Research Article

Association between County-level Gastroenterologist and General Surgeon Densities, and Colorectal Cancer Mortality in the United States: An Evaluation of a Nationwide Registry

Jonathan K Aboagye[1], Charles A Berko[2], Heather K Hayanga[3], Awori J Hayanga[4*]

[1]Department of Surgery, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA; [2] St Agnes Hospital, Baltimore, MD; [3]Johns Hopkins Medical Institutions, Baltimore, MD; [4]DeVos Heart and Lung Transplantation Program , Spectrum Health- Michigan State University, Grand Rapids, MI.

Abstract

Background: County-level density of providers of colorectal cancer (CRC) screening and treatment may influence its outcomes. We hypothesized that an increase in the density of general surgeons and gastroenterologist in counties is associated with a reduction in CRC mortality rate.
Methods: We analyzed a linked Surveillance Epidemiology and End Results 2006-2010and Area Resource File 2009 dataset comprising 2,608 counties. We calculated county-specific densities of gastroenterologists and general surgeons. Univariate and multivariate linear regression analyses were performed separately to assess associations between the county level age-adjusted colorectal cancer mortality rates and gastroenterologist, general surgeon densities, and other county level socioeconomic predictors.
Results: Gastroenterologist densities of 0.1 to 1.5, 1.5 to 3.0 and greater than 3.0 per 100,000 people were associated with a reduction of 1.32(95%CI 0.39-2.24), 0.99(95%CI 0.38-1.57) and 1.47(95%CI 0.94-2.01) per 100,000 CRC mortality respectively compared to counties without a gastroenterologist. Also, general surgeon densities of 0.1 to 5.0 and 5.1 to 10.0 per 100,000 people were associated with a reduction of 0.95(95%CI 0.38-1.52) and 0.85(95%CI 0.35-1.38) per 100,000 CRC mortality respectively, compared to counties without a general surgeon. An increase in median household income was associated with a reduction in CRC mortality across counties.
Conclusion: This study highlights geographic disparities in CRC mortality rates in this country, and their association with the distribution of specialists who provide screening and/or treatment services for this disease, and median household income.
Keywords: Gastroenterologists, general surgeons, colorectal cancer mortality, colonoscopy screening, geographic disparity.

Introduction

Colorectal cancer (CRC) is the second most common cause of cancer-related deaths in the United States (U.S.) and the third most common cancer in both men and women. In 2009, 136,717 people in the U.S. were

*Corresponding author: Awori J Hayanga, DeVos Heart and Lung Transplantation Program Spectrum Health- Michigan State University, 300 Barclay, Suite 201, Grand Rapids, MI. Email: jhayanga@me.com
Citation: Aboagye JK, et al. Association between County-level Gastroenterologist and General Surgeon Densities, and Colorectal Cancer Mortality in the United States: An Evaluation of a Nationwide Registry. Cancer Research Frontiers. 2015 Feb; 1(1): 89-98. doi: 10.17980/2015.89

Competing Interests: The authors declare that they have no competing interests.
Received Oct 24, 2014; Revised Jan 5, 2015; Accepted Feb 18, 2015; Published Feb 28, 2015.

diagnosed with CRC, of whom 70,223 were men and 66,494 women. In the same year 51,848 people in the US died from CRC, including 26,806 men and 25,042 women (1). Despite the huge public health threat posed by this disease, CRC screening rate remains comparatively unacceptable, lagging behind other evidence based cancer screening programs such as mammography and pap smears for breast and cervical cancers respectively. The latter have estimated screening rates of 67% and 80% respectively, but less than 40% of at risk population undergoes CRC screening. Additionally, there are marked disparities in mortality nationally between non-Hispanic whites and other racial/ethnic groups in the US (2-6).

Disparities in CRC mortality have been well documented by several studies (1-9), but only a limited number of them have focused on differences, stemming directly from access to care as a result of the paucity of gastroenterologists and surgeons (4,6-14). Many of these have examined the interactions of race (3-6,9,12-16), gender (10,15,17), disease stage (9,15) and insurance coverage (5,7,15,17-20) and colorectal cancer outcomes. Large population-based epidemiological studies have alluded to the possibility of geographic differences fuelling these disparities without conclusive association with outcomes and mortality (5,9).

More recently, the overall incidence and mortality of CRC has decreased (21), likely as a result of improved screening measures coupled with increasingly better access to improved quality of care with technological advancements and active surveillance programs. Disparities still persist, despite the strides made in combating these imbalances. To the best of our knowledge no current reports in the literature have conclusively addressed the differential mortality rates related to the variations in specialist density at the county level. To address this deficit, we sought to assess the association of density of providers of colorectal cancer screening and treatment and other county level socioeconomic factors, and colorectal cancer mortality rates.

Table 1: Demographics of Study Population

Number of counties	**2,608**
Total population	301,021,189
Female n (%)	152,643,080 (50.7)
Male n (%)	148,378,109 (49.3)
White n (%)	240,011,120 (79.7)
Black n (%)	38,873,425 (12.9)
Asian n (%)	13,529,636 (4.5)
Native American n (%)	2,919,710 (1.0)

Methods

Data sources and variables

We performed analyses on the Surveillance Epidemiology and End Results (SEER) data, linked to the Health Resources and Services Administration's Area Resource File (22) (ARF) 2009 data file (Department of Health and Human Services, Bureau of Health Professions, Rockville, Maryland). The ARF contains data on several county-level as well as state-level demographic and socio-economic indices used in the analysis, including gender, race, unemployment rate, education level, percentage of uninsured adults age <65, number of hospitals with oncology services, and median household income. Counties were categorized into quartiles based on their median household income (<$37,113; $37,113-42,965; $42,966-49,981; and >$49,981).

Notable among these files is the American Medical Association (AMA) master file, detailing the number of physicians per specialty working in a county. It also includes census and population estimates of economic, social, housing and agricultural indices across states and counties. Using the rural-urban continuum codes developed by the Department of Agriculture, counties were categorized into metropolitan or non-metro areas. The 2008 population estimates were used in all instances except the number of hospitals with oncology services and percentage of residents less than 65 years without health insurance, where 2007 and 2006 data were used respectively.

The densities of general surgeons, gastroenterologists and primary care physician per 100,000 people across each county were calculated using the 2008 AMA master file. We assumed a uniform population age structure across counties, enabling us to use the entire population in a county as the denominator in calculating the density of physicians. Primary care physician was defined as a physician who had received

Table 2. Predictors of colorectal cancer mortality

Variables	Effect on Colorectal cancer mortality per 100,000 (95% CI)			
	Unadjusted	p-value	Adjusted	p-value
Gastroenterologist per 100,000 people				
0	Reference (0)		Reference(0)	
0.1-1.5	-2.51(-3.47, -1.56)	<0.001	-1.31(-2.24, -0.39)	0.005
1.51-3.0	-1.90(-2.50, -1.30)	<0.001	-0.98(-1.59,-0.38)	0.001
>3.0	-2.30(-2.77, -1.83)	<0.001	-1.47(-2.01,-0.94)	<0.001
General surgeon per 100,000 people				
0	Reference(0)		Reference (0)	
0.1-5.0	-1.6(-2.19, -1.01)	<0.001	-0.95(-1.52.-0.38)	0.001
5.1-10.0	-1.86(-2.35, -1.36)	<0.001	-0.85(-1.35,-0.35)	0.001
10.1-15.0	1.72(-2.33, -1.11)	<0.001	-0.57(-1.19,0.05)	0.07
>15.0	-2.03(-2.71, -1.35)	<0.001	-0.65(-1.37,0.06)	0.07
Percentage of whites	-.60(-0.07,-0.05)	<0.001	-0.05(-0.06,-0.03)	<0.0001
Percentage of females	0.20(0.09, 0.30)	<0.001	0.13(0.03,0.22)	0.01
Percentage older than 25 years with high school diploma	-0.17(-.19, -0.15)	<0.001	-0.10(-0.13,-0.07)	<0.0001
Percentage younger than 65 years without health insurance	-0.07(-0.11, -0.04)	<0.001	-0.18(-0.22,-0.15)	<0.0001
Median household income				
Quartile 1 (<$37,113)	Reference		Reference(0)	
Quartile 2($37,113-$42,965)	-1.53(-2.05, -1.02)	<0.001	-0.11(-0.66,0.44)	0.70
Quartile 3 ($42,966-$49,985)	-2.91(-3.42, -2.39)	<0.001	-1.16(-1.77,-0.55)	<0.0001
Quartile 4 (>$49,985)	-3.96(-4.48, -3.44)	<0.001	-1.72(-2.40.-1.04)	<0.0001

Adjusted R-squared: 0.1743

CI: confidence interval.

training in family medicine, pediatrics or general internal medicine. The density of gastroenterologists were categorized into 0, 0.1-1.5, 1.6-3.0 and greater than 3.0 per 100,000 people. Similarly, general surgeons were categorized into 0, 0.1-5.0, 5.1-10.0, 10.1-15.0 and greater than 15.0 per 100,000 people after careful data exploration.

Outcomes and statistical analysis

Our primary outcome was age-adjusted county level colorectal cancer mortality rate, which was obtained from the National Center for Health Statistics from January 2006 to December 2010 (23). Counties without information on colorectal cancer mortality as well as provider density were excluded from the analysis after assuming missing data was random.

The densities of gastroenterologists, general surgeons and age-adjusted colorectal cancer mortality rates were mapped and compared. The latter was found to be normally distributed and without data on the number of colorectal cancer cases per county we used linear regression for the analysis. Univariate linear regression analysis was performed separately to assess associations between the county level age-adjusted colorectal cancer mortality and provider density, as well as other county level socio economic predictors. Furthermore two separate multivariate linear regression models was fitted by including predictors with a p-value less than 0.10 from the univariate analysis by a backward stepwise selection method. The initial model considered the densities of gastroenterologists and general surgeons as continuous variables and the latter as categorical. Results were considered significant if $p < 0.05$. Analyses were performed using Stata ICE version 12.

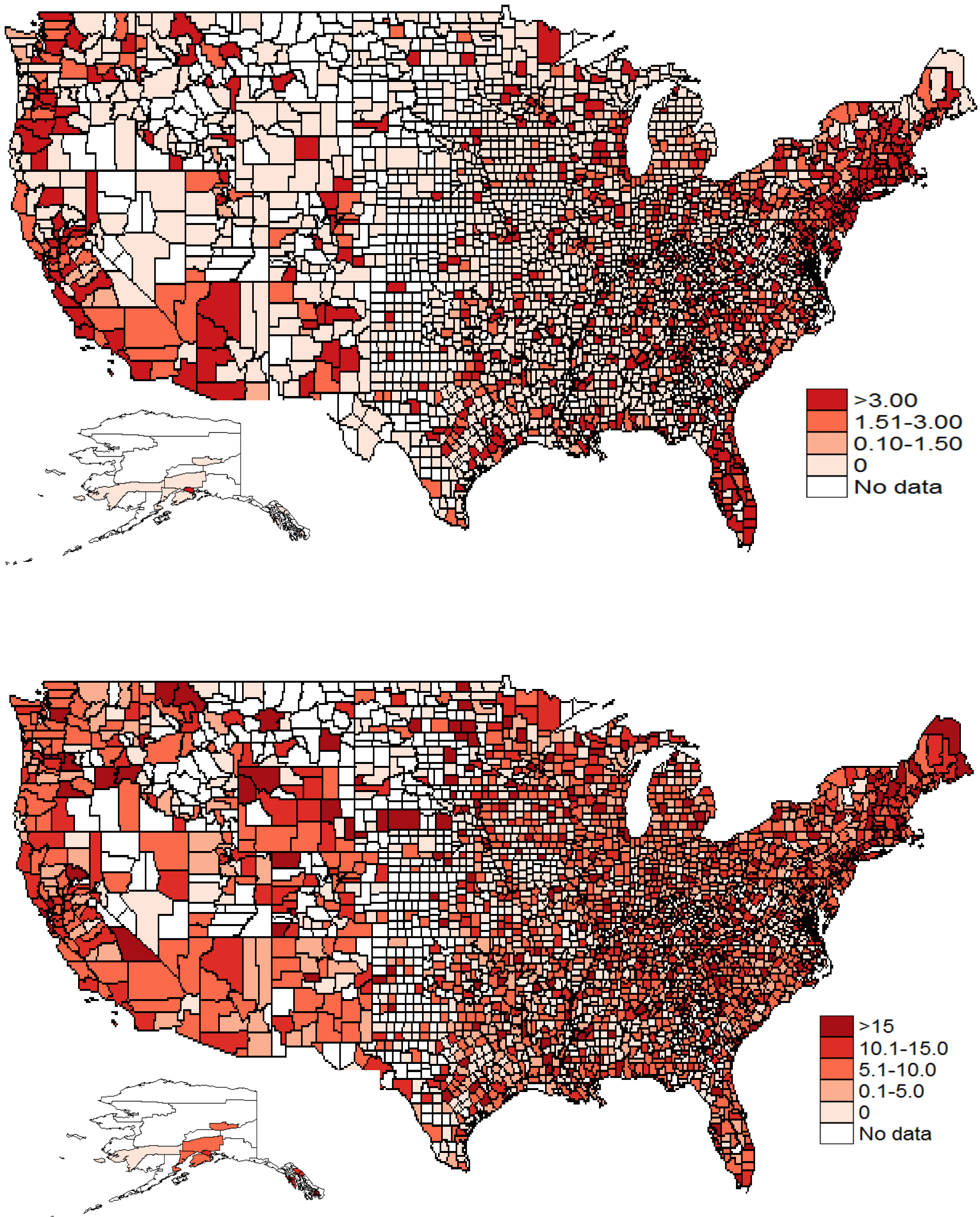

Figure 1. County distribution of gastroenterologist (upper panel) and general surgeon (lower panel) density per 100,000 people across the US.

Results

Of the 3,220 counties in the United States a total of 2,608 counties with complete data on age-adjusted mortality rates and provider density were included in the analysis. This comprised of a total of 301,021,189 residents with 152,643,080 (50.7%) females and 148,378,109 (49. 3%) males. By race there were 240,011,120 (79.7%) whites, 38,873,425 (12.9%) African Americans, 13,529,636 (4.5%) Asians and 2,919,710 (0.97%) Native Americans. (Table 1)

A greater density of gastroenterologists and general surgeons were observed across the east and pacific coast, with scattered distribution in the mid-west, southwest, southeast and central US. (Figure 1) Colorectal cancer mortality was greater across counties located in the south east, and central US relative to the rest of the country. (Figure 2)

With provider densities as continuous variables we observed that an increase of 1 gastroenterologist per 100,000 people was associated with a 13.9% (95% CI 5.50% -22.4 %) reduction in colorectal cancer mortality. No such association was observed for general surgeons (0.7% (95% CI -2.1%- 3.4%)). Using defined categories of gastroenterologist, counties with 0.1 to 1.5 gastroenterologists per 100,000 people was associated with a reduction of 1.31 (95% CI 0.39-2.24) per 100,000 deaths compared to counties without a gastroenterologist. Also, counties with gastroenterologist densities of 1.51 to 3.00 and greater than 3.0 per 100,000 people were associated with a reduction of 0.99 (95% CI 0.38-1.57) and 1.47 (95% CI 0.94-2.01) per 100,000 colorectal cancer mortality respectively, compared to counties without any gastroenterologist. Counties with general surgeon densities of between 0.1 to 5.0 and 5.1 to 10.0 per 100,000 people were associated with a reduction of 0.95 (95% CI 0.38-1.52) and 0.85 (95%CI 0.35-1.38) per 100,000 colorectal cancer mortality respectively, compared to counties without any general surgeon. However, no association was observed between counties with general surgeon densities of 10.1- 15.0 and greater than 15.0 per 100,000 people and age-adjusted county level colorectal cancer mortality.

Predictors of mortality included the median household income, percentages of females, whites, residents older than 25 years with high school diploma and those less than 65 years without health insurance. We observed a dose response relationship between the median household income and colorectal cancer mortality across counties. (Figure 3) While there was no difference in the mortality rate for counties with a median household income in the lower middle quartile ($37,113- $42,965) compared to the lowest quartile (<$37,113), a statistically significant reduction in colorectal cancer mortality was observed for the upper middle ($42,966-$49,981) 1.16(95% CI0.54 -1.77) and upper quartile (> $49,982) 1.72 (95% CI 1.04 -2.41,) compared to the lowest quartile of income group.

A percentage increase in residents older than 25 years with high school diploma was associated with a reduction of 0.10 (95% CI 0.07-0.13) per 100,000 colorectal cancer deaths. On the contrary, a percentage increase in residents younger than 65 years without health insurance was associated with a reduction of 0.18 (95% CI 0.22-0.15) per 100,000 colorectal cancer mortality. No association was observed between the density of primary care physicians and colorectal cancer mortality (p=0.58) (Table 2)

Comments

We have demonstrated an association between the densities of gastroenterologists and general surgeons per 100,000 people in counties across the US and colorectal cancer mortality. Several studies have shown geographic disparities (5,8,10,11,25) in access to colorectal cancer screening and treatment, and have postulated, that this might lead to disparities in outcomes for this condition (25,26). Others have shown geographic disparities in outcomes for colon cancer and have looked at barriers to colon cancer screening and treatment such as race and socioeconomic factors as possible mediators (25,27-30). This study uniquely examines the association between the county level density of providers of CRC screening or treatment, socioeconomic variables and colorectal cancer mortality rates.

The association of county level physician density and cancer related mortality has been shown in previous studies. Aneja et al (31) and Odisho et al(32) have separately shown in ecological studies an increased prostate cancer related mortality in areas with fewer densities of urologists and radiation oncologists respectively (31,32). Also, Backhus et al showed an association between lung cancer survival and provider density (33). These studies, including ours have been

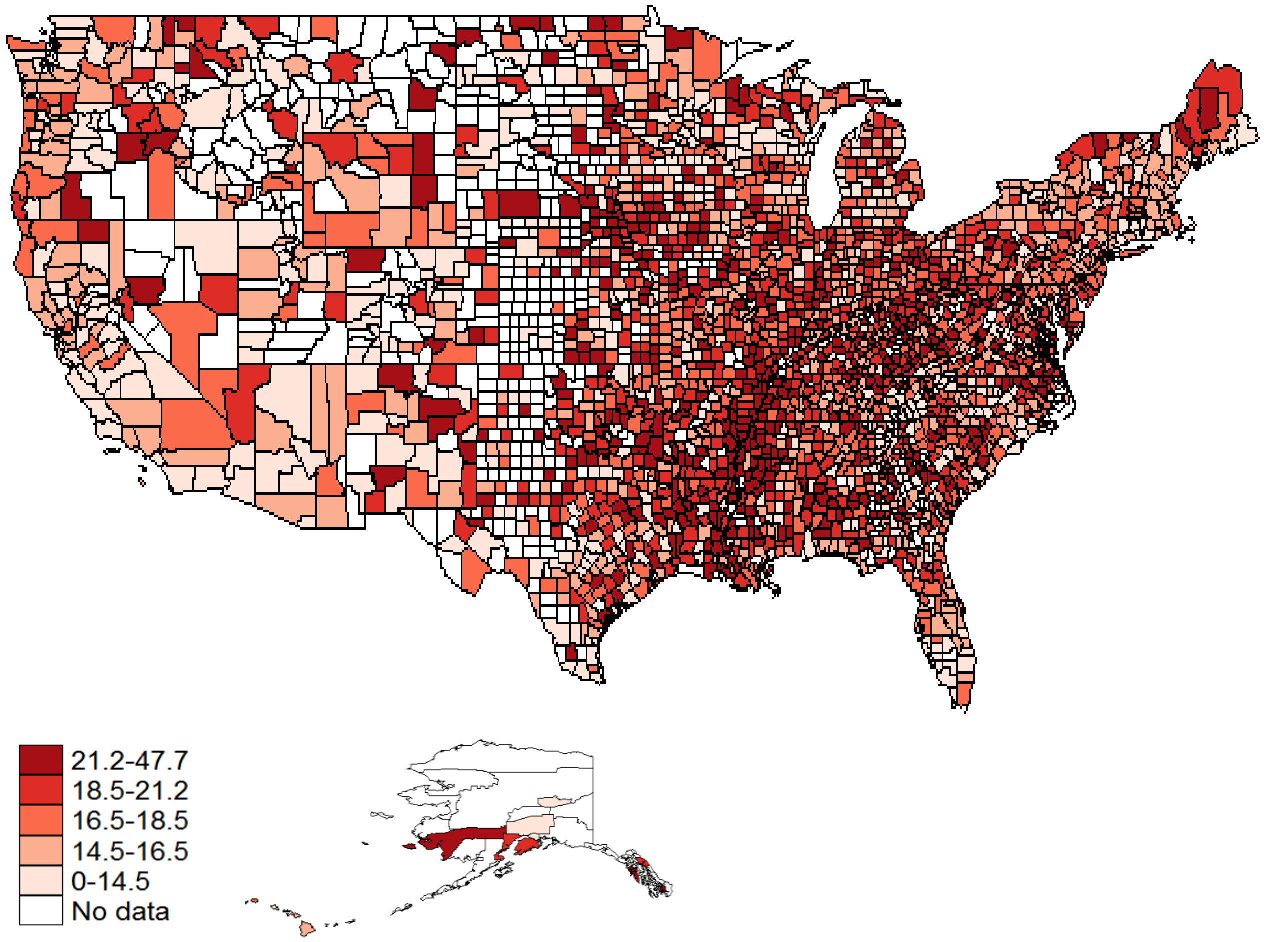

Figure 2. County distribution of Age-adjusted colorectal cancer mortality rate per 100,000 people in the US.

necessitated to point out the impact of the maldistribution of physicians in the United States. The recommendation by the United States Preventive Services Task Force (USPSTF) on colonoscopy screening for patients above fifty years emphasizes the importance of gastroenterologist and or general surgeons in colon cancer screening (34). This is in sharp contrast to ovarian, lung and prostate cancers which lack widely acceptable screening tools.

In spite of this, colon cancer continues to be the second most common cause of cancer related mortality in the US and colonoscopy lags behind other cancer screening tools like mammography. In the face of these advancements, there still exist geographic disparities in access to colonoscopy screening. Anderson et al showed an association between rural/urban habitation and adherence to colorectal cancer screening (8). Previous studies have also documented an association between the density of gastroenterologists and late stage diagnosis of colon cancer (35). These revelations, call for a concerted effort to improve access to colonoscopy screening by ensuring equitable distribution of specialists who provide these services. This situation could also be remedied to a certain extent by increasing the training spots for these providers. Although no association was observed between primary care physicians and colorectal cancer mortality, training primary care physicians to perform colonoscopy screening might potentially improve these disparities. The use of itinerant endoscopist could also be helpful to reach inhabitants in remote areas.

In spite of recent data showing a surge in colorectal cancer related procedures being performed by board certified colorectal surgeons, general surgeons across

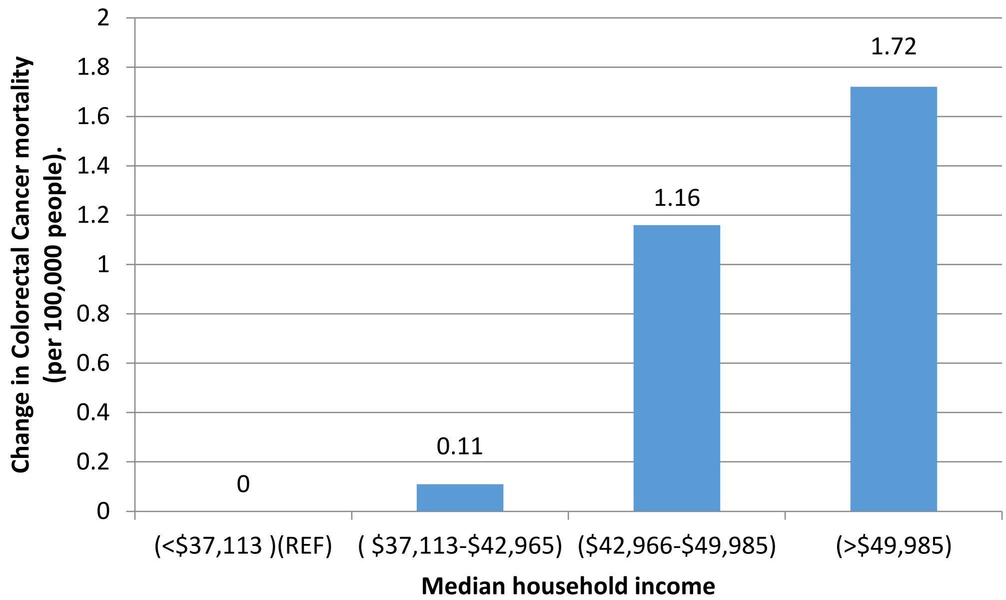

Figure 3. Reduction in colorectal cancer mortality per 100,000 people by median household income.

this country continue to perform the bulk of these procedures (36). Consequently, we sought to examine the association between the density of general surgeons per 100,000 people across counties and colorectal cancer mortality. General surgeon density of between 0.1 to 5.0 and 5.1 to 10.0 per 100,000 people was associated with a significant reduction in colorectal cancer mortality rates. However, a marginal association was observed for general surgeon density beyond 10 per 100,000 people compared to areas without a general surgeon. The density of general surgeons in an area can significantly affect access to their services. Haas et al reported that patients diagnosed with colorectal cancer and living in areas with high capacity of surgeons were more likely to receive surgical care compared to their counterparts in lower surgeon capacity areas (37).

Socioeconomic status is an important determinant of access to healthcare and has been shown to impact outcomes for colorectal cancer (28, 29). Interestingly, this study corroborates these findings by revealing that counties with higher median household income and increasing percentage of residents with high school diploma are associated with lower colorectal cancer mortality rates. While higher education might impact survival through higher income, it also empowers people to understand the importance of screening and seeking early intervention. Although the level of urbanicity was found to be associated with county level colorectal cancer mortality in the univariate analysis, this association diminished after the inclusion of provider density in the model. Similarly, no association was observed between the number of hospitals offering oncologic services in a county, unemployment rate and county level colorectal cancer mortality rate. Paradoxically, an increase in the proportion of people in a county younger than 65 years without health insurance was associated with a decrease in colorectal cancer mortality rate. This is in contrast to individual level studies that have reported better outcomes for patients with insurance coverage compared to those without (5, 7, 20). However, our finding is not in isolation, as another study on melanoma related mortality reported a similar association (38). We share their opinion that competing risks from other long term co-morbid condition like heart disease and diabetes might preferentially affect mortality of the less insured, painting a picture of a relatively lower cancer related mortality rate.

The results of this study should be interpreted bearing in mind all limitations inherent in ecological studies. It is noteworthy that no causal inferences can be made and that generalizing results to individual patients risks committing an ecological fallacy. Also, we failed to account for service providers with multiple locations of practice and this might potentially overestimate the provider density in some areas, while underestimating the disparity in others. However, we are conscious of the fact that any such effect might be minimal. In this paper we assumed that people living in a county receive health care services from the same county but this may not be entirely true. This study is also limited by other issues that confront large registries, which include the presence of missing information and unmeasured variables which could explain some of the associations seen. Furthermore, this study does not specifically identify physicians who provide colonoscopy screening and perform surgeries on patients diagnosed with colorectal cancer within the study period. Also, our inability to get data on stage specific incidence of county level colorectal cancer cases limited us from better observing the effect of county-level providers of screening and or treatment of CRC on its mortality. When calculating the county-level physician density, we used the entire population in a county as the denominator for lack of readily available age-specific population data and this may not correctly reflect the population at risk. Moreover with no significant population variation across counties in the US, this should even out. However, we believe this is an important step to formulate hypotheses, engender discussions and offer opportunities for further studies to investigate geographic disparities in the distribution of gastroenterologists and general surgeons and colorectal cancer mortality in the United States.

Geographic disparities in outcomes for colorectal cancer and other cancers should be of utmost concern to policy makers. This is because, while little can be done about genetic factors associated with outcomes for colon cancer, several steps can be taken to correct these disparities whether it is geographic, racial or socioeconomic to improve outcomes for patients. The need for an improvement in the specialist workforce distribution and numbers have been a subject of interest in recent studies (32, 39). The congregation of specialists like surgeons, gastroenterologists and radiation oncologist in urban centers, teaching hospitals and high income areas might preclude inhabitants of remote areas from benefiting from their life saving services at an earlier stage. Interventions like incentivizing physicians to work in underserved areas and outreach screening services are examples of the many interventions that have been suggested.

Our study unveils the existence of geographic disparity in colorectal cancer mortality rates in this country and its association with the distribution of specialist who provide screening and or treatment services for this disease and median household income. Consequently a concerted effort by all stakeholders must be made to stem this disparity. Moreover, further studies on county level screening colonoscopy rates and stage specific incidence and mortality rates would also help to shed light on this important subject. Accounting for county level colorectal cancer rates might contribute to explaining these findings.

Acknowledgements

The authors acknowledge the efforts of the Applied Research Program, NCI; the Office of Research, Development and Information, CMS; Information Management Services (IMS), Inc.; and the Surveillance, Epidemiology, and End Results (SEER) Program tumor registries in the creation of the SEER-Medicare database.

Abbreviations

CRC	colorectal cancer;
AMA	American Medical Association
SEER	Surveillance Epidemiology and End Results
ARF	Health Resources and Services Administration's Area Resource File
USPSTF	United States Preventive Services Task Force

References:

1. U.S. Cancer Statistics Working Group. United States cancer statistics: 1999–2009 incidence and mortality web-based report U.S. Department of Health and Human Services, Centers for Disease Control and Prevention and National Cancer Institute Website. http://www.cdc.gov/uscs. Updated 2012. Accessed 05/06/13.
2. Islami F, Kahn AR, Bickell NA, Schymura MJ, Boffetta P. Disentangling the effects of race/ethnicity and socioeconomic status of neighborhood in cancer stage distribution in New York city. Cancer Causes and Control. 2013 Jun;24(6):1069-78. doi: 10.1007/s10552-013-0184-2.

3. Jerant AF, Fenton JJ, Franks P. Determinants of racial/ethnic colorectal cancer screening disparities. Arch Intern Med. 2008;168(12):1317-1324. doi: 10.1001/archinte.168.12.1317.
4. Potter MB. Strategies and resources to address colorectal cancer screening rates and disparities in the United States and globally. Annu Rev Public Health. 2013;34:413-29. doi: 10.1146/annurev-publhealth-031912-114436.
5. Semrad TJ, Tancredi DJ, Baldwin LM, Green P, Fenton JJ. Geographic variation of racial/ethnic disparities in colorectal cancer testing among medicare enrollees. Cancer. 2011;117(8):1755-1763. doi: 10.1002/cncr.25668.
6. Cooper GS, Yuan Z, Rimm AA. Racial disparity in the incidence and case-fatality of colorectal cancer: Analysis of 329 united states counties. Cancer Epidemiology Biomarkers and Prevention. 1997;6(4):283-285.
7. Ananthakrishnan AN, Schellhase KG, Sparapani RA, Laud PW, Neuner JM. Disparities in colon cancer screening in the medicare population. Arch Intern Med. 2007;167(3):258-264. doi:10.1001/archinte.167.3.258
8. Anderson AE, Henry KA, Samadder NJ, Merrill RM, Kinney AY. Rural vs urban residence affects risk-appropriate colorectal cancer screening. Clinical Gastroenterology and Hepatology. 2013;11(5):526-533. doi: 10.1016/j.cgh.2012.11.025
9. Chien C, Morimoto LM, Tom J, Li CI. Differences in colorectal carcinoma stage and survival by race and ethnicity. Cancer. 2005;104(3):629-639. DOI: 10.1002/cncr.21204
10. Dupont-Lucas C, Dejardin O, Dancourt V, Launay L, Launoy G, Guittet L. Socio-geographical determinants of colonoscopy uptake after faecal occult blood test. Digestive and Liver Disease. 2011;43(9):714-720. doi: 10.1016/j.dld.2011.03.003
11. Fournel I, Cottet V, Binquet C, Jooste V, Faivre J, Bouvier AM, et al. Rural-urban inequalities in detection rates of colorectal tumors in the population. Digestive and Liver Disease. 2012;44(2):172-177. doi: 10.1016/j.dld.2011.09.005.
12. Morris AM, Billingsley KG, Baxter NN, Baldwin LM. Racial disparities in rectal cancer treatment: a population-based analysis. Arch Surg. 2004 Feb;139(2):151-156 doi:10.1001/archsurg.139.2.151.
13. Wassira LN, Pinheiro PS, Symanowski J, Hansen A. Racial-ethnic colorectal cancer survival disparities in the mountain west region: The case of blacks compared to whites. Ethnicity and Disease. 2013;23(1):103-109.
14. Hayanga AJ, Waljee AK, Kaiser HE, Chang DC, Morris AM. Racial clustering and access to colorectal surgeons, gastroenterologists, and radiation oncologists by African Americans and Asian Americans in the United States: A county-level data analysis. Archives of Surgery. 2009;144(6):532-535. doi:10.1001/archsurg.2009.68
15. Halpern MT, Pavluck AL, Ko CY, Ward EM. Factors associated with colon cancer stage at diagnosis. Dig Dis Sci. 2009;54(12):2680-2693. doi: 10.1007/s10620-008-0669-0
16. Rhoads KF, Cullen J, Ngo JV, Wren SM. Racial and ethnic differences in lymph node examination after colon cancer resection do not completely explain disparities in mortality. Cancer. 2012;118(2):469-477. doi: 10.1002/cncr.26316
17. Stanley SL, King JB, Thomas CC, Richardson LC. Factors associated with never being screened for colorectal cancer. J Community Health. 2013;38(1):31-39. doi: 10.1007/s10900-012-9600-x.
18. Foley KL, Song E-, Klepin H, Geiger A, Tooze J. Screening colonoscopy among colorectal cancer survivors insured by Medicaid. American Journal of Clinical Oncology: Cancer Clinical Trials. 2012;35(3):205-211. doi: 10.1097/COC.0b013e318209d21e
19. Shih YC, Zhao L, Elting LS. Does Medicare coverage of colonoscopy reduce racial/ethnic disparities in cancer screening among the elderly? Health Aff. 2006;25(4):1153-1162. doi: 10.1377/hlthaff.25.4.1153
20. Zuvekas SH, Taliaferro GS. Pathways to access: Health insurance, the health care delivery system, and racial/ethnic disparities, 1996-1999. Health Aff. 2003;22(2):139-153. doi: 10.1377/hlthaff.22.2.139
21. Edwards BK, Noone A-M, Mariotto AB, Simard EP, Boscoe FP, Henley SJ, et al. Annual Report to the Nation on the Status of Cancer, 1975–2010, featuring prevalence of comorbidity and impact on survival among persons with lung, colorectal, breast, or prostate cancer. Cancer 2014; 120(9):1290-314. doi: 10.1002/cncr.28509
22. Health Resources and Administration Services. Area resource file. http://www.arfsys.com/. Accessed 05/17/13.
23. National Cancer Institute. Surveillance epidemiology and end results (SEER). http://www.seer.cancer.gov. Accessed 05/17/13.

24. National Center for Health Statistics http://www.cdc.gov/nchs). Accessed on 05/17/13
25. Henry KA, Niu X, Boscoe FP. Geographic disparities in colorectal cancer survival. Int J Health Geogr. 2009 Jul 23;8:48. doi: 10.1186/1476-072X-8-48.
26. Sankaranarayanan J, Watanabe-Galloway S, Sun J, Qiu F, Boilesen EC, Thorson AG. Age and rural residence effects on accessing colorectal cancer treatments: A registry study. Am J Manag Care. 2010;16(4):265-273.
27. Liff JM, Chow W-, Greenberg RS. Rural-urban differences in stage at diagnosis. Possible relationship to cancer screening. Cancer. 1991;67(5):1454-1459.
28. Gomez SL, O'Malley CD, Stroup A, Shema SJ, Satariano WA. Longitudinal, population-based study of racial/ethnic differences in colorectal cancer survival: Impact of neighborhood socioeconomic status, treatment and comorbidity. BMC Cancer. 2007;7:193. doi:10.1186/1471-2407-7-193
29. Boyd C, Zhang-Salomons JY, Groome PA, Mackillop WJ. Associations between community income and cancer survival in ontario, canada, and the united states. J Clin Oncol. 1999 Jul;17(7):2244-55.
30. Hodgson DC, Fuchs CS, Ayanian JZ. Impact of patient and provider characteristics on the treatment and outcomes of colorectal cancer. J Natl Cancer Inst. 2001;93(7):501-515. doi: 10.1093/jnci/93.7.501
31. Aneja S, Smith BD, Gross CP, Wilson LD, Haffty BG, Roberts K, et al Geographic analysis of the radiation oncology workforce. International Journal of Radiation Oncology Biology Physics. 2012;82(5):1723-1729. doi: 10.1016/j.ijrobp.2011.01.070
32. Odisho AY, Cooperberg MR, Fradet V, Ahmad AE, Carroll PR. Urologist density and county-level urologic cancer mortality. Journal of Clinical Oncology. 2010;28(15):2499-2504. doi: 10.1200/JCO.2009.26.9597
33. Backhus LM, Hayanga AJ, Au D, Zeliadt SB. The effect of provider density on lung cancer survival among blacks and whites in the United States. Journal of Thoracic Oncology. 2013;8(5):549-553. doi: 10.1097/JTO.0b013e318287c24c
34. USPSTF. Recommendation statement: Screening guidelines for colorectal cancer. http://www.uspreventiveservicestaskforce.org/uspstf08/colocancer/colors.htm. Updated 2012. Accessed 02/23/13.
35. Soneji S, Armstrong K, Asch DA. Socioeconomic and physician supply determinants of racial disparities in colorectal cancer screening. Journal of Oncology Practice. 2012;8(5):e125-e134. doi: 10.1200/JOP.2011.000511.
36. Etzioni DA, Cannom RR, Madoff RD, Ault GT, Beart RW Jr. Colorectal procedures: What proportion is performed by American board of colon and rectal surgery-certified surgeons?. Dis Colon Rectum 2010 May;53(5):713-720. doi: 10.1007/DCR.0b013e3181d32084
37. Haas JS, Brawarsky P, Iyer A, Fitzmaurice GM, Neville BA, Earle C. Association of area sociodemographic characteristics and capacity for treatment with disparities in colorectal cancer care and mortality. Cancer. 2011;117(18):4267-4276. doi: 10.1002/cncr.26034
38. Aneja S, Aneja S, Bordeaux JS. Association of Increased Dermatologist Density with Lower Melanoma Mortality. Arch Dermatol. 2012;148(2):174-178. doi: 10.1001/archdermatol.2011.345
39. Aboagye JK, Kaiser HE, Hayanga AJ. Rural-Urban Differences in Access to Specialist Providers of Colorectal Cancer Care in the United States: A Physician Workforce Issue. JAMA Surg. 2014 Apr 16. doi: 10.1001/jamasurg.2013.5062.