CLINICAL RESEARCH STUDY

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Using Online Colorectal Cancer Risk Calculators to Guide Screening Decision-Making

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ABSTRACT

BACKGROUND: Several online calculators estimate colorectal cancer risk, but their consistency is unknown. Our objectives were to quantify the variation in predicted risk and to determine which calculators are best used in the clinical setting.

METHODS: We used the Google search engine to identify online colorectal cancer risk calculators and assessed the output of each for 3 hypothetical screening scenarios (low-, average-, and high-risk), varied by age (50, 62, 75 years), sex, and race (Black, White), with risk levels based on risk-appropriate values for variables in each model. Estimated risks for models within a given scenario were rated as consistent or inconsistent based on comparison with either the absolute magnitude of difference or average lifetime risk of colorectal cancer. Summary statistics for consistent and inconsistent estimates were compared using chi-square and Fisher's exact tests.

RESULTS: We identified 5 online colorectal cancer risk calculators. Inconsistencies were found in none of 5-year, 19% of 10-year, and 81% of lifetime colorectal cancer risk estimate comparisons ($P < .001$). For a 50-year-old, 22% of risk estimate comparisons were inconsistent, vs 33% for a 62-year-old, and 36% for a 75-year-old ($P = 0.14$).

CONCLUSIONS: Online colorectal cancer risk models are more consistent in predicting colorectal cancer risk for 5- and 10-year time frames compared with lifetime. For a US population, the National Cancer Institute's Colorectal Cancer Risk Assessment Tool is a rigorously developed calculator that can be used in the clinical setting to provide 5-year and lifetime risk estimates.

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KEYWORDS: Colorectal cancer; Risk calculator; Risk prediction model

INTRODUCTION

While screening has contributed to a decline in its incidence and mortality, colorectal cancer remains the second leading cause of cancer-related mortality in the United States.[1] Strategies for early detection and prevention range from organized programs in which all adults are offered a screening test, to a more tailored approach based on risk, overall health status, and patient preferences.[2,3] Several factors beyond age, such as race, sex, family history, obesity, and lifestyle habits (eg, diet, exercise, tobacco, and alcohol use) contribute to an individual's colorectal cancer risk. With more than 90 million men and women between the ages of 45 and 75 years in the United States,[4] many of whom are screen eligible, factors beyond age need to be considered in order to optimize screening. A personalized approach to colorectal cancer screening, by using multiple factors to tailor screening based on individualized risk profile, has the potential to guide allocation of resources to those who are most likely to benefit, while reducing exposure to unnecessary harms.

Several risk prediction models have been developed,[5,6] some of which are available as risk assessment tools (ie, risk calculators). These tools incorporate multiple risk factors to provide risk estimates and are intended to facilitate

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decision-making for colorectal cancer screening, but their widespread use in the clinical setting thus far has been limited. In October 2019, Helsingen et al[7] published a guideline that incorporated an individual's predicted colorectal cancer risk, as determined by the QCancer model. The expert panel suggested screening individuals between the ages of 50 and 75 years whose 15-year colorectal cancer risk was >3%. Whether the currently available risk assessment tools are consistent in their risk estimates is unknown. The primary objectives of this study were to examine easily accessible colorectal cancer risk assessment tools to quantify the variation in risk estimates and to determine which models best guide screening decisions in clinical practice.

CLINICAL SIGNIFICANCE

- Currently available colorectal cancer risk calculators are more consistent in estimating risk for shorter time frames than for longer time frames.
- The methodology with which a model was developed, population of interest, and desired time frame for risk estimates should be considered when deciding which risk calculator to use for screening decision-making.
- The National Cancer Institute Colorectal Cancer Risk Assessment Tool provides the most accurate estimates for a US patient population.

METHODS

We used the Google search engine (Google Inc., Mountain View, Calif) to search "colorectal cancer risk calculators" to identify risk prediction models that are easily accessible and available as online risk assessment tools. We then reviewed each assessment tool to identify, and include, only those that provided a numerical risk estimate. For each included model, we reviewed published studies describing the methodology underlying each model's development and validation to assess the rigor of the supporting studies. We also identified the variables used to estimate colorectal cancer risk, and determined risk estimates for hypothetical low-, average-, and high-risk scenarios. Due to the nature of this study involving hypothetical scenarios, institutional review board approval was not required.

Hypothetical Scenarios

We created 3 hypothetical screening scenarios (low-, average-, and high-risk) varied by age (50, 62, and 75 years), sex, and race (Black, White). In each scenario, we used risk-appropriate values for tobacco use, body mass index, family history of colorectal cancer, exercise, diet, alcohol, and aspirin/non-steroidal anti-inflammatory drug (NSAID) use. Using these hypothetical scenarios, we determined the estimated colorectal cancer risk for each model for a 50-, 62-, and 75-year-old person. Risk estimates for the following time frames were then compared: 5-year, 10-year, 15-year, and lifetime colorectal cancer risk. We defined a low-, average-, and high-risk individual based on risk-appropriate values for factors included in each model as outlined in Appendix A (available online). All persons in these hypothetical scenarios were assumed to be presenting for index colorectal cancer screening.

Statistical Analysis

Two reviewers independently compared risk estimates for models within a specified time frame for each hypothetical scenario and categorized estimated risks as consistent or inconsistent with other model estimates. We compared 5-year and 10-year estimates and defined them as inconsistent if the absolute difference exceeded 1%. While this 1% threshold for a difference may seem both small and arbitrary, the short-term time frames must be considered, during which a very low colorectal cancer risk is expected. Furthermore, we favored sensitivity to identify any inconsistences worthy of noting. Only one risk calculator was available for 15-year estimates,[7] therefore, no comparisons for this time frame were made. For lifetime risk estimates, we first compared estimates relative to the average lifetime colorectal cancer risk of 5%-6% (± 0.5%).[8] For scenarios in which all lifetime risk estimates were above 6.5%, we reviewed differences between the estimates to determine whether they were consistent or inconsistent with each other. For example, if one risk calculator estimated risk above the 4.5%-6.5% range and the other within or below this range, these model estimates were considered to be inconsistent. Further, if one risk calculator estimated colorectal cancer risk as 7% while the other in the same scenario estimated risk as 10%-15%, both of which are above the average lifetime colorectal cancer risk of 5%-6%, they would still be defined as inconsistent with each other because the upper limit of the latter is twice the estimated risk of the former. Differences were resolved by discussion between the 2 reviewers. Summary statistics for consistent and inconsistent risk estimates were compared using chi-square and Fisher's exact tests.

RESULTS

Risk Calculators and Included Variables

We identified 6 easily accessible online colorectal cancer risk calculators through our Google search, including: National Cancer Institute's (NCI) Colorectal Cancer Risk Assessment Tool (https://ccrisktool.cancer.gov/calculator.html), Cleveland Clinic's (CC) Colon Cancer Risk Assessment (https://digestive.ccf.org/scores/go), Colorectal Cancer Predicted Risk Online (CRC-PRO) (https://riskcalc.org/ColorectalCancer/), QCancer (https://qcancer.org/15yr/colorectal/), My CancerIQ (https://www.mycanceriq.ca/Cancers/Colorectal), and Your Disease Risk (https://siteman.wustl.edu/prevention/ydr/). Outputs for estimated risks were discrete values for all calculators except for CC, My CancerIQ, and Your Disease Risk. CC's output of "average" risk was stated as

equal to 5% lifetime risk and "medium" risk as equal to 2-3 times the average lifetime risk. My CancerIQ estimated average risk as 1 in 16 (6%) for women and 1 in 14 (7%) for men, with outputs of either greater than, equal to, or below average risk. Given that the NCI, CC, CRC-PRO, QCancer, and My CancerIQ risk calculators provided numerical estimates, we included them in our study. Your Disease Risk was excluded as we were not able to translate the predicted qualitative risk assessment to a numerical value to allow for comparison with other models.

Published studies supporting development and validation of the NCI, CRC-PRO, and QCancer models are shown in Table 1.[9-13] The NCI, QCancer, and CRC-PRO models have been externally evaluated using the UK Biobank data and found to have poor calibration (Hosmer-Lemeshow $P < .05$) and only fair discrimination (area under the receiver operating characteristic curve [AUROC] 0.59-0.70).[10] However, when tested in an independent US cohort, the NCI model was well calibrated (expected-to-observed ratio 0.99-1.105) and had fair discrimination (AUROC 0.60-0.61).[14] When tested on a separate UK cohort, the QCancer-10-year colorectal cancer model was found to be well calibrated and to have very good-to-excellent discrimination (AUROC 0.85-0.86).[11] Published studies for My CancerIQ and Cleveland Clinic's Colon Cancer Risk Assessment Tool were not identified. The following variables were included in all models: age, sex, body mass index, tobacco use, and family history of colorectal cancer. Race and ethnicity, education level, physical activity, personal medical history (eg, colon polyps, colorectal cancer,

Table 1 Characteristics of Included Colorectal Cancer Risk Prediction Models

Model	Derivation Population	Validation Data			Colorectal Cancer Risk Estimate Output
		Patient Population	Calibration	Discrimination	
NCI	- 2 US population-based case-control studies[16] - Non-Hispanic White men and women ≥50 y of age - SEER incidence data (Black men and women included)	Externally validated in a US non-Hispanic White population of 263,402 participants 50-71 y of age	E/O = 0.99 (95% CI, 0.95-1.04) for men; 1.05 (95% CI, 0.98-1.11) for women	AUROC 0.61 (95% CI, 0.60-0.62) for men; 0.60 (95% CI, 0.59-0.62) for women	5-y; lifetime
		Externally validated in UK Biobank cohort*	Hosmer-Lemeshow $P < .0001$	AUROC 0.64 (95% CI 0.61-0.66) for men; 0.59 (95% CI 0.56-0.61) for women	
QCancer	UK cohort of 4,943,765 participants 25-84 y of age†,‡	UK cohort of 1,624,796 participants 25-84 y of age	Well-calibrated based on 10-y observed and expected estimates[11]	ROC 0.862 (95% CI, 0.858-0.866) for men; 0.847 (95% CI, 0.842-0.852) for women	1-15 y
		Externally validated in UK Biobank cohort*	Hosmer-Lemeshow $P < .05$	AUROC 0.70 (95% CI, 0.69-0.72) for men; 0.66 (95% CI, 0.64-0.68) for women	
CRC-PRO	- Multi-ethnic US cohort study§ - Cohort of residents from California and Hawaii 45-75 y of age	Internally validated, 10-fold cross validation		c-statistic 0.68 (95% CI, 0.67-0.69) for men; 0.68 (95% CI, 0.67-0.69) for women	10 y
		Externally validated in UK Biobank cohort*	Hosmer-Lemeshow $P < .0001$	AUROC 0.61 (95% CI, 0.59-0.64) for men; 0.64 (95% CI, 0.62-0.66) for women	
CC	Unavailable	Unavailable	Unavailable	Unavailable	Lifetime
My CancerIQ	Canadian White men and women	Unavailable	Unavailable	Unavailable	Lifetime

AUROC = area under the receiver operator curve; CC = Cleveland Clinic's Colon Cancer Risk Assessment; CI = confidence interval; CRC-PRO = Colorectal Cancer Predicted Risk Online calculator; c-statistic = concordance statistic; E/O = expected to observed ratio; NCI = National Cancer Institute's Colorectal Cancer Risk Assessment Tool; SEER = Surveillance, Epidemiology, and End Results program.

*UK Biobank cohort includes 373,112 participants 40-69 years of age.[6]

†Derivation and validation cohorts for QCancer: 90%-91% White/not recorded, remaining included Indian, Bangladeshi, other Asian, Caribbean, Black African, Chinese, or other.[7]

‡Data presented are for the 10-year QCancer model.

§Multiethnic cohort study: 26.4% Japanese-American, 22.9% White, 22% Latino, 16.3% African American, 6.5% Native Hawaiians, and 5.8% identified themselves as other ancestry.[9]

Table 2 Variables Included in the Risk Assessment Calculators

Consistently Included Variables*	Inconsistently Included Variables (%†)
Age	Race/ethnicity (80%)
Sex	Education level (20%)
Body mass index	Personal history of colon polyps (60%)
Family history of CRC	Personal medical history (80%) - Diabetes (60%) - Inflammatory bowel disease (40%) - Colorectal cancer (20%) - Other cancers (40%)
Tobacco use	Alcohol use (60%)
	Dietary habits (80%) (vegetable, fruit, red/processed meat, whole grains, milk product consumption)
	Medications (60%) - Aspirin/NSAIDs (60%) - Vitamin D (20%) - Multivitamin (40%) - Estrogen/hormone replacement therapy (60%)
	Physical activity/exercise (80%)
	Menopause status (20%)

CRC = colorectal cancer; NSAID = nonsteroidal anti-inflammatory drug.
*Variables included in all 5 risk assessment tools: National Cancer Institute's Colorectal Cancer Risk Assessment Tool, Cleveland Clinic's Colon Cancer Risk Assessment, Colorectal Cancer Predicted Risk Online, QCancer, My CancerIQ.
†% reflects proportion of risk assessment tools, out of 5, that included the listed variable.

diabetes, inflammatory bowel disease), medications (eg, aspirin, NSAIDs, vitamin D, multivitamins), alcohol use, dietary habits, and menopause status, were inconsistently included in the models (Table 2).

Risk Estimate Comparisons Based on Timeframe

Colorectal cancer risk estimate time frames ranged from 1 year to lifetime (Table 3), with NCI providing 5-year and lifetime estimates, CRC-PRO providing 10-year estimates, QCancer providing estimates at 1-year increments ranging from 1-15 years, and My CancerIQ and CC providing lifetime estimates. Based on variation in age, sex, race, and risk level, a total of 36 scenarios were available for comparison within each time frame (eg, for a 50-year-old low-risk White man, 5-year risk estimates for the NCI and QCancer models were compared and considered to be one scenario).

Five-year colorectal cancer risk estimates were available for the NCI and QCancer models. There were no inconsistencies in predicted colorectal cancer risk estimates between these models for low-, average-, and high-risk scenarios within the 5-year risk time frame for all 3 age groups (50-, 62-, and 75-year-olds), both sexes, and both races (Table 3). For example, a 50-year-old low-risk White man had a 5-year colorectal cancer risk of 0.3% based on the NCI model and 0.2% based on QCancer. Similarly, a 75-year-old high-risk Black man had a 5-year colorectal cancer risk of 3.1% based on NCI and 4.1% based on QCancer.

Ten-year colorectal cancer risk estimates were available for the CRC-PRO and QCancer models. Seven of the 36 (19%) scenarios were inconsistent for the 10-year time frame. For a 50-year-old, regardless of race, sex, or risk scenario, there were no inconsistencies in estimated risk between the 2 models. For a 62-year-old, the following 3 scenarios were inconsistent: average-risk Black woman (2% with CRC-PRO vs 0.9% with QCancer), high-risk Black man (5.0% colorectal cancer risk with CRC-PRO vs 2.4% with QCancer), and high-risk Black woman (4.0% with CRC-PRO vs 1.6% with QCancer). For a 75-year-old, the following 4 scenarios were inconsistent: low-risk White man (2% with CRC-PRO vs 3.3% with QCancer), low-risk Black man (2% with CRC-PRO vs 3.3% with QCancer), high-risk White woman (6% with CRC-PRO vs 4.8% with QCancer), and high-risk Black woman (6.0% with CRC-PRO vs 4.8% with QCancer).

Lifetime colorectal cancer risk estimates were available for the NCI, CC, and My CancerIQ models. My CancerIQ did not allow for selection for race and was derived using only a White population, therefore, we were unable to apply this model to Black individuals. Furthermore, while included in Table 3, My CancerIQ provided risk estimates as either greater than or less than average risk for men and women. Therefore, we did not use outputs from this calculator to determine estimates as consistent vs inconsistent with the other lifetime scenarios. When comparing NCI and CC estimates, a total of 29 of 36 comparisons (81%) for lifetime colorectal cancer risk were found to be inconsistent. Of the 29 lifetime inconsistencies, 8 (28%) were in the 50-year-old age group, 9 (31%) were in the 62-year-old age group, and 12 (41%) were in the 75-year-old age group (Table 3).

Among the 3 time frames for which more than one model provided colorectal cancer risk estimates, a greater number of inconsistencies were found in longer time frames as compared with shorter time frames (0% for 5-year vs 19% for 10-year vs 81% for lifetime; $P < .001$).

Risk Estimate Comparisons Based on Age

A total of 36 scenarios were available for comparison within each age group (50, 62, and 75 years of age) based on variations in risk, sex, and race. For each age group the following numbers of scenarios were inconsistent: 8 (22%) for the 50-year-old, 12 (33%) for the 62-year-old, and 16 (36%) for the 75-year-old ($P = .14$). A comparison of results by age group is described in detail in Appendix B (available online).

DISCUSSION

We compared colorectal cancer risk models that are currently available as easily accessible, online calculators and found differences in their development and validation based on published literature, included risk factors, and time

Table 3 Colorectal Cancer Risk Estimates

	Time Frame	Calculator	50-Year-Old			62-Year-Old			75-Year-Old		
			Low-Risk	Average-Risk	High-Risk	Low-Risk	Average-Risk	High-Risk	Low-Risk	Average-Risk	High-Risk
White male											
	5-year	NCI	0.3%*	0.4%*	1.0%*	0.4%*	0.6%*	1.6%*	0.7%*	1.1%*	3.1%*
		QCancer	0.2%*	0.3%*	0.7%*	0.7%*	0.8%*	1.4%*	1.4%*	1.7%*	4.1%*
	10-year	CRC-PRO	<0.1%*	1.0%*	2.0%*	1.0%*	2.0%*	4.0%*	2.0%†	4.0%*	10.0%*
		QCancer	0.5%*	0.6%*	1.7%*	1.6%*	1.9%*	3.2%*	3.3%†	4.0%	9.4%
	Lifetime	NCI	2.9%†	4.4%*	11.9%*	2.4%†	3.3%†	9.5%*	1.6%†	2.6%†	7.4%†
		CC	5.0%†	5.0%*	10%-15%*	5.0%†	5.0%†	10%-15%*	5.0%†	5.0%†	10%-15%†
		MyCancerIQ‡	<7.0%	>7.0%	>7.0%	<7.0%	>7.0%	>7.0%	<7.0%	>7.0%	>7.0%
White female											
	5-year	NCI	0.1%*	0.2%*	0.7%*	0.2%*	0.3%*	1.0%*	0.6%*	1.2%*	2.4%*
		QCancer	0.2%*	0.2%*	0.5%*	0.5%*	0.6%*	1.0%*	1.1%*	1.1%*	2.1%*
	10-year	CRC-PRO	<1.0%*	<1.0%*	1.0%*	1.0%*	1.0%*	3.0%*	2.0%*	2.0%*	6.0%†
		QCancer	0.5%*	0.5%*	1.2%*	1.2%*	1.3%*	2.3%*	2.5%*	2.6%*	4.8%†
	Lifetime	NCI	1.6%†	3.2%†	8.1%†	1.4%†	2.3%†	6.9%†	1.5%†	3.1%†	6.3%†
		CC	5.0%†	5.0%†	10%-15%†	5.0%†	5.0%†	10%-15%†	5.0%†	5.0%†	10%-15%†
		MyCancerIQ‡	<6.0%	>6.0%	>6.0%	<6.0%	>6.0%	>6.0%	<6.0%	>6.0%	>6.0%
Black male											
	5-year	NCI	0.3%*	0.4%*	1.0%*	0.6%*	0.8%*	2.3%*	0.7%*	1.1%*	3.1%*
		QCancer	0.2%*	0.3%*	0.7%*	0.5%*	0.6%*	1.0%*	1.4%*	1.7%*	4.1%*
	10-year	CRC-PRO	<0.1%*	1.0%*	2.0%*	1.0%*	2.0%*	5.0%†	2.0%†	4.0%*	10.0%*
		QCancer	0.5%*	0.6%*	1.7%*	1.2%*	1.4%*	2.4%†	3.3%†	4.0%*	9.4%*
	Lifetime	NCI	2.9%†	4.4%*	11.9%*	2.7%†	5.0%*	10.6%*	1.6%†	2.6%†	7.4%†
		CC	5.0%†	5.0%*	10%-15%*	5.0%†	5.0%*	10%-15%*	5.0%†	5.0%†	10%-15%†
Black female											
	5-year	NCI	0.1%*	0.2%*	0.7%*	0.3%*	0.4%*	1.4%*	0.6%*	1.2%*	2.4%*
		QCancer	0.2%*	0.2%*	0.5%*	0.4%*	0.4%*	0.7%*	1.1%*	1.1%*	2.1%*
	10-year	CRC-PRO	<1.0%*	<1.0%*	1.0%*	1.0%*	2.0%†	4.0%†	2.0%*	2.0%*	6.0%†
		QCancer	0.5%*	0.5%*	1.2%*	0.9%*	0.9%†	1.6%†	2.5%*	2.6%*	4.8%†
	Lifetime	NCI	1.6%†	3.2%†	8.1%†	1.5%†	2.6%†	7.7%†	1.5%†	3.1%†	6.3%†
		CC	5.0%†	5.0%†	10%-15%†	5.0%†	5.0%†	10%-15%†	5.0%†	5.0%†	10%-15%†

CC = Cleveland Clinic's Colon Cancer Risk Assessment; CRC-PRO = Colorectal Cancer Predicted Risk Online (CRC-PRO); NCI = National Cancer Institute's Colorectal Cancer Risk Assessment Tool.

*Indicates risk estimates that are consistent between models within a given scenario.

†Indicates risk estimates that are inconsistent between models in a given scenario.

‡My CancerIQ outputs were not used to determine estimates as consistent vs inconsistent for lifetime scenarios.

frames for risk estimation. When comparing risk estimates for scenarios within a specific time frame, we found greater inconsistencies in risk estimates for longer time frames compared with shorter time frames (ie, lifetime vs 5- or 10-year) and no differences in risk estimates based on age, race, or sex for 5-year time frames.

Based on our findings, when considering which colorectal cancer risk calculator to use in the clinical setting to guide screening decision-making, several points are worth consideration. First, the methodology with which a risk assessment tool was developed is important. Of the 5 colorectal cancer risk prediction models that we included, the methodologic data for development and validation were available for NCI, QCancer, and CRC-PRO. These have all been externally validated and were found to have poor calibration, with overestimation of risk and only modest discrimination when tested on the UK Biobank.[10] However, when using a large, US cohort for validation of the NCI tool[14] and a large, separate UK cohort for validation of QCancer,[11] both in populations for which they were intended, these models were well calibrated, and QCancer had good-to-excellent discrimination. In addition to the methodological rigor with which it was developed for predicting *future risk of* colorectal cancer, the NCI risk assessment tool provides an estimate for *current risk of* advanced neoplasia, which could also be used to guide screening decisions.[12,13]

Second, a colorectal cancer risk calculator should include variables that are applicable to the population of interest. For example, My CancerIQ is based on colorectal cancer risk among Canadian White men and women and does not have the option to vary race; therefore, this model may not generalize to, and should not be used for, non-White individuals. Similarly, QCancer was developed and validated in United Kingdom cohorts, therefore, it is unclear whether it can accurately predict risk for individuals outside of the United Kingdom. Furthermore, although QCancer and My CancerIQ include inflammatory bowel disease as a variable for colorectal cancer risk calculation, the risk assessment tools included in this study should be used to guide screening decision-making for patients without well-established risk factors such as inflammatory bowel disease or hereditary colorectal cancer syndromes.

Third, the desired time frame for estimating risk may also guide which risk calculator to use. We found that 5-year estimates were consistent for 50-, 62-, and 75-year-old individuals, regardless of race or sex. Ten-year estimates were also consistent for a 50-year-old individual. For 62- and 75-year-old individuals in our scenarios, inconsistencies started to emerge, although the clinical relevance of most of them is unclear as they were based on absolute differences of 1.3% or less between risk estimates. The low risk estimates (due to the short time frame of 5 and 10 years as compared with lifetime) may be of uncertain value to most healthy patients in their 50s or 60s, and their providers, when making decisions about screening. On the other hand, for a 75-year-old individual, thinking about a 5- to 10-year risk may be more meaningful. If the metric of interest is 5-year colorectal cancer risk, then either the NCI or QCancer risk assessment tools could be applied given their consistent estimates, regardless of age, race, or sex. However, if the metric of interest is 10- or 15-year colorectal cancer risk, then CRC-PRO and QCancer may be the more apropos risk assessment tools.

With these considerations, we found that the NCI risk assessment tool is the most appropriate risk calculator for a US patient population. When using such a tool clinically, providers should be aware that incorporating risk estimation into screening decision-making has the potential to improve screening uptake among those who are estimated as high-risk for colorectal cancer, but could dissuade individuals of lower estimated risk from screening, as shown in prior studies.[9,15] Thus, rather than using risk estimation to decide whether or not to screen an individual, a more optimal approach is to apply risk estimation to determine which test to use for screening (eg, stool-based test vs colonoscopy).

This study has limitations. First, the included models were identified using a Google search; therefore, it is possible that we did not include all currently publicly available risk models that would result from a systematic review of the literature. However, the intent of this study was to simulate a real-world setting where patients or providers could search for easily accessible risk assessment calculators rather than models available through an extensive literature search that may not be user friendly in a clinical setting. Second, the number of models that could be compared in a given time frame was limited due to the variation in model-specific time frames. Study strengths include the use of risk-based patient scenarios, comparison of risk estimates by 2 reviewers independently, and simulation of a real-world setting where a provider may search for, and access, readily available risk assessment tools.

In conclusion, publicly available, easy-to-access, colorectal cancer risk assessment tools are more consistent in risk estimation for 5 and 10 years, but have greater variation in predicted lifetime risk, regardless of sex and race. The underlying methodology used to develop the risk model, patient population characteristics, and risk estimate time frames of interest should be used to determine which risk calculator to apply in a particular clinical setting. For a US patient population, the NCI Colorectal Cancer Risk Assessment Tool could be integrated into clinical practice given the rigor with which it was developed, the included variables, and the range of time frames for which it provides risk estimates. A personalized approach to screening has the potential to optimize resource use and minimize exposure to unnecessary harms.

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SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjmed.2022.08.008.

APPENDIX A. ADDITIONAL DETAILS FOR VARIABLE INPUTS FOR EACH MODEL*

Model	Variable	Risk Scenario		
		Low-Risk	Average-Risk	High-Risk
NCI				
	Body mass index	20	24	35
	Servings vegetables/week in past month	More than 10	5-6	5-6
	If yes, cups/serving?	0.5-1.5	0.5-1.5	0.5 or less
	In past year, how many months of moderate physical activity?	12	12	0
	During those months, on average, how many hours/week?	More than 4	2-4	n/a
	In the past year, how many months of any vigorous activity?	12	12	0
	During those months, on average, how many hours/week?	More than 4	2-4	n/a
	During the past 10 y, have a colonoscopy/sigmoidoscopy, or both?	No	No	No
	If yes, did provider tell patient that he/she had colon or rectal polyp?	n/a	n/a	n/a
	During the past 30 d, medications containing aspirin at least 3 times a week?	Yes	No	No
	During the past 30 d, medications containing NSAIDs at least 3 times a week?	No	No	No
	For women, pre- or postmenopausal?	Post	Post	Post
	If post, how long ago were periods?	No periods within 1 year for age 50 y; >2 years for 62 and 75 y		
	If last period 2 or more years ago, did patient take any hormone replacement?	No	No	No
	Any immediate relatives with colon or rectal cancer?	No	No	Yes
	How many of these relatives had colon or rectal cancer?	n/a	n/a	1
	For men, smoked 100 or more cigarettes in his lifetime?	No	No	Yes (current; started at 20 y of age; 1-10/d)
CC				
	Body mass index	20	24	35
	Servings of fruits, grains, vegetables per day?	3-5	1	1
	Currently smoke?	No	No	Yes (1 pack/d for >10 y)
	If no, then past smoker?	No	No	n/a
	How many days/week do you engage in sustained physical exercise?	7 (60 min/d)	3 (45 min/d)	0
	Have you ever had colorectal cancer screening?	No	No	No
	Have you ever been diagnosed with colorectal cancer?	No	No	No
	Have you ever been diagnosed with colorectal precancerous polyps?	No	No	No
	Any family members (parents, grandparents, siblings, children, grandchildren, aunts, uncles, nieces, nephews, half siblings) been diagnosed with colorectal cancer or polyps?	No	No	Yes (mother at age 60 y who had polyps)
QCancer				
	Smoking status	Non-smoker	Non-smoker	Heavy smoker
	Alcohol status	0	1-2 units/d	1-2 units/d
	Family history of gastrointestinal cancer?	No	No	Yes
	For women, cancers of any of the following: breast, uterine, ovarian, cervical?	No	No	No
	For men, any of the following: oral cancer, lung cancer, or cancers of the blood?	No	No	No
	Do you currently have diabetes?	No	No	No
	Do you currently have ulcerative colitis?	No	No	No
	Do you currently have colon polyps?	No	No	No
CRC-PRO				
	Body mass index	20	24	35
	Pack years of smoking	0	0	30

(*Continued*)

Model	Variable	Risk Scenario		
		Low-Risk	Average-Risk	High-Risk
	Average number of alcoholic drinks per day	0	1	2
	Years of education	16	16	16
	Family history of colon cancer	No	No	Yes
	Regular use of aspirin	Yes	No	No
	Regular use of multivitamins	Yes	No	No
	History of diabetes	No	No	No
	Have you used estrogens?	No	No	No
	Hours of moderate physical activity/day	1	0.5	0
	Ounces of red meat intake per day (ounces/day)	0	2	4
My CancerIQ				
	Body mass index	20	24	35
	Have you ever been diagnosed with cancer (except non-melanoma skin cancer)?	No	No	No
	Has your biological parent, brother, sister, or child ever had colorectal cancer?	No	No	Yes
	How many years have you been on birth control pills?	0	0	0
	How many years in total have you taken hormone replacement therapy?	0	0	0
	Have you taken acetylsalicylic acid or aspirin every day for 15 years or more?	Yes	No	No
	Have you had inflammatory bowel disease for 10 years of more?	No	No	No
	Do you eat 3 or more servings of red or processed meat each week?	No	Yes	Yes
	On average, how many alcoholic drinks per week?	I don't drink	1-6	7-13
	How many servings of milk, milk products, or calcium-fortified alternatives on most days each week?	3 or more	1-2	<1
	If <1 or 1-2, then do you take a calcium supplement on most days of the week?	n/a	No	No
	Do you take a multivitamin on most days of the week?	Yes	No	No
	If no, do you take vitamin D (or calcium + vitamin D) most days of the week?	n/a	No	No
	On average, do you eat 3 or more servings of whole grains each day?	Yes	No	No
	Do you usually eat 5 or more servings of vegetables and fruit each day?	Yes	No	No
	Are you moderately active for at least 30 min/d, or at least 3 h/wk?	Yes	Yes	No
	Do you smoke cigarettes?	No	No	Yes
	Have you had either a fecal immunochemical test or fecal occult blood test in the past 2 y?	No	No	No
	Have you had a colonoscopy within the last 10 y?	No	No	No
	Within the last 10 y, have you had a flexible sigmoidoscopy?	No	No	No

CC = Cleveland Clinic's Colon Cancer Risk Assessment; CRC-PRO = Colorectal Cancer Predicted Risk Online calculator; NCI = National Cancer Institute's Colorectal Cancer Risk Assessment Tool; NSAID = nonsteroidal anti-inflammatory drug.

*Age, sex, race, and body mass index were included in each model and varied for each scenario as described in Methods.

APPENDIX B. RESULTS DETAILED BY AGE

For a 50-year-old individual, all 5-year and 10-year scenarios were consistent, regardless of race, sex, or risk scenario. However, for a 50-year-old low-risk individual, all lifetime scenarios were inconsistent. The National Cancer Institute's Colorectal Cancer Risk Assessment Tool (NCI) estimated colorectal risk as 1.6%-2.9% and Cleveland Clinic's Colon Cancer Risk Assessment (CC) estimated colorectal cancer risk as 5% for a low-risk 50-year-old individual, regardless of race or sex; therefore, these were rated as inconsistent. For 50-year-old average-risk White and Black women scenarios, lifetime colorectal cancer risk estimates were inconsistent between NCI and CC, which predicted risk as 3.2% and 5%, respectively. For a 50-year-old high-risk individual, lifetime colorectal cancer risk estimates were inconsistent for White and Black women, with NCI estimating risk as 8.1% and CC 10%-15%.

For a 62-year-old individual, all 5-year estimates were consistent, regardless of sex, race, or risk scenario. However, for a 62-year-old individual, 10-year scenarios were inconsistent for an average-risk Black woman (Colorectal Cancer Predicted Risk Online calculator [CRC-PRO] 2% vs QCancer calculator 0.9%). Ten-year scenarios were also inconsistent for a high-risk Black man (CRC-PRO 5% vs QCancer 2.4%) and high-risk Black woman (CRC-PRO 4% vs QCancer 1.6%). For a 62-year-old low-risk individual, all lifetime scenarios were inconsistent regardless of sex or race, with the NCI risk calculator estimating colorectal cancer risk <3%, as compared with CC, which estimated risk as 5%. For a 62-year-old average-risk individual, lifetime scenarios were inconsistent for a White man (NCI 3.3% vs CC 5%), White woman (NCI 2.3% vs CC 5%), and Black woman (NCI 2.6% vs CC 5%). For a 62-year-old high-risk individual, lifetime scenarios were inconsistent for a White woman (NCI 6.9% vs CC 10%-15%) and for a high-risk Black woman (NCI 7.7% vs CC 10%-15%).

For a 75-year-old low-risk individual, none of the 5-year risk estimates were inconsistent. Two of the 4 75-year-old low-risk 10-year risk estimates were inconsistent. For White and Black men, CRC-PRO predicted colorectal cancer risk as 2%, vs QCancer, which predicted 3.3%. For a 75-year-old low-risk individual, all lifetime scenarios were inconsistent because the NCI risk calculator predicted lifetime colorectal cancer 1.5%-1.6%, whereas CC predicted 5%. For a 75-year-old average-risk individual, all lifetime scenarios were inconsistent, including for a White man (NCI 2.6% vs CC 5%), White woman (NCI 3.1% vs CC 5%), Black man (NCI 2.6% vs CC 5%), and Black woman (NCI 3.1% vs CC 5%). For a 75-year-old high-risk White woman, 10-year risk estimates were inconsistent (CRC-PRO 6% vs QCancer 4.8%). Finally, for a 75-year-old high-risk individual, all lifetime scenarios were inconsistent, regardless of race or sex. For example, for a White man, NCI predicted colorectal cancer risk as 7.4% vs CC 10%-15%. Similarly, for a White woman, NCI predicted 6.3% vs CC 10%-15%; for a Black man, NCI predicted 7.4% vs CC 10%-15%; and for a Black woman, NCI predicted 6.3% vs CC 10%-15%.