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Effects of Hospital Type and Distance on Lymph Node Assessment for Colon Cancer among Metropolitan and Non-metropolitan Patients in Appalachia

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Abstract

We studied differences in access to large or accredited cancer programs as a possible explanation for geographic disparities in adherence to the national guideline on lymph-node assessment for Stage I–III colon cancer. State cancer registries were linked with Medicare claims of patients diagnosed in 2006–2008 from Appalachian counties of four states. Metropolitan and non-metropolitan patients differed on adherence, proximity to high-volume or accredited hospitals, and hospital type. We modeled effects of hospital type on adherence with ordinary least squares and instrumental variables (instrumenting for hospital type with relative distance). The evidence was strongest for improved adherence in high-volume hospitals for non-metropolitan patients. We estimate that roughly 100 deaths might be prevented over 5 years among each year's incident cases if the non-metropolitan disparity in hospital volume were eliminated nationally. We conclude that regionalization or targeting smaller hospitals would improve adherence in non-metropolitan areas, but also argue for improving adherence generally.

Keywords

colon cancer; geographic access; quality of care; clinical guidelines; hospital volume

Introduction

This population-based study assesses differences in geographic access to hospitals with large or accredited cancer programs, and asks if hospital differences contribute to disparities between residents of metropolitan and non-metropolitan counties in the quality of colon cancer care. The patient sample was diagnosed with colon cancer from 2006 through 2008 and lived in the 167 Appalachian counties of Pennsylvania, Ohio, Kentucky, and North Carolina. Nearly half of the patients lived in non-metropolitan counties. The study uses data from state cancer registries linked with Medicare claims to select and characterize the patient sample, to identify hospitals performing cancer surgeries and measure surgical volume by hospital, and to assess adherence to a clinical guideline for colon cancer that is applicable to most patients.

Appalachia is a large, heterogeneous region extending from New York to Mississippi and encompassing 420 counties in 13 states (ARC, 2012). Parts of Appalachia are disadvantaged by geographic and socioeconomic factors negatively affecting access to health care: 42% of the population is rural (ARC, 2012), and nearly a quarter of Appalachian counties are classified by the Appalachian Regional Commission (ARC) as economically distressed. Nonetheless, one-sixth of Appalachian counties exceed the national median in economic status according to the ARC, and there are a number of cities in Appalachia—including Pittsburgh, Knoxville, and Winston-Salem. Under these circumstances, significant disparities in health and health care are likely within Appalachia. Furthermore, given the number of rural residents in Appalachia, focusing on Appalachia allows us to study cancer care for rural patients more intensively than sample sizes in national data would usually permit.

Colon cancer is often combined with rectal cancer in published statistics and research studies, but nearly three-quarters of new cases of colorectal cancer (CRC) are colon cancers

(ACS, 2015). Colorectal cancer ranks fourth in incidence and second in mortality among cancer types nationally (ACS, 2015), and exhibits excess incidence (Lengerich et al., 2005; Wingo et al., 2008) and mortality (Huang et al., 2002) in Appalachia.

Our study is aimed at identifying modifiable factors associated with variations in quality of cancer care. Specifically, we examine adherence to a clinical guideline for colon cancer that is applicable to most patients and is supported by strong evidence of survival benefit. The guideline recommends removal and assessment of at least 12 lymph nodes with surgical resection of Stage I–III colon cancer (CoC 2011a). It is endorsed by the Commission on Cancer (CoC) of the American College of Surgeons, the American Society of Clinical Oncology, and the National Comprehensive Cancer Network.

The expectation of survival benefit from the lymph node guideline is based on high-quality retrospective evidence (Chang, Rodriguez-Bigas, Skibber, & Moyer, 2007; Parsons et al., 2011). The survival benefit is believed to come mainly from “re-staging,” that is, discovering additional patients with node involvement who will benefit from adjuvant chemotherapy (Nathan et al., 2011; Bilimoria et al., 2008). Beyond re-staging, there may be additional therapeutic advantage from more complete surgical resection of local/regional disease (Parsons et al., 2011), but that contention is controversial.

Different studies have reported survival advantages of 7–34%, often utilizing different cutoff points for the number of lymph nodes sampled (Chang, Rodriguez-Bigas, Skibber, & Moyer, 2007). In the largest population-based study (86,394 patients), Parsons et al. (2011) reported a 17% reduction in the regression-adjusted 5-year hazard of death for 12–15 nodes compared to 1–8 nodes. From the data presented in the Parsons study, we calculate that the unadjusted improvement in 5-year survival for patients with 12+ nodes evaluated, compared to fewer than 12 nodes, is 8 percentage points. This estimate reflects monotonically increasing survival rates for categories of patients ranging from 0 to 40+ nodes evaluated, which we weighted by the 2006–2008 distribution of cases by number of nodes evaluated.

Providers with higher case volumes or specialized/accredited cancer practices have better quality of care and survival according to many, but not all studies of colon or colorectal cancer (Gruen et al., 2009; Hodgson, Fuchs, & Ayanian 2001; Hillner, Smith, & Desch, 2000; Paulson et al., 2008; Schrag et al., 2002; Ayanian et al., 2003). Rhoads et al. (2013) found that adherence to the lymph node guideline was lower in hospitals serving a high percentage of Medicaid patients. However, a recent study of lymph node assessment after colon resection (Nathan et al., 2011) concluded that nearly 80% of practice variation was explained by patient differences, while variation between hospitals greatly exceeded variation by physician within hospitals.

The main accrediting body for hospital cancer programs is the Commission on Cancer, established by the American College of Surgeons in 1922 as “a consortium of professional organizations dedicated to improving survival and quality of life for cancer patients (CoC 2014).” Nationally, there are about 1500 cancer programs accredited by the CoC (2015), in institutions that range from community hospitals to the 60 or so medical research centers selected by the National Cancer Institute for its Cancer Center Program (NCI 2015).

In an initial study published from our Appalachian data, Fleming et al. (2014) reported significantly better adherence to the lymph node guideline for metropolitan compared to non-metropolitan patients. The unadjusted relative rate of adherence was 1.1. In multivariate analyses, adherence was significantly associated with surgical treatment in hospitals with high CRC surgery volumes or accredited by the CoC, but a dummy variable distinguishing metropolitan and non-metropolitan patients was not significant.

New Contribution

In this study, we examine possible explanations for the difference between metropolitan and non-metropolitan patients in adherence to the lymph node guideline, especially explanations involving geographic access to higher-performing hospital types. If the quality of care is lower for residents of non-metropolitan areas because they make less use of large or accredited hospitals, then quality could be improved in non-metropolitan areas by concentrating surgical volume in fewer hospitals, incentivizing hospitals to seek cancer accreditation or establish formal oncology relationships with major cancer programs, or encouraging patients to travel longer distances to reach large or accredited cancer programs. In population-based samples of patients from metropolitan and non-metropolitan counties, we quantify differences in the hospital types used for colon cancer surgery, as well as road distances to accredited and high-volume hospitals. We also compare patients from metropolitan and non-metropolitan counties on clinical and demographic characteristics that might also contribute to differences in guideline adherence. Then we estimate multivariate models to quantify the effect of distance on hospital type, and the effect of hospital type on adherence, separately for metropolitan and non-metropolitan patients and controlling for other differences between the two geographic samples. In our multivariate analyses, using relative distance to the nearest hospital of a particular type as an instrumental variable for hospital type, we address methodological concerns about the endogeneity of hospital type that could bias estimates of the effect of volume or accreditation on adherence to clinical guidelines.

Conceptual framework

Our analysis is guided by a conceptual framework that views each patient, in consultation with physicians and other information sources, as selecting a hospital for cancer surgery. Depending on the accreditation, volume, and other characteristics of the nearest hospital able to do the surgery, a patient may bypass that hospital in favor of another with more desirable characteristics. However, the likelihood of choosing a preferred, but more distant hospital diminishes with additional distance. Beyond convenience for the patient, choosing a nearby hospital reduces travel time for hospital visits by family members and may enhance care coordination by taking advantage of working relationships between local primary care physicians and local cancer surgeons.

The endogeneity of hospital characteristics implied by this framework complicates estimation of the effects of volume and accreditation on adherence to the lymph node guideline, effects that are centrally important in testing the hypothesis that geographic differences in the types of hospitals used by metropolitan and non-metropolitan patients

contribute to geographic differences in adherence. Of particular concern is the possibility that patient sorting leads to unmeasured differences in patient mix across hospitals that affect adherence. For example, in many settings, more severely ill or complicated patients may seek or may be advised to seek care at specialized or high-volume hospitals. Alternatively, patients with more income or education may be more likely to seek treatment at such facilities and may also be steered toward physicians who closely adhere to guidelines. More knowledgeable patients may even question surgeons about node assessment before undergoing surgery. In any of these and other similar scenarios, the endogeneity of hospital type could lead to incorrect conclusions about improvements in quality that could be realized by shifting patients to large, accredited cancer programs.

Fortunately, geographic differences in access to hospitals of different types, although potentially diminishing the quality of care for some patients, offer an empirical solution for unobserved case-mix bias in models of the effects of hospital type on quality of care. Researchers regularly use patient distance to hospitals of specific types as an instrumental variable (IV) for hospital type in these analyses (McClellan, McNeil & Newhouse, 1994; Gowrisankaran & Town, 1999; Geweke, Gowrisankaran, & Town, 2003). In our particular application, if the first stage of an IV analysis, implemented by two-stage least squares (2SLS), indicates that longer distances strongly discourage use of high-volume or accredited hospitals, and our second-stage regressions confirm that these hospital types follow the guideline more closely, holding other factors constant, then we will have shown that adherence to the guideline is diminished by reduced access to preferred hospital types.

Methods

Data

All patients diagnosed with colon cancer in 2006, 2007, or 2008 who resided at diagnosis in our Appalachian study area were identified from state cancer registries (N=15,113). Medicare claims for each Medicare patient over the period from 2005 to 2009, encompassing at least one calendar year before and after the diagnosis year, were obtained from the Centers for Medicare and Medicaid Services. After the Medicare linkage, the analytic sample was constructed as described in Figure 1. (Specific algorithms are available upon request.) Many of the exclusions that reduced the initial sample from 15,113 to 2,552 patients were aimed at narrowing to a homogeneous clinical population appropriate to the guideline (restricting to adenocarcinoma, first and only cancers, patients not qualifying for Medicare disability, Stage I–III with surgical resection). Other exclusions reflect data limitations (missing identifiers, failed linkages, incomplete claims data, and missing data items). Because Medicare claims were used in defining the sample and variables, the study was restricted to Medicare fee-for-service patients. Given the emphasis on distance to alternative hospital types, analyses were also restricted to patients treated by hospitals in an area defined by the four states and other states along their borders. Some patients affected by this exclusion (N=148) undoubtedly traveled to distant hospitals specifically for cancer treatment, but others may have been living temporarily elsewhere when diagnosed (wintering in Florida, for example) or may have stayed with family members living outside the region during treatment.

We constructed analytic variables by combining or choosing between registry and claims data, according to data availability and judgments about potential biases and reliability. Surgical resections were identified from CRC surgical codes on claims in the year after diagnosis and the most extensive primary surgery identified by the registry. Adherence to the lymph node guideline was measured directly from registry variables reporting the number of nodes removed and assessed. Covariates included patients' socio-demographic characteristics (age, gender, race, ethnicity) and clinical characteristics (stage, tumor size, tumor grade), taken from the registries. Comorbidity burden was assessed over the year before cancer diagnosis with a claims-based ACE-27 score adapted by Fleming et al. (2011), which considers 26 different comorbidities aggregated into four levels of severity: none, mild, moderate, and severe.

The hospital performing each patient's primary colon cancer surgery was identified from hospital identification codes in inpatient and outpatient surgical claims. The hospital's CoC accreditation status was measured as of 2011, as obtained from the CoC's web-based facility locator (CoC 2011b). In addition to "not accredited," we considered the CoC's five accreditation categories: (1) community hospital cancer program (requires 100–649 new cases annually); (2) community hospital comprehensive cancer program (requires 650 or more new cases annually); (3) integrated network cancer program (multiple hospitals under common ownership, no minimum caseload); (4) NCI-designated comprehensive cancer center program; and (5) academic comprehensive cancer program. Because only two unique network programs treated patients in our sample, we assigned those few patients to the community hospital comprehensive category.

Medicare colorectal surgery volume was determined for hospitals that performed colon surgery on anyone in our sample, or rectal cancer surgery in a similarly identified sample (Fleming et al., 2014). All hospitals in PA, OH, KY, NC, or neighboring states were considered, whether the hospital was located in Appalachia or not; hospitals outside the contiguous multi-state area were not considered. All Medicare claims for all Medicare patients treated for colorectal cancer in these hospitals in 2008 were obtained. After claims with procedure codes for CRC resection (omitting biopsies, polypectomies, and simple excisions) were extracted, the number of unique patients with claims was counted by hospital. The final variable was defined by quartiles of unique hospitals, ranked by Medicare volume.

Text addresses of patients at diagnosis (from the cancer registry) and hospitals that performed CRC surgery on sample patients (from the CMS Place of Service file) were geocoded into geographic coordinates and identifiers, using the ZIP code centroid for patients with missing street addresses and Internet look-ups when necessary for hospitals. After geocoding, we used the Network Analyst extension in ArcGIS 10.x to calculate the shortest driving distances in miles from each patient's residence to (1) the hospital where the patient had colon cancer surgery, (2) the nearest CRC surgical hospital, (3) the nearest hospital in the top quartile of CRC surgical volume, and (4) the nearest hospital with CoC accreditation of any type. Here, too, all hospitals in PA, OH, KY, NC, or neighboring states were considered, whether in Appalachia or not. Geocoded patient addresses were used to identify residents of metropolitan and non-metropolitan counties, based on Rural/Urban

Continuum Codes assigned by the U.S. Department of Agriculture (2003). County-level data on median household income come from 5 years of the American Community Survey, 2005–2009 (U.S. Bureau of the Census, 2014). We compared county incomes of metropolitan and non-metropolitan patients, but because the income data were for a single time period, we could not include county income in regression models that also controlled for county fixed effects.

Analysis—We compared metropolitan and non-metropolitan patients on guideline adherence, use of hospitals with high CRC surgical volumes or cancer accreditation, and distances from each patient’s residence to the nearest hospital performing CRC surgeries, nearest high-volume hospital, nearest accredited hospital, and the hospital where the patient actually had surgery. In addition, we tabulated characteristics of the sample in terms of model covariates, overall and separately for metropolitan and non-metropolitan patients. We used chi-square tests to test for significant differences between metropolitan and non-metropolitan patients involving multi-category variables, and t-tests for differences in mean distances or proportions within a single category. To inform our interpretation of findings related to the separate effects of accreditation and high-volume on adherence to the guideline, we also examined the overlap in hospital types in our patient sample.

To quantify the effects of hospital type and other factors on adherence to the lymph node guideline, we estimated linear probability models (LPMs) with adherence as the dependent variable. We modeled the dichotomous dependent variable with LPM (rather than logit or probit) because the coefficients are immediately interpretable as partial effects on probabilities and because use of LPM is likely to be innocuous in settings, such as ours, where the mean of the dependent variable (.68) is not close to zero or one. As a sensitivity check, we re-estimated all models as probits, using the two-stage residual inclusion (2SRI) estimator of Terza, Basu, and Rathouz (2008) in place of 2SLS when instrumenting for hospital choice.

All regression models controlled for patient demographics and clinical characteristics, as well as county and year fixed effects. Although results were virtually identical when indicators for cancer stage were included, we opted to omit stage from the models because of the increased possibility of re-staging when 12+ lymph nodes were assessed, thereby creating an ex post association between stage and our dependent variable.

The main explanatory variables of interest were binary hospital indicators for surgical volume in the fourth quartile of hospitals performing Medicare CRC surgeries and for any level of CoC accreditation. We estimated separate models for patients in metropolitan and non-metropolitan counties. Robust standard errors, clustered by county, were used in all regression models. To account for the likely endogeneity of hospital choice, we employed a common instrumental variables strategy, in which the type of hospital chosen by each patient is predicted from the distance from the patient’s residence to the nearest hospital of interest (high-volume or CoC), minus the distance to the nearest hospital of any type (McClellan, McNeil, & Newhouse, 1994; Gowrisankaran & Town, 1999; Geweke, Gowrisankaran, & Town, 2003). We implemented this strategy by estimating a 2SLS model for adherence to the lymph node guideline with instruments for both endogenous variables (receipt of care at

a high-volume or CoC hospital) on the right-hand side. Importantly, given Appalachia's varying terrain, we considered the shortest driving distance instead of straight-line distance. Used in conjunction with county fixed effects, our IV estimator compares adherence rates among patients within the same county who lived relatively far from, versus relatively close to, a high-volume or accredited hospital.

Results

As shown in Table 1, adherence to the lymph node guideline in our analytic sample was 7 percentage-points higher for residents of metropolitan counties compared to non-metropolitan counties. Table 1 further demonstrates that adherence to the guideline was strongly associated with hospital accreditation and volume. Between patients treated in the top and bottom quartiles of hospitals by volume, there was a gap of 26 percentage points in adherence (80% compared to 54%). There was a similar gap between NCI-designated cancer centers and unaccredited hospitals. Even for smaller accredited community cancer programs compared to unaccredited hospitals, the improvement associated with accreditation was 14 percentage points.

Furthermore, metropolitan and non-metropolitan patients differed significantly in their use of large or accredited hospitals (Table 2). Compared to non-metropolitan patients, metropolitan patients were almost twice as likely to go to high-volume hospitals. Metropolitan patients were half again as likely to go to accredited hospitals. The overlap in hospital types is shown separately for metropolitan and non-metropolitan patients in Figure 2. In the metropolitan sample, the largest percentage of patients used hospitals that were high-volume and accredited, followed by hospitals that were accredited but not high-volume. In the non-metropolitan sample, the largest percentage of patients used hospitals that were neither high-volume nor accredited, followed by hospitals that were accredited but not high-volume. Few patients in either sample used high-volume hospitals that were not accredited.

There were also significant differences between metropolitan and non-metropolitan patients in age, gender, and race/ethnicity (Table 2), but not clinical characteristics such as stage, tumor size, or tumor grade (data not shown). Additionally, the two samples differed dramatically on median county income. Nearly 9 out of 10 non-metropolitan patients lived in counties with median incomes in the bottom two categories (roughly below the median for the entire patient sample), while nearly two-thirds of metropolitan patients lived in counties with median incomes in the top two categories.

As expected, there were also differences between metropolitan and non-metropolitan patients in distance travelled for colon cancer surgery, and proximity to hospitals of different types (Table 3). On average, the nearest high-volume hospital was 17 miles from metropolitan patients, compared to 47 miles from non-metropolitan patients. The nearest accredited hospital was 9 miles from metropolitan patients, compared to 25 miles from non-metropolitan patients. Both types of patients faced longer distances to reach hospitals with high surgical volumes than some level of cancer accreditation.

On average, non-metropolitan patients travelled 11 miles farther for colon cancer surgery than metropolitan patients (23 miles versus 12 miles). However, in both samples, the majority of patients went to the nearest hospital that performed CRC surgeries. The nearest hospital to 35% of metropolitan patients performed a high volume of CRC surgeries; the nearest hospital to 65% of metropolitan patients was accredited. (For these patients, the regression variable measuring relative distance to a high-volume or accredited hospital was zero.) By contrast, the nearest hospital to 6% of non-metropolitan patients performed a high volume of CRC surgeries, and the nearest hospital to 31% of non-metropolitan patients was accredited. For non-metropolitan patients, relative distances to preferred hospital types were significantly longer, an average of 37 extra miles to reach a high-volume hospital versus 11 miles for metropolitan patients, and an average of 16 extra miles to reach an accredited hospital versus 3 miles for metropolitan patients.

In Table 4, we report coefficients from LPM models incorporating patient characteristics, along with county and year fixed effects. Models estimated with OLS are displayed in the first and third columns of the tables (separately for metropolitan and non-metropolitan patients), while IV/2SLS models are displayed in the second and fourth columns. In the 2SLS columns, information about first-stage estimates of the relationship between relative distance and hospital type is shown below second-stage estimates of the relationship between hospital type and adherence.

In models estimated by OLS, the effects of hospital volume and accreditation on adherence were statistically significant for both metropolitan and non-metropolitan patients. Three of the four coefficients were large and fairly similar in size, but the coefficient on accreditation was smaller in the non-metropolitan sample. Thus, OLS models suggest that shifting patients to high-volume and/or accredited hospitals would improve adherence in both metropolitan and non-metropolitan areas. As expected, the corresponding marginal effects from probit models (available upon request) were very similar.

Estimates from the first stage of the 2SLS analysis show that relative distance to the nearest high-volume or accredited hospital (that is, miles beyond the nearest hospital) strongly predicted use of these hospital types. For example, for metropolitan patients, each additional mile to the nearest high-volume hospital reduced the probability of using a high-volume hospital by 1.8 percentage points (Table 4). Each additional mile reduced the probability of using an accredited hospital by 3.2 percentage points. The smaller effect of distance on volume is in keeping with longer average distances to high-volume hospitals—even in metropolitan areas. The corresponding coefficients for non-metropolitan patients were about half as large in absolute value, implying that two miles of additional driving had about the same effect on hospital choices of non-metropolitan patients as one mile for metropolitan patients.

To avoid finite-sample bias from weak instruments, it is important that our relative distance instruments exert a sufficiently strong influence on the choice of high-volume and accredited hospitals. At the bottom of Table 4, we report Cragg-Donald and Kleibergen-Paap statistics, which are commonly used to test the null hypothesis of “weak instruments” when multiple endogenous variables are present (Cragg and Donald, 1993; Kleibergen and Paap, 2006).

Stock and Yogo (2005, Table 5.2) compiled critical values for these test statistics. For the case of two endogenous regressors and two instruments, the largest of the Stock-Yogo critical values is 7.03, which allows us in all cases to reject the hypothesis that our instruments are weak.

For metropolitan patients, the 2SLS estimates of the effects of volume or accreditation on adherence, displayed in the second column of Table 4, were close to zero and statistically insignificant. For non-metropolitan patients, the 2SLS estimate for high-volume hospitals was statistically significant and about twice as large as the OLS estimate (49.8 percentage points compared to 23.1 percentage points). The non-metropolitan 2SLS estimate for accreditation was also larger than the OLS estimate (14.1 percentage points compared to 7.9 percentage points). However, the 2SLS estimate for accreditation had a much larger standard error and did not approach statistical significance. In all cases, the marginal effects from the nonlinear 2SRI estimator (available upon request) were quite similar to the 2SLS estimates.

The only covariates in Table 4 that were significant for both metropolitan and non-metropolitan patients were tumor size and year of diagnosis. More lymph nodes were assessed in patients with larger tumors, and adherence to the guideline improved over time. Although there were differences between the metropolitan and non-metropolitan models in the statistical significance of other covariates, usually these differences were not themselves statistically significant. The most important exception was tumor size, where the gradient linking larger tumors to more complete lymph node assessment was significantly steeper in non-metropolitan areas than metropolitan areas. There was also some suggestion that adherence was more tightly linked to tumor differentiation in the non-metropolitan sample, paralleling the geographic difference related to tumor size, but the difference between the metropolitan and non-metropolitan coefficients was significant only for moderately differentiated tumors and not for poorly differentiated tumors. Finally, the regression-adjusted adherence rate was significantly lower in the age group from 76–80 in the non-metropolitan sample.

Discussion

In the Appalachian sample that we studied, 68% of Medicare fee-for-service patients with resected Stage I–III colon cancer had 12+ lymph nodes removed and assessed in keeping with a national guideline. Adherence to the guideline was 7 percentage points lower for residents of non-metropolitan counties than residents of metropolitan counties. Adherence to the guideline was strongly associated with treatment in high-volume or accredited hospitals, but fewer than a third of non-metropolitan patients went to high-volume hospitals, compared to more than half of metropolitan patients. Just over half of non-metropolitan patients had surgery in hospitals with accredited cancer programs, compared to three-quarters of metropolitan patients.

Assuming a 5-year survival advantage of 8 percentage points from adherence to the guideline, as suggested in the introduction, our IV estimate of a 50 percentage-point increase in adherence for non-metropolitan patients treated in high-volume hospitals implies a 4 percentage-point improvement in survival. Eliminating the geographic disparity in use of

high-volume hospitals would have prevented about 10 deaths in our non-metropolitan sample, out of about 450 expected deaths over 5 years (survival rates by Stage I–III from Parsons et al., 2011; incidence rates by Stage I–III from Gunderson et al., 2010). With 15% of the U.S. population living outside of metropolitan areas, and 80% of 93,000 incident cases of colon cancer (ACS, 2015) diagnosed at Stage I–III (SEER, 2015), about 100 lives might be saved over 5 years in each year's cohort of newly diagnosed patients if the non-metropolitan disparity in use of high-volume hospitals were eliminated nationally. Raising the adherence rate to 90% of all non-metropolitan patients nationally might save about 230 lives over 5 years in each year's cohort of newly diagnosed patients. Raising the adherence rate to 90% for all metropolitan patients nationally might save about 960 lives over 5 years among each year's newly diagnosed patients.

From our multivariate models, the evidence is strongest for a causal effect of high volume on guideline adherence for non-metropolitan patients. When we accounted for the endogeneity of hospital choice using a common IV estimation strategy, there was little evidence of improvement in adherence to the lymph node guideline for residents of metropolitan counties who were treated at accredited or high-volume hospitals. The IV estimate for non-metropolitan patients who went to accredited hospitals was larger than the OLS estimate, but was not statistically significant. The findings for metropolitan areas might be explained by competition encouraged by the number and proximity of hospitals, which could narrow quality differentials otherwise associated with accreditation and volume. Alternatively, surgeons in metropolitan areas may have larger and stronger professional networks that encourage wider adoption of best practices compared to surgeons in non-metropolitan areas. We suspect that empirically isolating the effect of accreditation from the effect of high-volume was particularly challenging in our non-metropolitan sample, where 40% of cancer surgeries occurred in hospitals with neither characteristic. Measuring proximity in driving time, instead of driving distance, might have sharpened our view of access differences within metropolitan counties, while dampening apparent differences in access between metropolitan and non-metropolitan counties. Additionally, ranking hospitals according to a narrower measure of cancer surgical volume, based only on Medicare patients instead of all patients, might have influenced our estimates of the effect of volume on adherence.

Two other national guidelines recommend chemotherapy within 4 months of diagnosis for surgically resected patients under age 80 with Stage III colon cancer, and radiation for surgically resected patients under age 80 with Stage III rectal cancer (CoC, 2011a). We do not know if our findings related to the effects of hospital type on lymph node assessment would extend to these other CRC guidelines, because the relevant samples were too small in our data to support the necessary analyses. Ayanian et al. (2003) found significantly lower use of radiation therapy for rectal cancer in low-volume hospitals, but no volume-related differences in use of chemotherapy for colon cancer. Baldwin et al. (2008) reported even longer distances to radiation and chemotherapy providers than to surgical providers for colorectal cancer patients in rural areas.

Additionally, we cannot be sure that findings based on the Appalachian counties of four states can be generalized to the rest of Appalachia or to other regions with disparate geographic access to large or accredited cancer programs. However, if the Appalachian

Medicare enrollees in our sample are typical of Medicare enrollees across the U.S in their apparent reluctance to travel beyond the nearest available hospital for colon cancer surgery, disparities in our Medicare sample related to the use of accredited or high-volume facilities by metropolitan and non-metropolitan patients are probably also typical. We have no reason to think that lymph node assessment in the smaller, unaccredited hospitals used by non-metropolitan patients in our sample was unrepresentative of care in other such hospitals.

In summary, our study suggests that the uneven spatial distribution of large, accredited cancer centers does indeed contribute to a disparity in adherence to the lymph node guideline for patients outside metropolitan areas. Regionalizing CRC surgery in large, accredited hospitals might increase guideline adherence for non-metropolitan patients, but would further increase travel distances for some patients. As it is, our data show that the majority of patients—in and out of metropolitan areas—went to the closest possible hospital for cancer surgery. Quality improvement programs targeting smaller, unaccredited hospitals would narrow geographic differences and improve colon-cancer survival in Appalachia and other sparsely populated regions, where such hospitals are frequently the only providers easily accessible to patients.

At the same time, attention should be directed to improving care for the third of metropolitan patients whose treatment fell short of the guideline. Because our preferred models did not find that accreditation or volume were associated with better adherence to the guideline when residents of the same metropolitan counties were compared, quality improvement efforts may need to look across metropolitan areas. With 85% of the U.S. population living in metropolitan areas, opportunities for reducing colon-cancer mortality that go beyond erasing urban-rural disparities should not be ignored.

Evidence supporting dissemination of the lymph-node guideline suggests that lives of colon cancer patients could be extended by improving adherence to the guideline. However, better adherence is unlikely to be achieved without imposing additional costs on patients and families (for example, to travel to larger, but more distant cancer centers) or on hospitals (to mount quality improvement programs addressing the guideline). The wisdom of undertaking these particular life-saving efforts as a matter of public health policy, compared to other initiatives that would also improve the quality of cancer treatment, will depend on the relative cost-effectiveness of alternative strategies (i.e., the years of life that could be saved with similar investments in each approach).

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Colon cancer cases in Appalachian counties, reporting source other than autopsy or death certificate.

Figure 1.
Study participants and exclusion criteria

Figure 2.
Hospital use by volume and accreditation according to location of patient residence

Table 1

Adherence to lymph node guideline by location of patient residence, hospital volume, and hospital accreditation (N=2552)

	Percent adherent
All	68%
Metro	71% *
Non-Metro	64% *
Surgical facility volume Q1	54 *
Surgical facility volume Q2	57 *
Surgical facility volume Q3	61 *
Surgical facility volume Q4	80 *
Not accredited	55 *
Accredited as	
Community Hospital	69 *
Comprehensive Community Hospital	75 *
Academic	78 *
NCI Designated	84 *

Sample is Stage I–III colon cancer patients with surgical resection.

* Adherence varies significantly across categories of the variable ($p < .05$).

Table 2

Sample characteristics by location of patient residence (N=2552)

Selected covariates	All	Metro N=1414	Non-metro N=1138
All	100%	100%	100%
Surgical facility volume Q1	6	3 *	9 *
Surgical facility volume Q2	20	12 *	29 *
Surgical facility volume Q3	33	33	32
Surgical facility volume Q4	42	52 *	29 *
Not accredited	34	23 *	46 *
Community Hospital	16	12 *	21 *
Comprehensive Community Hospital	35	44 *	24 *
NCI Designated Comprehensive	4	6 *	2 *
Academic Comprehensive	12	15 *	7 *
Age 66–70	18	16 *	20 *
Age 71–75	20	19	21
Age 76–80	24	23	26
Age 81+	38	42 *	33 *
Male	41	39 *	44 *
Female	59	61 *	56 *
White	97	96 *	99 *
Black, Non-Hispanic	2	3 *	1 *
Other, Non-Hispanic	0	1	0
Hispanic	0	0	0
Median county income <\$38K (Q1)	24	9 *	43 *
Median county income \$38K–42K (Q2)	37	30 *	45 *
Median county income \$42K–46K (Q3)	20	29 *	9 *
Median county income \$46K+ (Q4)	19	32 *	3 *

Sample is Stage I–III colon cancer patients with surgical resection.

* Significant difference between metro and non-metro patients ($p < .05$)

Table 3

Absolute and relative distances to colorectal cancer resection hospitals by location of patient residence (N=2552)

	All	Metro	Non-Metro
Mean (median) road distance to colorectal cancer resection hospital in miles			
Treating hospital	17 (9)	12 * (7)	23 * (15)
Nearest hospital	8 (6)	6 * (5)	10 * (9)
Nearest high-volume hospital	30 (25)	17 * (12)	47 * (42)
Nearest accredited hospital	16 (12)	9 * (6)	25 * (24)
Percentage by use and characteristics of nearest hospital			
Nearest facility provided treatment	54%	53%	54%
Nearest facility is high-volume	22%	35% *	6% *
Nearest facility is accredited	50%	65% *	31% *
Mean relative distance beyond nearest in miles			
Treating hospital	9	6 *	13 *
Nearest high-volume hospital	23	11 *	37 *
Nearest accredited hospital	9	3 *	16 *

High-volume is defined as top quartile of unique facilities.

* Significant difference between metro and non-metro patients (p<.05).

Table 4

Multivariate estimates of effects of hospital volume and accreditation on adherence to lymph node guideline

Coefficients	Metro (N=1414)		Non-Metro (N=1138)	
	OLS	2SLS	OLS	2SLS
High volume (with standard error)	.177 [*] (.040)	-.112 [†] (.168)	.231 [*] (.041)	.498 ^{**†} (.198)
Accreditation (with standard error)	.176 [*] (.043)	.062 (.113)	.079 [*] (.037)	.141 (.130)
Age 71–75	.057	.045	.019	.038
Age 76–80	.041	.058 [†]	-.072 [*]	-.043 [†]
Age 81+	.027	.029	-.076 [*]	-.053
Female	.052 [*]	.057 [*]	.006	-.003
Black, Non-Hispanic	-.062	-.080	-.287	-.255
Other, Non-Hispanic	-.015	.038	-.029	.102
Hispanic	-.098	-.094	-.442 [*]	-.346 [*]
Tumor size (mm)	.001 [*]	.001 ^{**†}	.004 [*]	.004 ^{**†}
Tumor Moderately differentiated	-.109 [*]	-.077 [†]	.105 [*]	.102 ^{**†}
Tumor Poorly/undifferentiated	-.001	.025	.082	.076
Tumor Grade Not determined/Not applicable	-.122	-.192	.014	.084
Mild comorbidity burden	-.086 [*]	-.096 [*]	.007	-.004
Moderate comorbidity burden	-.063	-.074	.020	.014
Severe comorbidity burden	-.097 [*]	-.111 [*]	-.010	-.024
Diagnosed in 2007	.083 [*]	.093 [*]	.112 [*]	.120 [*]
Diagnosed in 2008	.121 [*]	.121 [*]	.099 [*]	.096 [*]
First-stage estimates				
Relative distance to high-volume hospital (standard error)	--	-.018 ^{**†} (.004)	--	-.007 ^{**†} (.002)
Relative distance to accredited hospital (standard error)	--	-.032 ^{**†} (.006)	--	-.018 ^{**†} (.003)
Weak-instrument tests (H0: equation is weakly identified)				
Cragg-Donald statistic	--	42.28	--	9.24
Kleibergen-Paap statistic	--	11.97	--	7.92
Stock-Yogo critical value	--	7.03	--	7.03

* Coefficient significantly different from zero, $p < .05$.[†] Metropolitan 2SLS coefficient significantly different from non-metropolitan coefficient, $p < .05$.

All first- and second-stage models included county fixed effects. Omitted group is unaccredited hospital without high volume, age 66–70, male, white non-Hispanic, well differentiated tumor, no comorbidities, diagnosed in 2006.