Gastro Hep Advances 2023;2:810–817

ORIGINAL RESEARCH—CLINICAL

Gastroenterology Specialist Supply and Early-Onset Colorectal Cancer Incidence and Mortality in the U.S., 2014–2018

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BACKGROUND AND AIMS: The burden of early-onset colorectal cancer (EoCRC) has been increasing among young adult populations in the U.S. The aim of this study was to investigate the relationship between the incidence and mortality of EoCRC and the supply of gastroenterology (GI) specialists and primary care physicians (PCP). **METHODS:** This was an ecological study of EoCRC cases among US counties that occurred between 2014 and 2018. Data was obtained from US cancer statistics. County-level data, including sociodemographic (eg, percentage of female, non-White residents, poverty rate, rurality) and physician supply (GI specialists and PCPs) was obtained from area health resources files. We estimated linear mixed-effects models with the county as a random effect to examine the association of physician supply with 5-year average age-adjusted EoCRC incidence and mortality. Models were adjusted for aggregate county-level socioeconomic characteristics. Multicollinearity was tested through variation inflation. **RESULTS:** Analysis included 855 US counties. Mean age-adjusted EoCRC incidence and mortality rates between 2014–2018 were 9.5 (standard deviation [SD]: 2.7) and 2.7 (SD: 0.8) per 100,000 persons, respectively. In the adjusted model, GI supply was associated with lower EoCRC incidence (−5.6 percentage-point change per SD; 95% confidence interval, −11.0 to −0.1) but not with EoCRC mortality (P = .558). PCP supply was associated with lower EoCRC mortality (−27.0 percentage-point change per SD; 95% confidence interval, −46.1 to −7.8) but not with EoCRC incidence (P = .077). **CONCLUSION:** Greater GI specialist supply was associated with a reduction in EoCRC incidence but not improved mortality. Study findings suggest the need for early colorectal cancer screening efforts and the potential for expanding GI services and referrals in medically underserved areas.

Keywords: Early-Onset Colorectal Cancer; Physician Supply; Gastroenterologist; Primary Care

Introduction

Young adults in the United States (US) are experiencing an increased risk of colorectal cancer (CRC). In the period 1995–2015, the rate of early-onset colorectal cancers (EoCRCs), defined as those diagnosed before the age of 50, increased by more than 60%, while the average onset cancer rate declined steadily.[1,2] Before 2030, CRC is expected to be the leading cause of cancer mortality among US adults aged 20–49 years.[3] In response to this growing burden, the US Preventive Services Task Force now recommends initiating average-risk CRC screening at 45 years of age, down from 50 years in the previous versions.[4]

There is increasing evidence of geographical disparities in gastrointestinal diseases, including CRC, in the U.S.[5,6] Geographical access to care disparities, such as rurality and availability of healthcare providers, often shape access to screening and treatment opportunities.[7] For example, several studies have shown that greater physician supply leads to increased cancer screening, earlier detection of malignancy, and lower CRC incidence.[8–10] However, many of these studies did not specify physician specialties, nor did they take into consideration other specialists who are likely to be involved in the diagnosis and treatment of CRC, such as gastroenterologists (GI). As of yet, little is known about the role of GI specialist availability and access in the EoCRC burden.

As the number of young and advanced CRC patients increases,[3] GI specialists are playing an increasingly important role not only in diagnosing and preventing the disease but also in performing endoscopic procedures (treatment) and managing other gastrointestinal complications.[11,12] Current evidence regarding EoCRC risk is limited to individual behavioral factors (eg, lifestyle, smoking, diet).[13,14] The relationship between area-level or geographic factors and EoCRC outcomes

Abbreviations used in this paper: AHRF, area health resource files; AMA, American Medical Association; CRC, colorectal cancer; EoCRC, early-onset colorectal cancer; FIPS, Federal Information Processing Standard; GI, gastroenterologist; PCMH, patient-centered medical home; PCP, primary care physician; SD, standard deviation; SEER, surveillance, epidemiology, and end results; US, United States; USPSTF, The US Preventive Services Task Force; VIF, variance inflation factor.

Most current article

2772-5723
https://doi.org/10.1016/j.gastha.2023.04.001

needs to be better understood. A better understanding of these disparities in relation to the availability and access to GI specialists is needed to inform GI societies and policy interventions to address the growing burden of EoCRC. Therefore, in this study, we sought to examine the EoCRC incidence and mortality by comparing the supply of GI specialists and physicians with that of other specialties (eg, primary care, radiation oncology) at the county level.

Materials and Methods

Study Design and Data

This was an ecological study examining the association of GI specialist supply with EoCRC incidence and mortality rates. We used data from the 2014–2018 US cancer statistics, which combined data from the Center for Disease Control and Prevention's National Program of Cancer Registries, the National Cancer Institute's Surveillance, Epidemiology, and End Results Program, and the National Vital Statistics System.[15,16] The cancer statistics data are collected from population-based registries in 50 states and the District of Columbia, covering over 98% of the cancer population.[15] Using the county-level Federal Information Processing Standard codes, we linked the cancer statistics data to the 2014–2015 area health resource files (AHRF).[17] The area health resource files data provides county-level socioeconomic indicators (eg, population density, race/ethnicity distribution, poverty rate) and healthcare resources available, including physician supply in each county from the American Medical Association (AMA) Physician Masterfile.[17] Our initial sample included 3141 US counties. Despite the increasing EoCRC rates, cases recorded were relatively low (<16 cases) in the data, which needed to be suppressed to ensure the confidentiality and stability of rate estimates in compliance with the Center for Disease Control and Prevention's data suppression rules.[18] This resulted in 855 counties having complete incidence data and 243 counties having complete mortality data in our final analytic samples. This study was deemed as nonhuman subject research by the University of Florida Institutional Review Board since it used deidentified and publicly available data. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guideline for cross-sectional studies.[19]

Primary Outcomes

Our primary outcomes were age-adjusted EoCRC incidence and mortality rates per 100,000 population (standardized to the 2000 US population).[15,16] EoCRC cases were identified using the International classification of diseases for oncology codes colon (C18.0, C18.2–18.7) and rectum (C19.9, C20.9) and deaths using the surveillance, epidemiology, and end results cause of death recode (201040–201060) among patients ages 20–49.[15,16] All rates were averaged over 5-year (2014–2018) to account for year-to-year variations, consistent with previous ecological studies.[5,20,21]

Physician Supply

Data on physician supply were obtained from the 2014–2015 AMA Physician Masterfile. GI specialists were defined as the number of nonfederally employed physicians with a medical specialty in gastroenterology and a surgical specialty in colon or rectal surgery. We also included other physician specialties available in the AMA Masterfile to explore their association with EoCRC outcomes. They included radiation oncologists, general surgeons, and primary care physicians (PCPs) using identified primary specialties. PCPs are physicians (including doctor of medicines and doctor of osteopathic medicines) who provide direct patient care in at least one of the 4 primary care specialties: general and family practice, general internal medicine, pediatrics, and obstetrics and gynecology. Physician specialty supply was calculated for each county based on the number of residents per 100,000.

County Covariates

We considered county-level characteristics that may confound the association between physician supply and EoCRC outcomes based on previous ecological studies on GI outcomes.[8–10] They included percentages of the population categorized as women, Black, Hispanic, with less than a high school education, poverty rate, and rural or urban status (based on the 2013 rural/urban continuum codes from the U.S. Department of Agriculture's Economic Research Service).[22] Although we considered other covariates such as median family income level, uninsured, and unemployment rates, they were removed from the analysis given the indication of problematic levels of collinearity issue using variance inflation factors.[23] For example, the poverty rate was highly correlated with median family income or the uninsured rate (variation inflation [VIF] >4). This multicollinearity issue can cause model estimations to be unstable and imprecise and make it hard to determine the effects of each variable on the study outcomes.[23] After removing those 3 variables, we retested for multicollinearity and found no further issues with VIF <3.

Statistical Analysis

Our primary analysis was to examine the association of GI specialist supply (2014–2015 data) with age-adjusted EoCRC incidence and mortality (2015–2018 data). All continuous variables were z-scored (having a mean of 0 and a standard deviation [SD] of 1), allowing the coefficient of each independent variable to reflect the change in the outcome variable to enable a fair comparison in the analysis.[24] In addition to descriptive statistics (mean, proportion), Pearson correlation was used to explore the bivariate associations between physician supply and EoCRC outcomes. We then estimated a linear mixed-effects model with the county as the random effect (allowing intercepts to vary among counties) and clustering of standard errors at the state level. Collinearity among the key study variables was tested, and there was strong collinearity among physician supply types, including radiation oncologist and general surgeon supplies (VIFs >4). Therefore, they were not included in the adjusted model. The model was adjusted for the percentages of Black, Hispanic, women, those without a high school education, poverty rate, and rural and urban status. We report the regression coefficients, which can be interpreted as a percent-point change in outcome per 1 SD increase in each independent variable. For example, if an estimated coefficient for GI supply with its SD value of 3 is −0.13 in the model of EoCRC incidence, it can be interpreted as 3 GI specialists supply

Table 1. Characteristics of US Counties With Complete Information, 2014–2015

Characteristics	Values
Provider supply, mean (SD)	
Gastroenterology specialist supply, per 100,000	4.1 (3.8)
Radiation oncologist, per 100,000	1.4 (1.6)
General surgeons, per 100,000	10.4 (9.4)
Primary care physician supply, per 100,000	70.2 (30.3)
Population sociodemographic, mean (SD)	
Median age, years	38.5 (4.4)
Population women, %	50.7 (1.3)
Population Black, %	11.1 (12.5)
Population Hispanic, %	10.9 (13.4)
Population with less than high school education, %	12.7 (5.6)
Population in poverty, %[a]	15.5 (5.7)
Geographic	
Census regions, %	
Midwest	21.4
Northeast	16.5
South	47.3
West	14.8
Rural area, %	18.0
Early-onset CRC outcomes, mean (SD)	
Age-adjusted early-onset CRC incidence, per 100,000[b]	9.5 (2.7)
Age-adjusted early-onset CRC death, per 100,000[b]	2.7 (0.8)

SD, standard deviation; CRC, colorectal cancer.
[a]Defined as family income less than 138% of the federal poverty level.
[b]Adjusted to the 2000 US standard population https://seer.cancer.gov/stdpopulations/stdpop.19ages.html.

being associated with a −13 percent-point change in EoCRC incidence. *P* values were two-sided with an alpha <.05 to determine statistical significance. All analyses were conducted using SAS 9.4 (SAS Institute, NC) and weighted the relevant county population.

Results

A total of 855 US counties were included in this study (for the EoCRC mortality analysis, 243 counties were included). Mean age-adjusted EoCRC incidence and mortality rates between 2014–2018 were 9.5 (SD: 2.7) per 100,000 and 2.7 (SD: 0.8), respectively (Table 1). Mean GI specialist supply was 4.1 (SD: 3.8) per 100,000 population, and PCP supply was 70.2 (SD: 30.3) per 100,000 population. Most counties included in the study were located in the South region (47.3%), and 18% were identified as rural counties.

Average county-specific GI supply rate estimates for 2014–2015 ranged from 0.0 to 32.5 per 100,000, and PCP supply ranged from 2.2 to 197.5 per 100,000 population (Figure 1A and B). In general, both GI and PCP supplies were higher in the Pacific census division (California, Washington) and the New England division (Massachusetts, New Hampshire). Notably, counties in Florida had a higher GI supply than other regions (Figure 1A). Average county-specific EoCRC incidence and mortality ranged from 4.5 to 45.3 per 100,000 and from 1.3 to 6.4 per 100,000, respectively. Across the U.S., the 2015–2018 age-adjusted EoCRC incidence rates were higher in the South census region (North Carolina, Alabama) and Northeast (New York, Vermont) (Figure 1C). EoCRC mortality rates appeared to be higher in the southern region (Figure 1D).

We used bivariate mapping to visualize variations among physician supply and EoCRC outcomes across the US counties (Figure 2). Overall, counties in the south and midwest regions had the highest EoCRC burden (both incidence and mortality), while GI or PCP supply was the lowest. A small negative correlation was found between GI supply and EoCRC incidence ($r = -0.17$, $P < .001$) but not between GI supply and EoCRC mortality ($r = -0.11$, $P = .12$). PCP supply had significant negative correlations with both EoCRC incidence ($r = -0.19$, $P < .001$) and mortality ($r = -0.19$, $P = .002$).

In Table 2, our random effects model analysis showed that both GI specialists and PCP supply were negatively and significantly associated with EoCRC incidence. GI supply was associated with a −13.4 percentage-point change per SD (95% confidence interval [CI], −17.3 to −9.5). PCP supply was also associated with lower EoCRC incidence (−18.1 percentage-point change per SD; 95% CI, −23.1 to −13.1). In the adjusted model, GI supply remained statistically significant and was associated with lower EoCRC incidence (−5.6 percentage-point change per SD; 95% CI, −11.0 to −0.1); however, PCP supply was no longer statistically significant ($P = .077$). Similar to the results of EoCRC incidence, both GI specialists (−10.5 percentage-point change per SD; 95% CI, −19.9 to −1.0) and PCP supply (−22.0 percentage-point change per SD; 95% CI, −34.8 to −9.2) were negatively associated with EoCRC mortality (Table 3). However, in the covariate-adjusted model, the association between GI specialist supply and EoCRC mortality became no longer significant ($P = .558$), whereas PCP supply was associated with lower mortality (−27.0 percentage-point change per SD; 95% CI, −46.1 to −7.8).

To ease the interpretation of the main findings, we calculated the expected changes in EoCRC outcome with an increase of 5 GI specialists and 10 PCPs (Figure 3). Our estimates showed that an increase of 5 GI specialists per 100,000 was associated with a significant reduction in EoCRC incidence by 21.3% (95% CI, −39.1% to −3.5%). An increase of 10 PCPs was associated with a reduction in EoCRC mortality by 9.2% (95% CI, −15.7% to −2.7%).

Discussion

We conducted this study to examine the association of GI and PCP supply with EoCRC outcomes (incidence and mortality) and attempted to determine to what extent the supply of GI or PCP is associated with improved outcomes. Using national cancer registry data linked to county-level characteristics and physician supply, we found that greater physician supply was associated with reduced

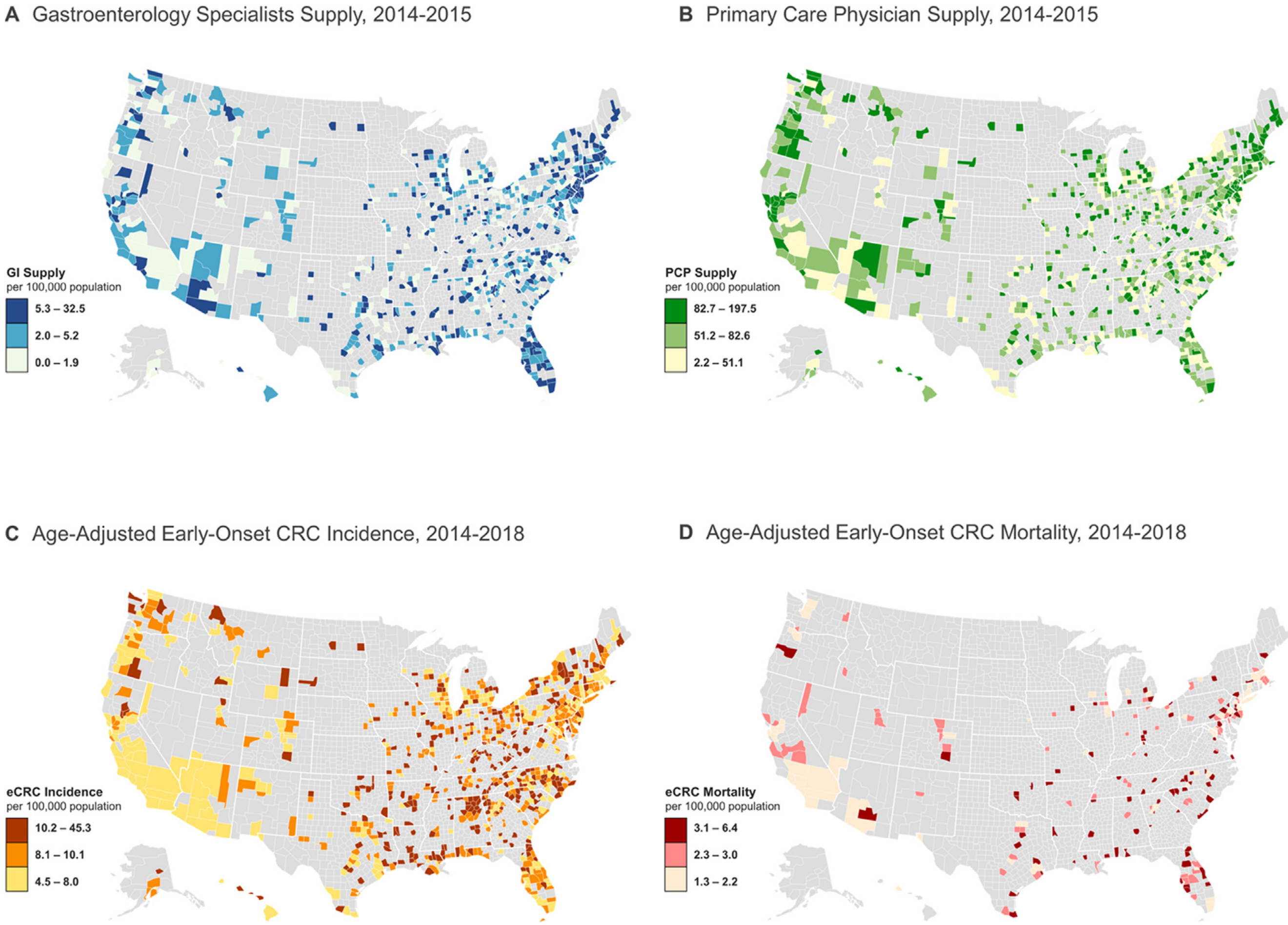

Figure 1. Geographic variations in provider supply and early-onset CRC outcomes among US counties.

EoCRC incidence and mortality. Specifically, one GI specialist supply was associated with a 4.3% lower incidence and one PCP with a 0.5% lower mortality after adjusting for county-level sociodemographic factors. Numerous studies have examined the relationship between physician supply and cancer outcomes, with findings suggesting that counties with higher physician supplies have lower cancer incidences and mortality rates.[8,10,25–27] Our findings of the association between GI and PCP supply and EoCRC outcomes confirm the previous studies and add to the literature concerning this association.

GI specialists are primarily involved in screening and diagnosing gastroenterological neoplasia as well as endoscopic treatment.[11] The reduction in the number of EoCRC cases may be attributable to the increased access to endoscopic procedures (eg, colonoscopy) with the removal of adenomatous polyps.[8,11,27] We also found in the adjusted analysis that the negative association between PCP supply and EoCRC incidence did not reach statistical significance after including GI supply. It is true that PCPs provide referrals for GI screenings and CRC screenings,[8–10] but it appears that the availability of GI specialists is more important when it comes to EoCRC prevention and early detection. This is contrary to previous studies indicating that a greater supply of PCPs facilitates CRC screening and reduces the late-onset of CRC (diagnosed age >50).[8–10] One potential explanation for this discrepancy is that previous US Preventive Services Task Force guidelines[28,29] (before 2021) recommended initiating CRC screening at age 50, and PCPs were likely to follow the guidelines during the study period (2014–2018) and not likely to recommend CRC screening for those under age 50. Therefore, the PCPs supply did not correlate with EoCRC incidence, but the GI supply did. There is also a possibility that young adults with CRC may present other GI-related symptoms (inflammatory bowel disease or clinical features of Lynch syndrome)[30,31] and could be referred to GI specialists, which may increase the chances of malignancy being detected. Nevertheless, as the EoCRC screening guidelines are being updated,[4] PCP availability may become more important in EoCRC prevention and detection. PCPs are at the forefront of managing chronic diseases such as diabetes, cardiovascular disease, and cancer.[32,33] Prior research has demonstrated that greater PCP supply is associated with improved mortality for many cancer types and overall life expectancy.[34] Follow-up studies with newly available data are needed to confirm the findings of this study and assess the impact of the screening guidelines change on EoCRC outcomes.

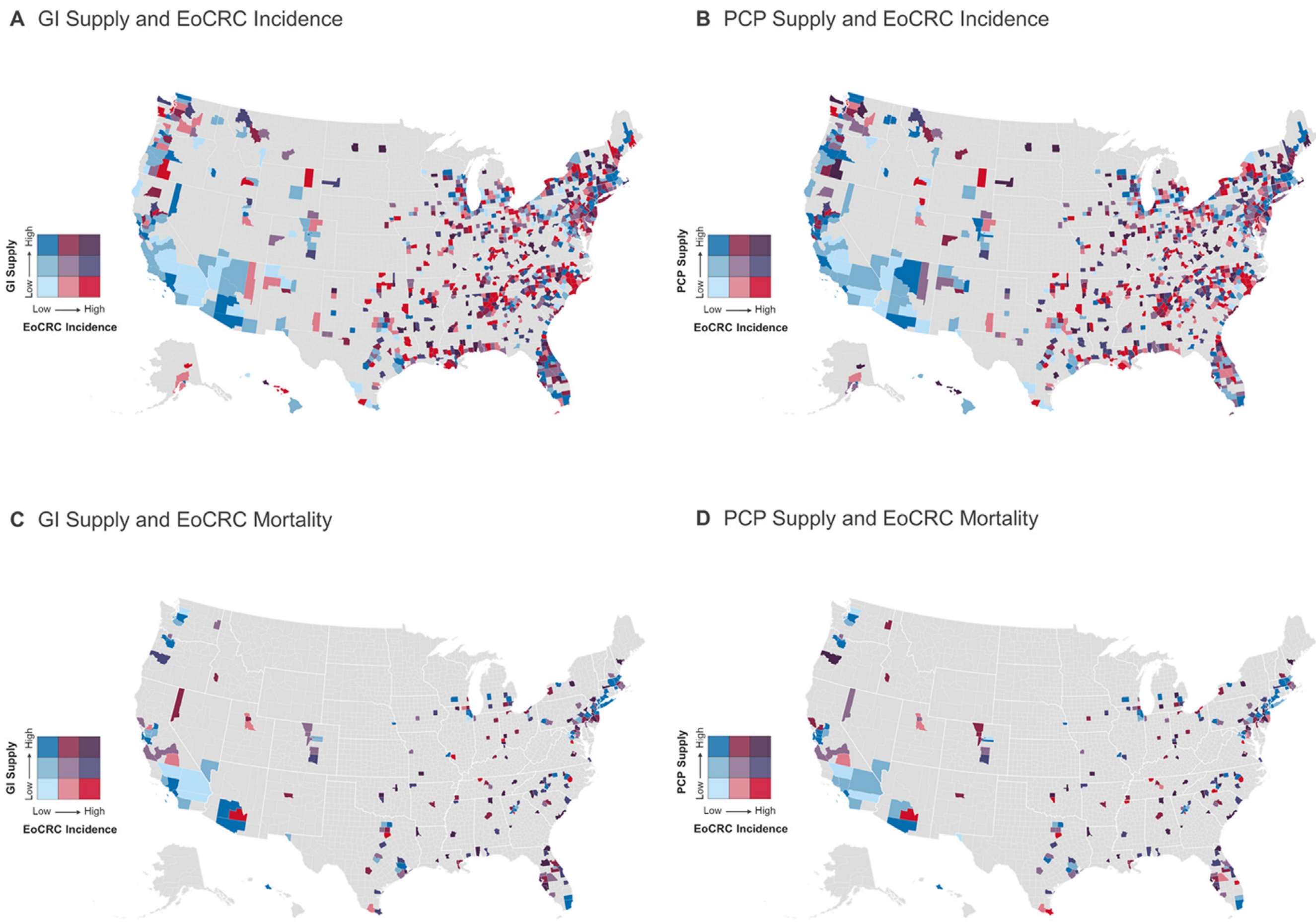

Figure 2. Bivariate mapping of provider supply and early-onset CRC (EoCRC) outcomes among US counties.

In addition to these primary findings, our findings also point to a multidisciplinary approach combining gastroenterology and primary care as an effective strategy for the prevention and management of EoCRC and common digestive diseases,[35] rather than increasing the number of physicians or specialty-specific care. In an evaluation of the patient-centered medical home model with GI specialists embedded, there was a significant reduction in time for specialty consultations and a better coordination of GI services (including abdominal computed tomography, ultrasound, and magnetic resonance imaging).[35] Primary care and specialty care providers have historically faced significant barriers to delivering coordinated care. Communication between providers can be a challenge, particularly when it comes to the

Table 2. Unadjusted and Adjusted Associations of Provider Supply and Other County-Level Covariates With Early-Onset CRC Incidence

Variables[a]	Unadjusted estimates (SE)[b]	*P*-value	Adjusted estimates (SE)[b]	*P*-value
Provider supply				
Gastroenterology specialist supply, per 100,000	−0.13 (0.02)	<.001	−0.06 (0.03)	.03
Primary care physician supply, per 100,000	−0.18 (0.03)	<.001	−0.06 (0.04)	.07
Radiation oncologist, per 100,000	−0.10 (0.02)	<.001	-	-
General surgeons, per 100,000	−0.10 (0.02)	<.001	-	-
Other covariates				
Population women, %	0.04 (0.05)	.47	−0.06 (0.05)	.25
Population Black, %	0.03 (0.02)	.27	0.07 (0.03)	.01
Population Hispanic, %	−0.18 (0.02)	<.001	−0.39 (0.02)	<.001
Population with less than high school education, %	0.05 (0.03)	.08	0.37 (0.04)	<.001
Population in poverty, %	0.08 (0.02)	.001	0.03 (0.03)	.34
Rural area (binary)	0.95	<.001	0.47 (0.08)	<.001

SE, standard error.
[a]All continuous variables were z-scored to address skewness of data, allowing fair comparison of magnitude of coefficients.
[b]Coefficients can be interpreted as a percent-point change in outcome per 1 SD, increase in each independent variable.

Table 3. Unadjusted and Adjusted Associations of Provider Supply and Other County-Level Covariates With Early-Onset CRC Mortality

Variables[a]	Unadjusted estimates (SE)[b]	*P*-value	Adjusted estimates (SE)[b]	*P*-value
Provider supply				
Gastroenterology specialist supply, per 100,000	−0.10 (0.05)	.03	−0.04 (0.07)	.56
Primary care physician supply, per 100,000	−0.22 (0.06)	<.001	−0.27 (0.10)	.006
Radiation oncologist, per 100,000	−0.03 (0.05)	.490	-	-
General surgeons, per 100,000	−0.04 (0.05)	.498	-	-
Other covariates				
Population women, %	0.26 (0.14)	.07	−0.04 (0.17)	.81
Population Black, %	0.17 (0.05)	.001	−0.06 (0.07)	.37
Population Hispanic, %	−0.16 (0.04)	<.001	−0.34 (0.07)	<.001
Population with less than high school education, %	−0.03 (0.06)	.65	−0.03 (0.12)	.79
Population in poverty, %	0.21 (0.06)	<.001	0.40 (0.09)	<.001
Rural area (binary)	0.71 (0.10)	<.001	0.59 (0.12)	<.001

SE, standard error.
[a]All continuous variables were z-scored to address skewness of data, allowing fair comparison of magnitude of coefficients.
[b]Coefficients can be interpreted as a percent-point change in outcome per 1 SD, increase in each independent variable.

reasons for and expectations associated with specialty consult requests, which can result in timely access to care being delayed for patients.[36,37] It would be an interesting venue for future studies on the development and evaluation of the impact of multidisciplinary EoCRC care.[38] The development of policies that promote specialized and integrated multidisciplinary care for EoCRC may also be necessary to alleviate and effectively manage the EoCRC burden.

Although not the focus of this study, we also found that counties with a greater proportion of Black population were associated with increased EoCRC incidence and mortality, even after adjusting for physician supply and other county-level socioeconomic factors. Previous studies have consistently found racial and ethnic disparities in EoCRC outcomes, demonstrating that Black individuals had the highest EoCRC incidence (6% higher)[39] and mortality rates (40% higher risk) than Whites.[40] Additionally, we found that a larger proportion of Hispanics was associated with lower EoCRC incidence and mortality. This is consistent with previous epidemiological studies. Overall, EoCRC incidence was lower for Hispanics (10.0 per 100,000) than Whites (12.5 per 100,000). However, the annual average increase of EoCRC was higher among Hispanics (1.9%) than Whites (1.4%) between 2001 and 2016,[41] and they had significantly lower survival rates (16% higher 5-year mortality than Whites).[40] These disparities may be due to unequal access and timeliness of cancer treatment given that racial and ethnic minority groups are less likely to get cancer screening and high-quality cancer treatment (eg, adjuvant chemotherapy, radiotherapy) compared with White patients.[42,43]

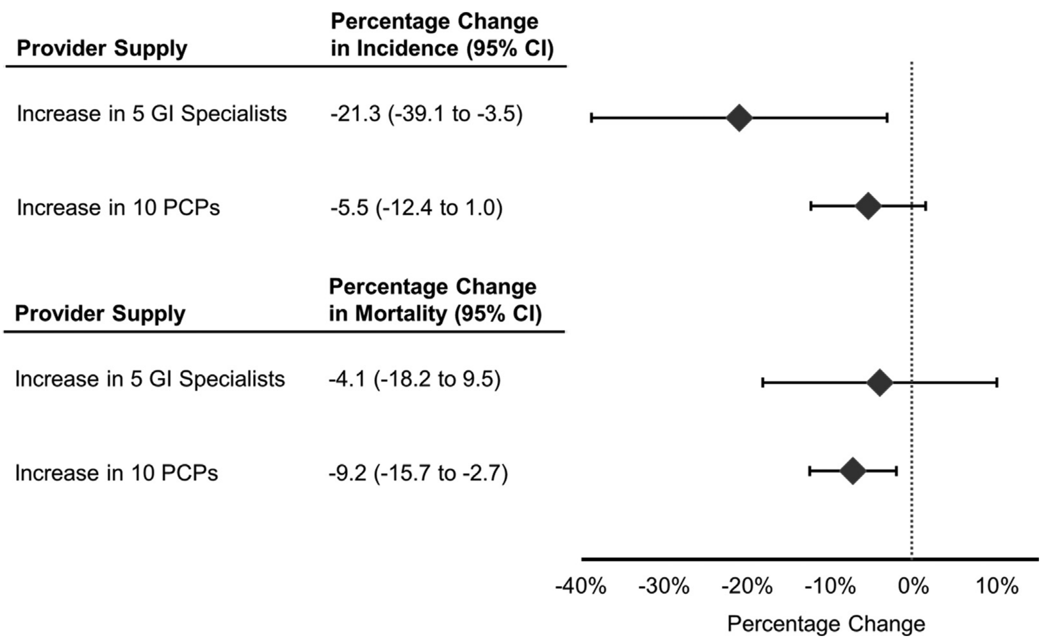

Figure 3. Changes in early-onset CRC outcomes by increase in gastroenterology specialists and primary care physicians. Error bars indicate 95% confidence interval.

Several limitations of this study are important to note. First, the main unit of analysis was county level and aggregate EoCRC outcomes, which are subject to the ecological fallacy.[44] In other words, this study doesn't imply that population-level associations influence individuals. Second, the nature of cross-sectional analysis does not allow causal inference to be drawn. Third, physician supply and provider availability does not necessarily lead to actual patient visits or realized access to care. Several factors influence the individual propensity to use healthcare services (eg, enabling factors and health needs).[45,46] Future research should employ a multilevel analysis approach that considers both individual and area-level factors to examine how health services can be accessed based on physician supply and proximity to healthcare facilities, as well as what types of services are provided for patients with EoCRC. Lastly, although the US Cancer Statistics data cover all 50 states (over 98% of the US population), the generalizability of our findings is limited since more than 70% of US counties lacked EoCRC data. As far as we know, however, this is the first attempt to investigate the association between GI and PCP supply and EoCRC outcomes using contemporary data from the national cancer registry.

Conclusion

The availability of more GI specialists was associated with a reduction in the incidence of EoCRC but not improved mortality. EoCRC mortality appeared to be influenced more by greater PCP supply. Our findings also highlight geographic-related disparities in early-onset CRC, suggesting the need for early CRC screening efforts and the potential for expanding gastroenterological services and referrals in medically underserved areas. It is necessary for future research to evaluate the realized access to care and types of health services provided, not just the availability of healthcare providers.

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Received January 18, 2023. Accepted April 11, 2023.

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Conflicts of Interest:
The authors disclose no conflicts.

Funding:
This study was supported by the American Gastroenterological Association Pilot Award in Digestive Health Disparities (AGA202022-21-05). The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Ethical Statement:
The corresponding author, on behalf of all authors, jointly and severally, certifies that their institution has approved the protocol for any investigation involving humans or animals and that all experimentation was conducted in conformity with ethical and humane principles of research.

Data Transparency Statement:
All data that support the findings of this study are publicly available from the Centers for Disease Control and Prevention (https://www.cdc.gov/cancer/npcr/index.htm) and the U.S. Department of Health and Human Services (https://data.hrsa.gov/topics/health-workforce/ahrf).

Reporting Guidelines:
STROBE.