.228	0.222
Coagulopathy	0.034	0.035	0.034
Deficiency anemia	0.055	0.053	0.056
Other comorbidities§	0.025	0.023	0.026
1 vessel revascularized	0.140	0.142	0.138
2 vessel revascularized	0.329	0.339	0.322
3 vessels revascularized	0.314	0.310	0.317
4+ vessels revascularized	0.163	0.152	0.171
Cardiopulmonary bypass	0.774	0.784	0.767
Emergency	0.221	0.234	0.212
Urgent	0.280	0.316	0.254
Admitting-hospital characteristics			
Graded	0.925	0.896	0.947
Grades are average	0.776	0.726	0.813
Grades are superior	0.102	0.127	0.083
Lagged surgeon volume	138.806 (57.895)	137.983 (57.705)	139.409 (58.028)
Lagged hospital volume	528.382 (276.14)	538.904 (276.284)	520.669 (275.782)
Bed size between 200 and 400	0.303	0.275	0.323
Bed size above 400	0.638	0.659	0.623

*SDs for continuous variables are reported in parentheses.
†Sample sizes for readmission are smaller. They are 10,000 whole sample, 42,606 no graded hospital nearby, and 58,305 graded hospital nearby.
‡Patient characteristics also include 3 seasonal dummies and 8 regional dummies that are not shown in this table.
§This dummy variable equals 1 if the patient has ≥ 1 of the remaining Elixhauser comorbidities.

the coefficients easier to read. As expected, the coefficients for IV1 and IV2 are negative, for IV3 and IV4 are positive, and all are significant. The F statistics on the joint significance of all 4 IVs are >10, evidence against the possibility that the IVs are only weakly correlated with travel distance to the admitting hospital.[29]

Table 4 shows our main results. Estimates of the marginal effect of travel distance on in-hospital mortality and readmission using Probit are reported in columns 1 and 6; the other columns show the estimated relationships using IV Probit. The estimates in columns 1–5 suggest that patients traveling further for surgery were more likely to die in the hospital. The effect of travel distance on mortality is considerably larger when IV estimation is used (columns 2–5), suggesting that Probit estimates are downward biased because of measurement error or because of the confounding effects from patients with stronger wills to live traveling further or traveling further to a center of excellence. The estimates in columns 6–10 suggest that the correlation between travel distance and the readmission rate is not statistically significant.

Validity of Instrumental Variables

Our results for in-hospital mortality in particular hinge on the quality of our instrumental variables. For example, for the instrumental-variable "Lives near graded hospital" to be valid, it must be correlated with travel distance (as is demonstrated in Table 3) but not correlated with health outcomes. Although we cannot directly test this latter assumption, there is evidence to support its validity. First, health indicators such as age and the prevalence of comorbidities are similar between those patients who live near a graded CABG hospital and those who do not (Table 2), suggesting that there is no obvious selection based on health conditions that would explain the different mortality rates.

Second, if the assumption is true, we can calculate a simple Wald estimate of the effect of travel distance on health outcomes by dividing the decrease in the mortality rate due to being near a graded hospital (the difference between columns 2 and 3 in Table 2, or 0.3 percentage points) and by the decrease in travel distance due to being near a graded hospital (the difference between columns 2 and 3, translated to hundreds of miles, or 0.145).[30] The Wald estimate ($-0.3/-0.145$) indicates that every additional 100 miles of travel is associated with a 0.021 increase in the mortality rate, which is very close to the estimates reported for IV1 and IV2 on Table 4 and suggests that living near a graded hospital is not correlated with observable differences in mortality rates.

Third, if our IVs do capture crucial elements concerning a patient's hospital choice, so that living near a graded hospital leads to shorter travel distances to the admitting hospital, then we would expect to see a larger effect if the hospital has an average or superior grade. Columns 3 and 5 of Table 3 show results consistent with this expectation.

Fourth, including the IVs in the main specification does not change our results, and the IV coefficients are insignificant. Finally, we reestimated the specification as a linear probability model so we could test the relevance of the IVs after the first-stage estimations using a Kleibergen-Paap rank LM test, under the null hypothesis that the instruments are jointly uncorrelated with travel distance,[31,32] and the validity of the IVs using the Hansen's J test, under the null hypothesis that the instruments are jointly exogenous.[31,33] Test results indicated that the IVs are strong and that there is no overidentification problem when using IV2 or IV4.

Patient Severity

We investigate whether traveling further was more harmful for sicker patients by reestimating our equations on subsamples of low-severity (Elixhauser index <2) and high-severity (Elixhauser index ≥ 2) patients. (First-stage results were similar to those on Table 3.) The results in columns 2–5 of Table 5 indicate that travel distance did not affect the mortality of relatively healthy patients, once the effects of endogeneity are controlled. However, for high-severity patients, mortality rates were 2 to 5 times higher among those

TABLE 3. First-stage Results on the Effects of Hospital Grades on Patient Travel Distance†

	(1) Mean (SD)	(2) IV1	(3) IV2	(4) IV3	(5) IV4
Live near graded hospital	0.577 (0.494)	−0.127*** (0.008)	−0.043* (0.023)		
Live near hospital with average or superior grade	0.550 (0.498)		−0.088*** (0.022)		
Distance to the closest graded hospital‡	0.109 (0.093)			0.936*** (0.059)	0.329** (0.162)
Distance to the closest hospital with average or superior grade‡	0.115 (0.096)				0.613*** (0.137)
F statistics on joint significance of instrumental variables		259.5	147.6	253.4	182.2
Sample size	102,858	102,858	102,858	102,858	102,858

†The first-stage estimates an OLS model of patient's actual travel distance. The equation includes patient and admitting-hospital characteristics and admitting hospital and year fixed effects. Values of the dependent variable "Travel distance" are divided by 100. Robust SEs, clustered by admitting hospital, are reported in brackets.
‡Values of distance to the closest graded hospital and to the closest hospital with average or superior grade are divided by 100.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

TABLE 4. Travel Distance to Admitting Hospital and Health Outcomes[†]

	Mortality					Readmission				
	(1) Probit	(2) IV1	(3) IV2	(4) IV3	(5) IV4	(6) Probit	(7) IV1	(8) IV2	(9) IV3	(10) IV4
Travel distance	0.008*** (0.002)	0.022*** (0.008)	0.022*** (0.008)	0.014*** (0.004)	0.013*** (0.004)	0.008 (0.012)	0.024 (0.033)	0.021 (0.032)	0.007 (0.025)	0.006 (0.024)
Durbin-Wu-Hausman Test		2.067	2.395	0.489	0.258		0.396	0.291	0.002	0.005
P		0.150	0.122	0.484	0.611		0.529	0.589	0.966	0.943
Sample size	102,858	102,858	102,858	102,858	102,858	100,911	100,911	100,911	100,911	100,911

[†]Marginal effects of travel distance are reported. Equation includes patient and admitting-hospital characteristics and admitting hospital and year fixed effects. Values of the dependent variable "Travel distance" are divided by 100. Robust SEs, clustered by admitting hospital, are reported in brackets.

*Significant at the 10 %level.

**Significant at the 5% level.

***Significant at the 1% level.

TABLE 5. Health Outcomes and Travel Distance to Admitting Hospital, By Patient Severity[†]

	Mortality					Readmission				
	(1) Probit	(2) IV1	(3) IV2	(4) IV3	(5) IV4	(6) Probit	(7) IV1	(8) IV2	(9) IV3	(10) IV4
Low-severity patients										
Travel distance	0.005** (0.003)	0.001 (0.009)	0.003 (0.009)	0.006 (0.006)	0.006 (0.006)	0.020 (0.018)	0.059* (0.036)	0.055 (0.035)	0.021 (0.032)	0.023 (0.031)
Durbin-Wu-Hausman Test		0.614	0.303	0.0387	0.0435		2.173	1.814	0.003	0.028
P		0.433	0.582	0.844	0.835		0.140	0.178	0.958	0.868
Sample size	57,386	57,386	57,386	57,386	57,386	56,515	56,515	56,515	56,515	56,515
High-severity patients										
Travel distance	0.009*** (0.002)	0.050*** (0.015)	0.048*** (0.014)	0.024*** (0.008)	0.022*** (0.008)	−0.007 (0.016)	−0.016 (0.045)	−0.018 (0.044)	−0.003 (0.037)	−0.007 (0.036)
Durbin-Wu-Hausman Test		9.311	8.963	2.573	1.849		0.0553	0.0843	0.0205	0.000
P		0.002	0.003	0.109	0.174		0.814	0.772	0.886	0.999
Sample size	44,530	44,530	44,530	44,530	44,530	44,396	44,396	44,396	44,396	44,396

[†]Marginal effects of travel distance are reported. Equation includes patient and admitting-hospital characteristics and admitting hospital and year fixed effects. Values of the dependent variable "Travel distance" are divided by 100. Robust SEs, clustered by admitting hospital, are reported in brackets.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

who traveled further. Moreover, the Durbin-Wu-Hausman test rejects the hypothesis that travel distance is exogenous for these patients, suggesting that Probit estimation underestimates the true effect of travel distance on severely ill patients because of better outcomes among those who travel further to centers of excellence or who have stronger wills to live.

Columns 6–10 of Table 5 again show that travel distance has little effect on readmission. Although results from IV1 indicate that low-severity patients might be experiencing higher readmission rates, the estimated effect is marginally significant, and travel distance is not significant in the other specifications.

DISCUSSION

We use IVs based on the quality of nearby hospitals to investigate whether traveling further to a hospital for a one-time, scheduled, surgical procedure harms patients. The results of the first-stage estimations imply that the local availability of better quality hospitals was associated with less travel for patients. Estimation of our main specification suggests that in-hospital mortality rates are higher for more severely ill patients who travel further to their admitting hospital. Readmission rates did not appear to be strongly related to travel distance.

The number of CABG surgery centers increased during our sample period because in December 1996, Pennsylvania repealed its Certificate of Need law, which, until then, had restricted the entry of new CABG programs. Consequently, the average distance traveled by severely ill patients in our sample fell by 2.66 miles during our sample period. Multiplying this reduction by the estimated coefficients in Table 5 (0.00022 and 0.0005 when rescaled to represent deaths per additional mile traveled), we concluded that mortality rates fell by 0.0005852 to 0.00133 because of shorter travel distances, a reduction of 4.5%–10.23% (based on a mean mortality of 0.013 for severely ill patients over the sample period).

Our results are in line with those of a very different study that compared predicted to actual outcomes for patients undergoing a number of different types of elective surgeries at the Mayo Clinic, which relied on risk-adjusting to control for confounding effects and which came to the unexpected conclusion that patients who lived closer to the hospital did better than predicted.[14] Such findings contribute to the debate as to the desirability of steering patients to high-volume providers for specialized surgery.[1,3] The mortality effects we found are small but provide evidence that travel distance may negatively affect health outcomes even for the type of complex surgery most likely to benefit from greater regionalization. However, given the potential gains from increased surgical volume and the cost of new programs,[4,34–36] the appropriate policy goal may be to try to improve the quality of care at existing locations rather than increasing the number of providers.[37]

Our analysis has limitations. Although our results about the effects of travel may generalize to other types of scheduled surgery, the specific findings apply to CABG patients in Pennsylvania. Further, our readmission data are confined to readmission in the quarter following surgery and may be missing important readmissions occurring sooner after a patient's operation occurs. This may partly explain why we did not find a precise effect on readmission. We also lack data on whether a patient dies once they have left the hospital, so we are unable to discern the effects of travel on other important patient outcomes such as 7-day or 30-day mortality.

Finally, although our analysis suggests that longer travel distance harms patients, we do not identify the specific causes of harm. Various mechanisms such as psychological stress, lack of family support, and difficulties in coordinating care may explain why outcomes are worse for patients who travel further, but each mechanism calls for a different response, such as providing preoperative care and education at more locations, or supplementing the informal care provided by families by encouraging the use of hospitalists, intensivists, and/or information technology. More research on why travel distance affects health outcomes is necessary before the appropriate policy responses can be determined.

ACKNOWLEDGMENTS

The authors thank Muzhe Yang, Justin Wang, and participants at the Eastern Economic Conference and the International Industrial Organization Conference for their comments.

REFERENCES

1. Birkmeyer JD, Siewers AE, Marth NJ, et al. Regionalization of high-risk surgery and implications for patient travel times. *JAMA*. 2003;290:2703–2708.
2. Kansagra SM, Curtis LH, Schulman KA. Regionalization of percutaneous transluminal coronary angioplasty and implications for patient travel distance. *JAMA*. 2004;292:1717–1723.
3. Dimick JB, Finlayson SRG, Birkmeyer JD. Regional availability of high-volume hospitals for major surgery. *Health Aff*. 2004;23:VAR45–VAR53.
4. Cutler DM, Huckman RS, Kolstad JT. Input constraints and the efficiency of entry: lessons from cardiac surgery. *Am Econ J*. 2010;2:51–76.
5. Currie J, Reagan PB. Distance to hospital and children's use of preventive care: is being closer better, and for whom? *Econ Inq*. 2003;41:378–391.
6. Buchmueller TC, Jacobson M, Wold C. How far to the hospital? The effect of hospital closures on access to care. *J Health Econ*. 2006;25:740–761.
7. Hulzebos EHJ, Helders PJM, Favie NJ, et al. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. *JAMA*. 2006;296:1851–1857.
8. Lamarche D, Taddeo R, Pepler C. The preparation of patients for cardiac surgery. *Clin Nurs Res*. 1998;7:390–405.
9. Arthur HM, Daniels C, McKelvie R, et al. Effect of a preoperative intervention on preoperative and postoperative outcomes in low-risk patients awaiting elective coronary artery bypass graft surgery: a randomized, controlled trial. *Ann Intern Med*. 2000;133:253–262.
10. Lamont EB, Hayreh D, Pickett KE, et al. Is patient travel distance associated with survival on phase II clinical trials in oncology? *J Natl Cancer Inst*. 2003;95:1370–1375.
11. Paltiel O, Ronen I, Pollicach A, et al. Two-way referral bias: evidence from a clinical audit of lymphoma in a teaching hospital. *J Clin Epidemiol*. 1998;51:93–98.
12. Lenhard RE Jr, Enterline FP, Crowley J, et al. The effects of distance from primary treatment centers on survival among patients with multiple myeloma. *J Clin Oncol*. 1987;5:1640–1645.

13. Ballard DJ, Bryant SC, O'Brien PC, et al. Referral selection bias in the Medicare hospital mortality prediction model: are centers of referral for Medicare beneficiaries necessarily centers of excellence? *Health Serv Res*. 1994;28:771–784.
14. Etzioni DA, Fowl RJ, Wasif N, et al. Distance bias and surgical outcomes. *Med Care*. 2013;51:238–244.
15. Cameron AC, Trivedi PK. *Microeconometrics: Methods and Applications*. Cambridge: Cambridge University Press; 2005:908–909.
16. Luft HS, Garnick DW, Mark DH, et al. Does quality influence choice of hospital? *JAMA*. 1990;263:2899–2906.
17. Burns LR, Wholey DR. The impact of physician characteristics in conditional choice models for hospital care. *J Health Econ*. 1992;11: 43–62.
18. Tay A. Assessing competition in hospital care markets: The importance of accounting for quality differentiation. *RAND J Econ*. 2003;34: 786–814.
19. McClellan M, McNeil BJ, Newhouse JP. Does more intensive treatment of acute myocardial infarction reduce mortality? *JAMA*. 1994; 270:1832–1836.
20. McClellan M, Newhouse JP. The marginal cost-effectiveness of medical technology: a panel instrumental-variables approach. *J Econometrics*. 1997;77:39–64.
21. Kessler DP, McClellan MB. Is hospital competition socially wasteful? *Q Jf Econ*. 2000;115:577–615.
22. Ettner SL, Hermann RC. The role of profit status under imperfect information: evidence from the treatment patterns of elderly Medicare beneficiaries hospitalized for psychiatric diagnoses. *J Health Econ*. 2001;20:23–49.
23. Sloan FA, Picone GA, Taylor DH Jr, et al. Hospital ownership and cost and quality of care: is there a dime's worth of difference? *J Health Econ*. 2001;20:1–21.
24. *Technical Notes for Pennsylvania's Guide to Coronary Artery Bypass Graft Surgery*. Vol. I–V. Harrisburg: Pennsylvania Health Care Cost Containment Council, 1994–2005. Available at: http://www.phc4.org/reports/cabg. Accessed October 4, 2013.
25. Bliss RL, Katz JN, Wright EA, et al. Estimating proximity to care: are straight line and zipcode centroid distances acceptable proxy measures? *Med Care*. 2012;50:99–106.
26. *Pennsylvania's Guide to Coronary Artery Bypass Graft Surgery*. Vol. I-V. Harrisburg: Pennsylvania Health Care Cost Containment Council, 1994-2005. Available at: http://www.phc4.org/reports/cabg. Accessed October 4, 2013.
27. Dranove D, Sfekas A. Start spreading the news: a structural estimate of the effects of New York hospital report cards. *J Health Econ*. 2008;27.5:1201–1207.
28. Elixhauser A, Steiner C, Harris DR, et al. Comorbidity measures for use with administrative data. *Med Care*. 1998;36:8–27.
29. Staiger D, Stock JH. Instrumental variables regressions with weak instruments. *Econometrica*. 1997;65:557–586.
30. Chandra A, Staiger DO. Productivity spillovers in health care: evidence from the treatment of heart attacks. *J Political Econ*. 2007;115:103–140.
31. Baum CF, Schaffer ME, Stillman S. Enhanced routines for instrumental variables/GMM estimation and testing. *Stata J*. 2007;7:465–506.
32. Kleibergen F, Paap R. Generalized reduced rank tests using the singular value decomposition. *J Econom*. 2006;133:97–126.
33. Angrist JD, Pischke JS. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press; 2009.
34. Grumbach K, Anderson GM, Luft HS, et al. Regionalization of cardiac surgery in the United States and Canada. *JAMA*. 1995;274:1282–1288.
35. Gaynor M, Seider H, Vogt WB. The volume-outcome effect, scale economies, and learning-by-doing. *Am Econ Assoc Pap Proc*. 2005;95:243–247.
36. Halm AE, Lee C, Chassin MR. Is volume related to outcome in health care? A systematic review and methodologic critique of the literature. *Ann Intern Med*. 2002;137:511–520.
37. Birkmeyer JD. Should we regionalize major surgery? Potential benefits and policy considerations. *J Am Coll Surg*. 2000;190:341–349.