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Primary care colorectal cancer screening correlates with breast cancer screening: implications for colorectal cancer screening improvement interventions

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ABSTRACT

Objective: National colorectal cancer (CRC) screening rates have plateaued. To optimize interventions targeting those unscreened, a better understanding is needed of how this preventive service fits in with multiple preventive and chronic care needs managed by primary care providers (PCPs). This study examines whether PCP practices of other preventive and chronic care needs correlate with CRC screening.

Methods: We performed a retrospective cohort study of 90 PCPs and 33,137 CRC screening-eligible patients. Five PCP quality metrics (breast cancer screening, cervical cancer screening, HgbA1c and LDL testing, and blood pressure control) were measured. A baseline correlation test was performed between these metrics and PCP CRC screening rates. Multivariable logistic regression with clustering at the clinic-level estimated odds ratios and 95% confidence intervals for these PCP quality metrics, patient and PCP characteristics, and their relationship to CRC screening.

Results: PCP CRC screening rates have a strong correlation with breast cancer screening rates ($r = 0.7414$, $p < 0.001$) and a weak correlation with the other quality metrics. In the final adjusted model, the only PCP quality metric that significantly predicted CRC screening was breast cancer screening (OR 1.25; 95% CI 1.11–1.42; $p < 0.001$).

Conclusions: PCP CRC screening rates are highly concordant with breast cancer screening. CRC screening is weakly concordant with cervical cancer screening and chronic disease management metrics. Efforts targeting PCPs to increase CRC screening rates could be bundled with breast cancer screening improvement interventions to increase their impact and success.

Introduction

Colorectal cancer (CRC) continues to be the second leading cause of cancer-related deaths for both men and women in the United States[1]. Screening for CRC has swiftly become a priority for many healthcare systems, in part, due to the National Colorectal Cancer Roundtable call for 80% of patients to receive this screening by 2018. In the past decade, nationally, there was a significant improvement in CRC screening rates from 54% in 2002 to 65% in 2010[2]. However, a plateau has been reached with one third of eligible adults remaining unscreened[2]. While multiple prior studies have identified successful patient,

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provider, and system interventions that increase CRC screening[3–10], in order to optimize current interventions targeting those unscreened, we need to understand how this preventive service fits with multiple preventive care needs and chronic disease management provided by primary care providers (PCPs).

Many healthcare systems are now struggling to manage the "double burden" of patients' preventive services and chronic condition care for which PCPs bear the ultimate responsibility[11]. PCPs are increasingly pressured to achieve performance targets for multiple preventive care and chronic disease quality metrics. Within a single clinical encounter they are forced to prioritize these multiple demands, including those of different preventive services[12]. These potentially competing demands[13] can be viewed as concordant or discordant with CRC screening based on patient and PCP workflows. At the patient-level, the concept that different patient co-morbidities can be concordant or discordant with a particular disease and impact its outcomes has been previously studied[14, 15]. In this case, concordant conditions are conditions that are defined as having similar pathophysiology, similar self-management plans, or similar goals for the patient[14, 15]. For example in patients with diabetes and other chronic conditions, those with more concordant conditions will experience better diabetes outcomes due to provider cueing and synergistic goals. In contrast, those with more discordant conditions will experience worse diabetes outcomes due to distraction and competition for limited patient resources [14, 16].

This study applies a similar concept at the PCP-level by examining whether practice patterns, as measured by performance on preventive and chronic disease metrics, can be classified as concordant or discordant with CRC screening. We hypothesized that delivery of other preventive services (e.g. breast cancer and cervical cancer screening) would be concordant with CRC screening rates and that chronic disease management performance (e.g. diabetes and cardiovascular disease management) will be discordant with CRC screening rates. The information gained from this study can be used to help optimize existing healthcare system interventions to increase CRC screening.

Methods

Study setting and population

We conducted a retrospective analysis of PCP practices in one of the 12 largest multi-specialty physician groups in the United States in which primary care is delivered by over 300 providers in more than 40 primary care clinic sites in both academic and community settings. The healthcare organization is a long-standing participant in the Wisconsin Collaborative for Healthcare Quality (WCHQ); a voluntary, state-wide partnership of healthcare organizations, health plans, and employers that has been publicly tracking multiple performance metrics for healthcare systems across Wisconsin since 2005[17]. We report on PCPs with >100 patients in their panel eligible for CRC screening. Excluding PCPs with small numbers of eligible patients confers stability of the results[18]. Patients were considered eligible for CRC screening if they were ages 50–75 and "currently managed" by the physician group. Currently managed is defined as having at least two primary care office visits in an outpatient, non-urgent care setting in the past 36 months with at least one visit in the past 2 years. Patients were excluded if they had a history of a total colectomy. We used a previously published algorithm by Pham et al[19]. to assign patients to PCPs. The study was determined to be exempt by the University of Wisconsin-Madison Institutional Review Board.

Outcome variable

The outcome variable was patient completion of CRC screening. Electronic medical record (EMR) data were used to identify billing and procedure codes consistent with the Healthcare Effectiveness Data and Information Set (HEDIS) definitions[20]. We determined if eligible patients had (a) fecal occult blood test in the past year, (b) flexible sigmoidoscopy, double contrast barium enema, or computed tomographic (CT) colonography in the past 5 years, or (c) colonoscopy in the prior 10 years[21]. The EMR data captured systematically collected patient reported information on CRC screening even if testing was completed outside of the healthcare organization.

Preventive care and chronic disease management metrics

Five quality metrics were calculated for each PCP during the study period (1 January 2007 to 31 December 2009). Preventive care metrics were defined as: (1) breast cancer screening rates and (2) cervical cancer screening rates. Chronic disease metrics were: (3) HgbA1C testing and (4) LDL testing among patients with diabetes mellitus and (5) blood pressure control for patients with diagnosed hypertension with or without diabetes. The definitions used to calculate the numerators and denominators for each performance metric are shown in Table 1 and reflect the established definitions set forth by WCHQ [17].

Covariates

EMR data were used to identify multiple patient and PCP characteristics to include in the final models. Patient factors included age, sex, race (white, non-white), marital status, primary language (English, Non-English), insurance coverage (Commercial, Medicare, Medicaid, or Uninsured), comorbidities (congestive heart failure, diabetes mellitus, hypertension), and a healthcare resource utilization score. The healthcare resource utilization score

Table 1 Primary care provider preventive care and chronic disease management metrics in 2009 ($N = 90$ PCPs)

Metric	Denominator definition	Denominator exclusions	Numerator definition	Quality metric performance (mean, SD)[a]
Colorectal Cancer Screening	Patients ages 50–75 with two office visits in 36 months and one office visit in 24 months with a PCP regardless of diagnosis.	Patients with a history of a total colectomy.	Patients who have had a minimum of one of the following in the measurement period: FOBT in prior 12 months, Flexible sigmoidoscopy in the prior 5 years, CT colonography in the past 5 years, or colonoscopy in the past 10 years.	0.66 (0.13)
Breast Cancer Screening	Female patients 40–68 years old with two office visits in 36 months and one office visit in 24 months with a PCP or OB-GYN regardless of diagnosis.	Patients with transgender status or a history of a unilateral or bilateral mastectomy prior to the end of the measurement period.	Women who have had a mammogram or breast MRI in the prior 24 months.	0.72 (0.13)
Cervical Cancer Screening	Female patients 21–64 years old with two office visits in 36 months and one office visit in 24 months with a PCP or OB-GYN regardless of diagnosis.	Patients with transgender status or a history of a partial or total hysterectomy prior to the end of the measurement period.	Women 21–29 years old who have had a minimum of one cervical cancer screening (cytology) in the past 36 months. Women 30–64 years old who have had one screening (cytology) in the past 36 months or one screening (cytology) and an HPV test in the past 5 years.	0.81 (0.07)
Diabetes Care: HgbA1c Testing	Patients with diabetes 18–75 years of age with a minimum of two diabetes coded office visits and must be seen by a PCP or Endocrinologist for two office visits in 24 months and one visit in 12 months.	Patients with gestational diabetes.	Patients with two or more HgbA1c tests within the past year.	0.66 (0.13)
Diabetes Care: LDL Testing	Patients with diabetes 18–75 years of age with a minimum of two diabetes coded office visits and must be seen by a PCP or Endocrinologist for two office visits in 24 months and one visit in 12 months.	Patients with gestational diabetes.	Patients with one LDL cholesterol test within the past year.	0.79 (0.13)
Blood Pressure Control	Patients 18–85 years old with a minimum of two HTN coded office visits and must be seen by a PCP or Cardiologist for two visits in 24 months and one office visit in 12 months. At least one diagnosis of HTN must be within the year prior to the measurement period or within the first 6 months of the measurement period.	Patients with one diagnosis of ESRD within the prior 24 months.	Patients whose most recent BP is adequately controlled in the past 12 months. For patients < 60 years old and for patients of any age with a diagnosis of diabetes and/or CKD, control is a representative SBP < 140 mmHg and a representative DBP < 90 mmHg. For patients ≥ 60 years old without diabetes or CKD, control is a representative SBP < 150 mmHg and a representative DBP < 90 mmHg. If multiple BPs are performed on the same day, the lowest reading is selected. BP measurements from hospital stays, emergency room or urgent care visits, and self-reported BPs are excluded.	0.69 (0.11)

PCP primary care provider, *FOBT* fecal occult blood test, *OB-GYN* obstetrician gynecologist, *MRI* magnetic resonance imaging, *HPV* human papilloma virus, *LDL* low density lipoprotein, *HTN* hypertension, *ESRD* end stage renal disease, *BP* blood pressure, *CKD* chronic kidney disease, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

[a]All performance rates for quality metrics were calculated for the 2009 calendar year using 2007 and 2008 as the baseline years to create the denominator populations

Table 2 Overall sample characteristics for patients ($N = 33,137$) and providers ($N = 90$)

Patient characteristics	$N = 33,137$
Age (%)	
50–54	26.5
55–59	26.8
60–64	21.4
65–69	14.2
70–75	11.2
Sex (%)	
Female	57.8
Race (%)	
Non-white	6.7
Marital status (%)	
Married	71.5
Language (%)	
Non-English (as primary language)	0.9
Insurance (%)	
Commercial	67.6
Medicare	25.2
Medicaid	1.5
Uninsured	5.7
Comorbidities (%)	
Congestive heart failure	1.3
Diabetes mellitus	9.5
Hypertension	36.9
ACG Resource Utilization Score (mean, SD)	0.58 (0.42)
Primary care provider characteristics	**$N = 90$**
Sex (%)	
Female	54.4
Specialty (%)	
Internal medicine	48.9
Family medicine	51.1
Years in practice (%)	
<10 yrs	17.8
10–20 yrs	36.7
>20 yrs	45.6
Practicing at a hospital owned clinic, %	32.2
Number of patients eligible for colorectal cancer screening in a provider's panel (mean, SD)	397.1 (199.7)

ACG ambulatory care group, *SD* standard deviation

was calculated with Ambulatory Care Groups (ACG)[22, 23] using outpatient and inpatient diagnoses from 2008 (the baseline year of this study). This score is based on evidence that certain groups of medical conditions have similar healthcare resource utilization. The score was divided into quintiles for the purpose of this study. PCP characteristics included: sex, specialty (internal medicine, family medicine), years in practice, and size of patient panel eligible for CRC screening. We also measured the percent of PCPs who practiced at hospital-owned versus physician-owned clinics. During the study period, clinics at our healthcare organization were owned and managed by either the hospital or the physician group practice. Variations in ownership and management are associated with different clinic infrastructure and populations served.

Statistical analysis

Preventive care (breast cancer screening, cervical cancer screening) and chronic disease management metrics (HgbA1c testing and LDL testing for patients with diabetes, and blood pressure control for patients with hypertension with or without diabetes) were calculated for each PCP for the year 2009 and tested for correlation with CRC screening rates using the pwcorr procedure in Stata. Hierarchical multivariate logistic regression with robust estimation of the standard errors and clustering at the clinic-level was performed with the logit procedure in Stata. Three models were run to obtain the odds ratios and 95% confidence intervals for the PCP quality metrics, patient characteristics, and provider characteristics as predictors of the primary outcome, completion of CRC screening at the patient level. The first model included only the PCP quality metrics, the second model added patient characteristics, and the third model included both patient and provider characteristics. Analyses were carried out with Stata 12.0 (StataCorp, College Station, TX) and SAS 9.3 (SAS Institute, Cary, NC) software. All tests of significance used two-sided P values at the $P < 0.05$ level.

Results

Sample characteristics

Ninety PCPs were identified with >100 patients in their panel eligible for CRC screening. 33,137 patients across these PCPs met the eligibility criteria for CRC screening outlined in the previously described methodology. The majority of patients were 50–60 years old, 58% were female, 93% were White, almost three-quarters were married, and more than two-thirds had commercial insurance coverage (Table 2). The mean ACG score was 0.58 which means that on average, patients in the sample were predicted to have a lower than average composite health needs or illness burden. Among the 90 PCPs, 54% were women, 49% practice in Internal Medicine, a little less than half had been in practice for more than 20 years,

Table 3 Correlation matrix for preventive care and chronic disease management metrics (*N* = 90 PCPs, *N* = 33,137 patients)

Metric	CRC screening	Breast cancer screening	Cervical cancer screening	Diabetes HgbA1c testing	Diabetes LDL testing	Blood pressure control
CRC screening	1.0000					
Breast cancer screening	*r* = *0.7414*†	1.0000				
Cervical cancer screening	***r* = 0.2642**†	*r* = 0.4355†	1.0000			
Diabetes HbgA1c testing	***r* = 0.2335**†	*r* = 0.1410†	*r* = 0.1819†	1.0000		
Diabetes LDL testing	***r* = 0.1718**†	*r* = 0.0165†	*r* = 0.1423†	*r* = 0.5390†	1.0000	
Blood pressure control	***r* = 0.2040**†	*r* = 0.2926†	*r* = 0.1195†	*r* = 0.0560†	*r* = –0.0114*	1.0000

r correlation coefficient
Italic results represent strong positive relationship; bold terms represent weak positive relationship
*$p < 0.05$; †$p < 0.001$

and the average number of panel patients eligible for colorectal cancer screening is 397. Thirty percent of PCPs practiced in hospital-owned clinics with over two-thirds practicing in physician-owned clinics.

Correlation between colorectal cancer screening and PCP preventive care and chronic disease management metrics

At baseline, PCP CRC screening rates had a strong positive correlation with breast cancer screening rates ($r = 0.7414$, $p < 0.001$) and a weak positive correlation with cervical cancer screening ($r = 0.2642$, $p < 0.001$), diabetes HgbA1c and LDL testing ($r = 0.2335$, $p < 0.001$ and $r = 0.1718$, $p < 0.001$, respectively), and blood pressure control ($r = 0.2040$, $p < 0.001$) (Table 3). There were no quality metrics that were negatively correlated with CRC screening.

Multivariate models predicting colorectal cancer screening

Three logistic regression models, with a hierarchical structure to account for clustering within clinics, were built for analysis with sequential addition of quality metrics, patient characteristics, and provider characteristics to predict completion of CRC screening at the patient level (Table 4). The first model included only quality metrics and showed that the only metric significantly associated with CRC screening was breast cancer screening (OR 1.36; 95% CI 1.26–1.46; $p < 0.001$). After adjusting for patient characteristics (second model), the OR for breast cancer screening decreased slightly but remained significantly associated with CRC screening (OR 1.28; 95% CI 1.18–1.40; $p < 0.001$). In this model, multiple patient characteristics were also significant predictors of completing CRC screening such as: increasing patient age, White race, being married, primarily English speaking, having commercial insurance coverage, not having congestive heart failure or diabetes, and utilizing more healthcare resources. The third model included provider characteristics in addition to the quality metrics and patient characteristics. None of the provider characteristics were significant predictors of CRC screening completion in this model.

Discussion

We found that CRC screening is highly concordant with breast cancer screening rates. Even after adjusting for quality metrics, patient characteristics, and provider characteristics, a PCP's breast cancer screening rate significantly predicts CRC screening. More specifically, for each 10% increase in a PCP's breast cancer screening rate, there was a 25% greater likelihood of CRC screening completion for their patients. This finding is consistent with our hypothesis that breast cancer screening (a preventive care metric) would be concordant with CRC screening. However, contrary to our hypothesis, we found that cervical cancer screening (another preventive care metric) was only weakly associated with CRC screening and did not significantly predict CRC screening in the final adjusted model.

One potential reason for these findings is that the ages of the eligible patient populations for CRC screening (50–75 years) and breast cancer screening (women ages 40–68 years) are more similar than CRC screening and cervical cancer screening (women ages 21–64 years). Another possibility is that patients who complete breast cancer screening are more likely to complete CRC screening. However, the statistically significant association between PCP breast cancer screening rates and CRC screening remained even after adjusting for multiple patient-level variables. A third reason capitalizes on the concept of concordant and discordant workflow processes for preventive services that are delivered within a clinic visit[24]. Although initiated by PCPs, in our healthcare system the majority of CRC screening is completed through colonoscopies so the process of both CRC

Table 4 Adjusted odds ratios and 95% confidence intervals predicting CRC screening ($N = 33,137$ patients)

	Metrics Only		Metrics and patient characteristics		Metrics, patient, and provider characteristics	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Provider quality metrics (in tens of %)						
Breast cancer	1.36 (1.26, 1.46)	<0.001	1.28 (1.18, 1.4)	<0.001	1.25 (1.11, 1.42)	<0.001
Cervical cancer	0.94 (0.79, 1.11)	0.46	0.98 (0.84, 1.14)	0.77	1.04 (0.88, 1.22)	0.67
Diabetes A1c	1.03 (0.95, 1.12)	0.44	1.04 (0.96, 1.13)	0.34	1.03 (0.95, 1.13)	0.43
Diabetes LDL	1.08 (0.99, 1.18)	0.09	1.06 (0.98, 1.14)	0.13	1.07 (1.00, 1.15)	0.06
Blood pressure control	1.00 (0.93, 1.07)	0.97	1.01 (0.94, 1.08)	0.85	1.01 (0.94, 1.08)	0.80
Patient characteristics						
Age (years)				<0.001		<0.001
50–54			(ref)		(ref)	
55–59			1.30 (1.19, 1.43)		1.30 (1.19, 1.42)	
60–64			1.39 (1.29, 1.50)		1.39 (1.29, 1.5)	
65–69			1.61 (1.44, 1.80)		1.61 (1.45, 1.79)	
70–75			1.37 (1.15, 1.62)		1.37 (1.16, 1.61)	
Female			0.98 (0.91, 1.04)	0.48	1.00 (0.95, 1.07)	0.90
Non-White			0.83 (0.75, 0.91)	<0.001	0.83 (0.75, 0.91)	<0.001
Married			1.43 (1.36, 1.52)	<0.001	1.44 (1.36, 1.52)	<0.001
Non-English primary language			0.45 (0.34, 0.58)	<0.001	0.44 (0.34, 0.58)	<0.001
Insurance				<0.001		<0.001
Commercial			(ref)		(ref)	
Medicare			0.69 (0.62, 0.77)		0.69 (0.62, 0.77)	
Medicaid			0.34 (0.26, 0.46)		0.34 (0.26, 0.46)	
Uninsured			0.44 (0.4, 0.5)		0.44 (0.4, 0.5)	
Chronic conditions						
Congestive heart failure			0.50 (0.4, 0.63)	<0.001	0.50 (0.4, 0.63)	<0.001
Diabetes			0.80 (0.72, 0.88)	<0.001	0.80 (0.72, 0.88)	<0.001
Hypertension			0.97 (0.91, 1.04)	0.42	0.97 (0.91, 1.04)	0.374
ACG score				<0.001		<0.001
1st quintile			(ref)		(ref)	
2nd quintile			1.65 (1.5, 1.82)		1.65 (1.5, 1.82)	
3rd quintile			1.82 (1.64, 2.03)		1.82 (1.63, 2.03)	
4th quintile			1.91 (1.67, 2.17)		1.91 (1.67, 2.17)	
5th quintile			1.83 (1.63, 2.04)		1.83 (1.63, 2.04)	
Provider characteristics						
Female					0.90 (0.76, 1.06)	0.20
Primary specialty						
Internal medicine					(ref)	
Family medicine					0.91 (0.73, 1.13)	0.41

Table 4 continued

	Metrics Only		Metrics and patient characteristics		Metrics, patient, and provider characteristics	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Years in practice						0.73
<10					(ref)	
10–20					0.96 (0.76, 1.21)	
>20					0.92 (0.71, 1.19)	
Hospital-owned clinic					1.13 (0.91, 1.39)	0.26
Number of colorectal cancer screening-eligible patients (in hundreds)					1.00 (0.97, 1.04)	0.81

ACG ambulatory care group, *OR* odds ratio

screening and breast cancer screening takes place outside of the PCP clinic visit. In contrast, cervical cancer screening is an exam that must be performed within a PCP clinic visit and fit in amongst other patient needs[25]. Crabtree et al[12]. observed clinical preventive service delivery in 18 Midwestern family medicine clinics and found that preventive services may compete with each other when squeezed into an already overcrowded clinical encounter. They suggest that the structure of practices may need redesign so that some preventive services can be accomplished outside an encounter while others are integrated into illness visits[12].

PCPs are on the front lines of health care delivery and play a major role in CRC screening[25–28]. As such, they are often the focus of healthcare system interventions targeted towards increasing CRC screening[29]. In order to better understand how and why CRC screening improvement interventions succeed or fail, it is critical to also examine the context (e.g., workflows, available staff, tools and technology, cultural norms) in which the interventions are implemented. Understanding the workflows in a primary care clinic is a key component of the context. Magnan et al[16]. applied the concept of competing demands[13] to care for patients with diabetes and inferred that the competition of multiple care needs along with lack of integration of those needs could mean that patients with a higher number of comorbidities would be less likely to receive all recommended services. We used this model and its associated concepts of concordance and discordance to predict which PCP quality metrics may or may not be synergistic with completion of CRC screening. Our finding that breast cancer screening was the only PCP practice significantly associated with CRC screening, and that cervical cancer screening, HgbA1c and LDL testing, and blood pressure control did not significantly predict CRC screening, supports the idea that healthcare system interventions should focus on changes in the structure and workflows of primary care clinics to improve these quality metrics.

Our results also suggest that healthcare systems could bundle interventions for CRC and breast cancer screening to maximize screening rates. Several studies show that offering colon and breast cancer screening in tandem increases screening rates regardless of CRC screening modality, especially in underserved populations[30, 31]. Gastroenterologists and PCPs can partner with healthcare systems to develop specific electronic health record alerts/reminders and order sets that are triggered when a patient is overdue for both colon and breast cancer screening. In addition, gastroenterologists and PCPs can work with community outreach programs for breast cancer screening to help promote and expand screening to colon cancer. Shike et al[32]. and Miesfeldt et al[33]. showed success with this type of intervention in minority and under/uninsured women—populations that often have low uptake of CRC screening.

At the start of our study, we hypothesized that chronic disease management practices would be discordant with CRC screening. We found that while these are not truly discordant, there is only a weak association between CRC screening and HgbA1c testing, LDL testing, and blood pressure control. In addition, none of these metrics significantly predicted CRC screening in the final adjusted model. One potential explanation for not seeing a truly discordant relationship between CRC screening and these metrics may be the relatively high rates achieved for all of these metrics across our healthcare system; in part due to a system-wide quality improvement initiative for primary care redesign to decrease unnecessary variation in patient care that was implemented over the same time period as this study. The primary care redesign initiative began in 2008 with a mission to achieve the triple aim of better care, better health, and lower costs[34]. During the period of this study, the primary care redesign initiative was focused

on broad organizational change and not on specific preventive care or chronic disease management metrics. More specific initiatives focusing on CRC screening, breast cancer screening, and blood pressure control implemented interventions such as electronic health record alerts after 2009.

Our study has multiple strengths, as well as some limitations. One major strength is the use of standardized metrics and reporting algorithms to calculate our PCP quality metrics. Another strength is that our healthcare organization has the ability to capture multiple data points to calculate preventive care and chronic disease management metrics, even if testing occurred outside of our health system. In addition, we had a large sample of patients ($N = 33,137$) and we controlled for a number of patient and provider characteristics that have been associated with completion of CRC screening in prior studies[26, 35–38]. However, while adjusting for all of those covariates, as well as clustering at the clinic level in our statistical model, we were limited in our ability to account for other contextual factors within each clinic. Some other limitations may affect the generalizability of our results. First, we present data from a single large Midwestern medical practice with both academic and community clinics. However, large multi-specialty systems are becoming a preferred way to provide high quality healthcare and are increasingly recognized as critical to the understanding and improvement of healthcare delivery[39]. Second, our patient sample has little racial and ethnic diversity, was predominantly commercially insured, and relatively healthy. However, our study suggests that colon and breast cancer screening interventions can be bundled to increase both screening rates which has been successfully applied to minority and underserved populations, as shown by Shike et al.[32] and Miesfeldt et al.[33]. Finally, we present data on a select sample of patients who all met our criteria for being "currently managed" by the medical group and therefore, had a baseline level of engagement with the medical system.

Conclusions

We have reached a plateau with improvements in CRC screening rates. In order to reach the NCCRT goal of screening 80% of eligible patients by 2018 we need to optimize existing interventions and/or develop new interventions with higher impact. To do this, we need to better understand the context in which these interventions will be implemented. The competing demands model helps explain our current environment of preventive services delivery and our finding that PCP CRC screening rates correlate highly with breast cancer screening; both are procedures that occur outside of the PCP clinic visit. Health care systems can leverage this correlation and bundle CRC and breast cancer screening interventions together to increase impact and success.

Study Highlights

What Is Current Knowledge

- Colorectal cancer (CRC) screening rates have increased but one-third of eligible patients remain unscreened.
- The National Colorectal Cancer Roundtable (NCCRT) has announced a major goal of screening 80% of eligible patients by 2018.
- Current interventions to increase CRC screening rates need to be optimized to reach the NCCRT goal.

What Is New Here

- Primary care provider (PCP) CRC screening rates correlate highly with breast cancer screening rates.
- Health care systems can leverage this correlation and bundle CRC and breast cancer screening interventions together to increase impact and success.

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Conflict of interest

Guarantor of the article: Jennifer Weiss, MD, MS.
Specific author contributions: Jennifer Weiss and Maureen Smith (involved in all aspects of the manuscript); Aaron Potvien (data analysis and interpretation of data); Sally Kraft and Nancy Pandhi (study concept and design, acquisition and interpretation of data, critical revision of the manuscript for important intellectual content); Pascale Carayon (study concept and design, interpretation of data, critical revision of the manuscript for important intellectual content). All authors approved the final draft submitted.
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References

1. Siegel, R. L., Miller, K. D. & Jemal, A. Cancer statistics, 2016. *CA Cancer J Clin* **66**, 7–30 (2016).
2. Centers for Disease Control and Prevention. Vital signs: colorectal cancer screening test use--United States, 2012. *MMWR Morb. Mortal. Wkly Rep.* **62**, 881–888 (2013).
3. Phillips, L. et al. Improving breast and colon cancer screening rates: a comparison of letters, automated phone calls, or both. *J. Am. Board Fam. Med.* **28**, 46–54 (2015).
4. Levy, B. T. et al. A randomized controlled trial to improve colon cancer screening in rural family medicine: an Iowa Research Network (IRENE) study. *J. Am. Board Fam. Med.* **26**, 486–497 (2013).
5. Myers, R. E. et al. Behavioral interventions to increase adherence in colorectal-cancer screening. *Med Care.* **29**, 1039–1050 (1991).
6. Wardle, J. et al. Increasing attendance at colorectal cancer screening: testing the efficacy of a mailed, psychoeducational intervention in a community sample of older adults. *Health Psychol.* **22**, 99–105 (2003).
7. Ferreira, M. R. et al. Health care provider-directed intervention to increase colorectal cancer screening among veterans: Results of a randomized controlled trial. *J. Clin. Oncol.* **23**, 1548–1554 (2005).
8. Myers, R. E. et al. Impact of a physician-oriented intervention on follow-up in colorectal cancer screening. *Prev. Med.* **38**, 375–381 (2004).
9. Litzelman, D. K. et al. Requiring physicians to respond to computerized reminders improves their compliance with preventive care protocols. *J. Gen. Intern Med.* **8**, 311–317 (1993).
10. Hudson, S. V. et al. The effects of teamwork and system support on colorectal cancer screening in primary care practices. *Cancer Detect Prev.* **31**, 417–423 (2007).
11. Epping-Jordan, J. E. et al. Improving the quality of health care for chronic conditions. *Qual. Saf. Health Care.* **13**, 299–305 (2004).
12. Crabtree, B. F. et al. Delivery of clinical preventive services in family medicine offices. *Ann. Fam. Med.* **3**, 430–435 (2005).
13. Jaen, C. R., Stange, K. C. & Nutting, P. A. Competing demands of primary care: a model for the delivery of clinical preventive services. *J. Fam. Pract.* **38**, 166–171 (1994).
14. Piette, J. D. & Kerr, E. A. The impact of comorbid chronic conditions on diabetes care. *Diabetes Care.* **29**, 725–731 (2006).
15. Lagu, T. et al. The impact of concordant and discordant conditions on the quality of care for hyperlipidemia. *J. Gen. Intern Med.* **23**, 1208–1213 (2008).
16. Magnan, E. M. et al. The impact of a patient's concordant and discordant chronic conditions on diabetes care quality measures. *J. Diabetes Complicat.* **29**, 288–294 (2015).
17. Wisconsin Collaborative for Healthcare Quality 2017. *Wisconsin Collaborative for Healthcare Quality Home Page*. http://www.wchq.org/ (2017).
18. Krein, S. L. et al. Whom should we profile? Examining diabetes care practice variation among primary care providers, provider groups, and health care facilities. *Health Serv. Res.* **37**, 1159–1180 (2002).
19. Pham, H. H. et al. Care patterns in Medicare and their implications for pay for performance. *N. Engl. J. Med* **356**, 1130–1139 (2007).
20. National Committee for Quality Assurance. *HEDIS & Quality Measurement*. http://www.ncqa.org/HEDISQualityMeasurement.aspx (2017).
21. Levin, B. et al Screening and surveillance for the early detection of colorectal cancer and adenomatous polyps, 2008: a joint guideline from the American Cancer Society, the US Multi-Society Task Force on Colorectal Cancer, and the American College of Radiology. *CA Cancer J Clin* **58**, 130–160 (2008).
22. Petersen, L. A. et al. Comparison of the predictive validity of diagnosis-based risk adjusters for clinical outcomes. *Med. Care.* **43**, 61–67 (2005).
23. Perkins, A. J. et al. Common comorbidity scales were similar in their ability to predict health care costs and mortality. *J. Clin. Epidemiol.* **57**, 1040–1048 (2004).
24. Albright, B. B. et al. Preventive care quality of medicare accountable care organizations: associations of organizational characteristics with performance. *Med. Care.* **54**, 326–335 (2016).
25. Klabunde, C. N. et al. A national survey of primary care physicians' colorectal cancer screening recommendations and practices. *Prev. Med.* **36**, 352–362 (2003).
26. Klabunde, C. N. et al. Barriers to colorectal cancer screening: a comparison of reports from primary care physicians and average-risk adults. *Med Care.* **43**, 939–944 (2005).
27. Seeff, L. C. et al. Patterns and predictors of colorectal cancer test use in the adult US population. *Cancer* **100**, 2093–2103 (2004).
28. Berkowitz, Z. et al. Beliefs, risk perceptions, and gaps in knowledge as barriers to colorectal cancer screening in older adults. *J. Am. Geriatr. Soc.* **56**, 307–314 (2008).
29. Klabunde, C. N. et al. Improving colorectal cancer screening in primary care practice: innovative strategies and future directions. *J. Gen. Intern Med.* **22**, 1195–1205 (2007).
30. Davis, T. C. et al. Joint breast and colorectal cancer screenings in medically underserved women. *J. Community Support Oncol.* **13**, 47–54 (2015).
31. Hillyer, G. C. et al. Feasibility and efficacy of pairing fecal immunochemical testing with mammography for increasing colorectal cancer screening among uninsured Latinas in northern Manhattan. *Prev. Med.* **53**, 194–198 (2011).
32. Shike, M. et al. Expanding colorectal cancer screening among minority women. *Cancer* **117**, 70–76 (2011).
33. Miesfeldt, S. et al. Colorectal cancer screening pilot program for underserved women in Cumberland County, Maine. *J. Community Health* **35**, 109–114 (2010).
34. Kraft, S. et al. Building the learning health system: describing an organizational infrastructure to support continuous learning. *Learn. Health Sys.* **1**, e10034 (2017).
35. Weiss, J. M. et al. Predictors of colorectal cancer screening variation among primary-care providers and clinics. *Am. J. Gastroenterol.* **108**, 1159–1167 (2013).
36. Cokkinides, V. E. et al. Correlates of underutilization of colorectal cancer screening among U.S. adults, age 50 years and older. *Prev. Med.* **36**, 85–91 (2003).
37. Christman, L. K. et al. Colorectal cancer screening among a sample of community health center attendees. *J. Health Care Poor Under.* **15**, 281–293 (2004).
38. Meissner, H. I. et al. Patterns of colorectal cancer screening uptake among men and women in the United States. *Cancer Epidemiol. Biomark. Prev.* **15**, 389–394 (2006).
39. Crosson, F. J. The delivery system matters. *Health Aff.* **24**, 1543–1548 (2005).