Original Article

# Colorectal Cancer Screening: Estimated Future Colonoscopy Need and Current Volume and Capacity

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**BACKGROUND:** In 2014, a national campaign was launched to increase colorectal cancer (CRC) screening rates in the United States to 80% by 2018; it is unknown whether there is sufficient colonoscopy capacity to reach this goal. This study estimated the number of colonoscopies needed to screen 80% of the eligible population with fecal immunochemical testing (FIT) or colonoscopy and determined whether there was sufficient colonoscopy capacity to meet the need. **METHODS:** The Microsimulation Screening Analysis–Colon model was used to simulate CRC screening test use in the United States (2014-2040); the implementation of a national screening program in 2014 with FIT or colonoscopy with 80% participation was assumed. The 2012 Survey of Endoscopic Capacity (SECAP) estimated the number of colonoscopies that were performed and the number that could be performed. **RESULTS:** If a national screening program started in 2014, by 2024, approximately 47 million FIT procedures and 5.1 million colonoscopies would be needed annually to screen the eligible population with a program using FIT as the primary screening test; approximately 11 to 13 million colonoscopies would be needed annually to screen the eligible population with a colonoscopy-only screening program. According to the SECAP survey, an estimated 15 million colonoscopies were performed in 2012, and an additional 10.5 million colonoscopies could be performed. **CONCLUSIONS:** The estimated colonoscopy capacity is sufficient to screen 80% of the eligible US population with FIT, colonoscopy, or a mix of tests. Future analyses should take into account the geographic distribution of colonoscopy capacity. ***Cancer* 2016;000:000–000**. © *2016 American Cancer Society.*

**KEYWORDS:** capacity, colonoscopy, colorectal cancer screening.

## INTRODUCTION

Colorectal cancer (CRC) is the second leading cause of cancer death among cancers that affect both men and women.[1] Although screening for CRC has been shown to effectively reduce the incidence of and mortality from the disease, only 58% of adults aged 50-75 years were up-to-date with CRC screening in 2013.[2,3] A recent initiative from the National Colorectal Cancer Roundtable, a coalition of public, private, and voluntary organizations, aims to increase CRC screening prevalence to 80% in the eligible population by 2018. Recent analyses estimated that reaching this goal would avert 280,000 new cases of CRC and 200,000 deaths from CRC by 2030 and that 24.4 million people would need to be screened.[4,5] No studies have estimated the number of CRC screening tests that would need to be performed each year if 80% prevalence were achieved or determined whether the current colonoscopy capacity could meet the increased demand. Over the past decade, colonoscopy use has increased rapidly, and colonoscopy has become the most commonly used test to screen for CRC, whereas the relative use of fecal occult blood testing (FOBT) has declined.

We used microsimulation modeling to estimate the expected number of colonoscopies needed to screen 80% of the eligible population with either fecal immunochemical testing (FIT) or colonoscopy over 10 years. We also conducted the national Survey of Endoscopic Capacity (SECAP) to estimate the number of colonoscopies performed in a year in the United States and the number of additional colonoscopies that could be performed (capacity). Resources (or capacity) are

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defined as nonmonetary resources, such as the number of staff, facility space, equipment, and time needed to perform colonoscopies, and do not include the actual costs of the procedures paid for by individuals or insurers.

## MATERIALS AND METHODS

### *Estimation of Screening Test Need*

The Microsimulation Screening Analysis–Colon model was used to simulate CRC screening test use in the United States (from 2014 to 2040) under the assumption of the implementation of a nationwide screening program in 2014. The main outcome of the model was the number of colonoscopies required per year to screen 80% of the population. Screening was implemented over the course of 10 years with FIT or colonoscopy as the primary screening test.

The model has been used previously to inform US Preventive Services Task Force guideline recommendations and has been described in detail elsewhere.[6,7] In brief, the model simulates a large population of individuals from birth to death. CRC is assumed to arise in this population according to the adenoma-carcinoma sequence, in which every cancer is preceded by an adenoma.[8] The risk for developing 1 or more adenomas depends on age, sex, and baseline individual risk. Adenomas can progress from small (1-5 mm) to medium (6-9 mm) to large ($\geq$10 mm). Most adenomas are assumed to be nonprogressive and will never develop into cancer. The progressive adenomas have the ability to become malignant and transform into stage I cancers. These cancers may successively progress to stages II, III, and IV until they are diagnosed at one of these stages. After diagnosis, the individual may or may not die of CRC; this depends on stage-specific survival and competing causes of death. With screening, underlying lesions (adenomas and preclinical cancers) may be detected; this depends on the sensitivity of the test for that lesion and, for endoscopic tests, on whether the lesion is within reach of the endoscope.

The current and future age distribution and size of the population were based on the 2008 population estimates of the US Census Bureau.[9] The simulated population size was equal to one-tenth of the actual US population size. This size was chosen to limit computation time and also avoid significant random outcome variation. The lifetime risk of CRC in the unscreened population was estimated to be approximately 6.5%. The natural history of the adenoma-carcinoma sequence was calibrated to adenoma prevalence data[10-14] and CRC incidence data from the Surveillance, Epidemiology, and End Results (SEER) program from 1975 to 1979 when incidence rates and adenoma prevalence had not yet been affected by screening.[15] To align the modeled CRC incidence in 2012 (based on observed screening patterns from 1978 forward) with 2012 SEER estimates, the adenoma onset rate was increased by 10% in isolation from other natural history parameters. Stage-specific CRC survival was based on 2000-2010 SEER data. Mortality rates from other causes were imputed from US life tables.[16] The inputs for the sensitivity and specificity of CRC screening tests were based on previous reviews of the literature and have been published previously.[6]

### Simulated scenarios

Age-specific use rates of colonoscopy, flexible sigmoidoscopy (FSIG), and guaiac fecal occult blood testing (gFOBT) until the start of a hypothetical national screening program in 2014 were based on National Health Interview Survey (NHIS) data from 1987 through 2010.[3] On the basis of these data, it was estimated that in 2013, 67% of US adults who were 50 years old or older had ever been screened with any test, 8.8% had undergone home FOBT within the last year, 4% had undergone sigmoidoscopy within the last 5 years, and 55% had undergone colonoscopy within the past 10 years. We assumed that there were no further increases in overall screening uptake in the period from the last NHIS to the start of the hypothetical screening program.

The model enrolled all US adults aged 50 to 75 years into a national screening program over 10 years; it started with the first cohort in 2014, which consisted of one-tenth of the age-eligible population. The model assumed that the remaining eligible population would continue to be screened at a projected estimate based on 2010 NHIS data until enrollment into the hypothetical national program. People were not invited for screening in the program until 1 year after their last FOBT, 5 years after their most recent sigmoidoscopy, or 10 years after their most recent colonoscopy. In the first scenario, we evaluated a program of annual FIT in which 80% of eligible adults participated; in the second scenario, we evaluated a program colonoscopy every 10 years with 80% participation. People with positive FIT results were referred for follow-up colonoscopy, and people with an adenoma detected were followed with colonoscopy surveillance, with the interval (3-5 years) dependent on the number and size of the adenomas detected on the most recent colonoscopy.[17,18]

### Sensitivity analysis

In a sensitivity analysis, we evaluated various alternative modeling scenarios to inform readers about the implications of other possible screening tests and adherence rates. Alternative modeling scenarios included alternative primary screening tests such as annual gFOBT, computed tomographic colonography (CTC) every 10 years, and FSIG every 5 years; higher assumed participation rates (100%) for FIT and colonoscopy screening; and a scenario of currently observed test-use patterns in NHIS (with both underuse and overuse), with an assumed linear increase in overall screening participation rates from 58% in 2013 to 80% by 2018. Test performance characteristics used in the primary and sensitivity analyses are provided in Supporting Table 1.

### *Estimation of Endoscopic Capacity*

SECAP II was conducted in 2012. The survey methodology was unchanged from that of the original SECAP study; a detailed description of the survey methodology has been published previously.[19] In brief, a list of all US medical facilities known to have purchased or leased lower endoscopic equipment between January 1, 2006 and December 31, 2010 was obtained from 3 major endoscopic equipment manufacturers: Olympus America, Inc, Fujinon, Inc, and Pentax Precision Instrument Corporation. The lists were merged, and duplicates were removed to create a sampling frame. A random sample of 2100 facilities (31% of all facilities), stratified by region and location (urban or rural), was selected to participate in the survey. A telephone screening questionnaire was administered to confirm study eligibility and to identify the person in charge of endoscopy. Of the 2100 facilities, 258 (12%) were found to be ineligible (they did not currently perform screening sigmoidoscopy or colonoscopy on adults or could not be located). A self-administered questionnaire, a personalized cover letter, a postage-paid return envelope, and a $40.00 incentive were sent by Federal Express to a person identified by each eligible facility. Respondents were asked to provide an estimate of the total number of sigmoidoscopies and colonoscopies performed by all endoscopists at the practice site per week, the percentage of procedures performed by endoscopist specialty, and the additional number of sigmoidoscopies and colonoscopies that could be performed with no other investment of resources.

Of the 1842 eligible facilities, 1269 returned valid surveys (overall response rate, 68.9%). To provide national capacity estimates, the universe of facilities was adjusted according to the ineligibility rate, and survey data were weighted to adjust for the sampling weight and nonresponse. Annual estimates of capacity were obtained by multiplication of the weighted weekly estimates of the current and potential capacity by the number of work weeks per year (50 weeks). Survey data were analyzed with Stata 12.1.

For the estimation of endoscopic capacity, 2 questions were critical to the analysis: 1) the number of procedures currently performed and 2) the additional number of procedures that could be performed. If answers to both of these questions were missing, the survey was excluded from the analysis. If the survey was missing data for 1 of the 2 key question, then these values were imputed with a variation of the hot-deck method, as described previously.[19]

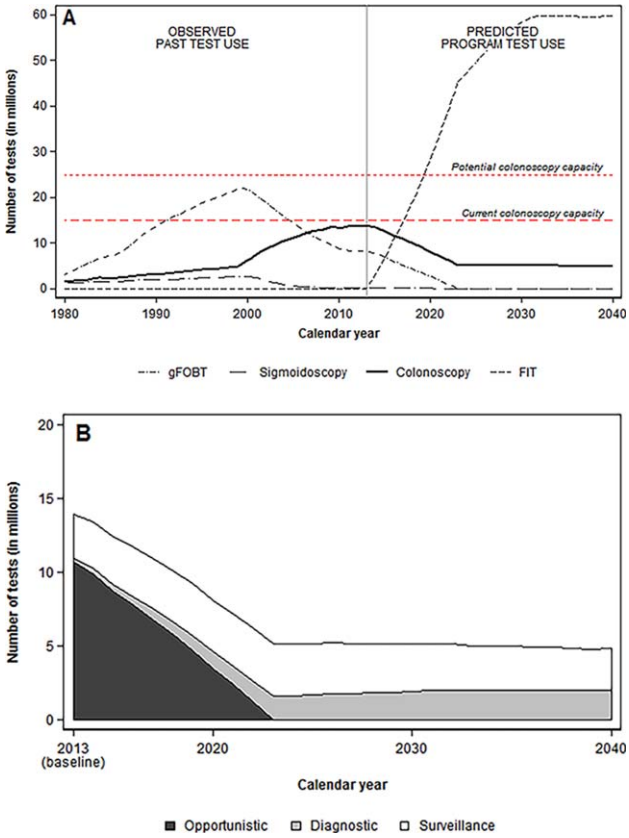


**Figure 1.** (A) Number of colorectal cancer tests per year before and after the start of a hypothetical national screening program with FIT in 2014 by test type. (B) Number of colonoscopies per year before and after the start of a hypothetical national screening program with FIT by colonoscopy indication. FIT indicates fecal immunochemical testing; gFOBT, guaiac fecal occult blood testing.

## RESULTS

### *Simulation Results*

According to recent CRC screening patterns, an estimated 8.4 million FOBT procedures and 14 million

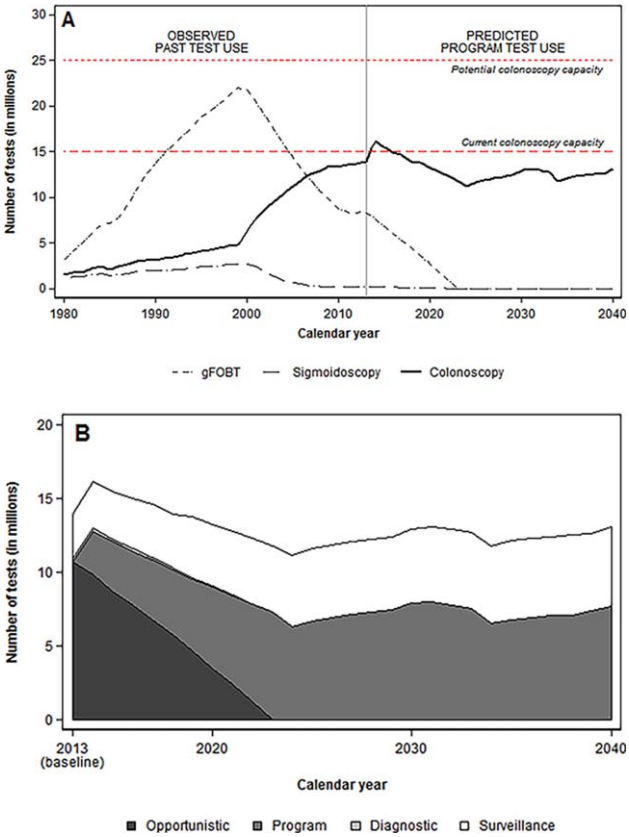


**Figure 2.** (A) Number of colorectal cancer tests per year before and after the start of a hypothetical national screening program with colonoscopy by test type. (B) Number of colonoscopies per year before and after the start of a hypothetical national screening program with colonoscopy by colonoscopy indication. gFOBT indicates guaiac fecal occult blood testing.

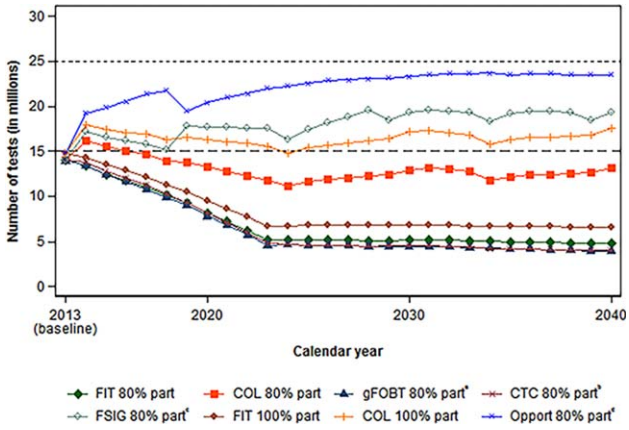


**Figure 3.** Predicted colonoscopy use under various modeling scenarios (in millions). [a]Annual testing with Hemoccult II. [b]Testing with CTC every 10 years. [c]Testing with FSIG every 5 years. The numbers represent sigmoidoscopy and colonoscopy use. [d]In the scenario with opportunistic screening, we assumed that future screening patterns according to age and test type would be similar to those shown by the 2013 National Health Interview Survey data. The screen rate was increased linearly from approximately 60% to 80% from 2013 to late 2018. COL indicates colonoscopy; CTC, computed tomographic colonography; FIT, fecal immunochemical testing; FSIG, flexible sigmoidoscopy; gFOBT, guaiac fecal occult blood testing; Opport, opportunistic; part, participation.

colonoscopies were performed in 2013. Approximately 3.3 million of these colonoscopies were estimated to have been performed for diagnostic and surveillance purposes (Fig. 1A).

### FIT scenario

Under the assumption of the introduction of a FIT screening program in 2014, a total of 3.3 million FIT procedures would need to be performed to screen 80% of eligible adults, aged 50 to 75 years, invited to the first round of screening (one-tenth of the eligible population). The total number of colonoscopies needed in 2014 would be 13.4 million: 3.5 million for diagnostic or surveillance purposes and 9.9 million for screening performed outside the program (Fig. 1B). By 2024, approximately 47 million FIT procedures and 5.1 million diagnostic (32%) and surveillance colonoscopies (68%) would have to be performed. The number of FIT procedures would gradually increase to approximately 60 million tests annually by 2030, but the number of colonoscopies would remain steady.

### Colonoscopy scenario

The introduction of a colonoscopy screening program in 2014 would require 12.8 million screening colonoscopies and 3.4 million diagnostic and surveillance colonoscopies (Fig. 2A,B). By 2024, 11 to 13 million colonoscopies would have to be performed annually, with approximately 57% being performed for screening and approximately 43% being performed for surveillance, and the number would remain level through 2030.

### Sensitivity analysis

Estimated colonoscopy requirements, assuming participation by 80% of all eligible adults, were similar for annual FIT, annual gFOBT, and CTC testing every 10 years (Fig. 3). FSIG every 5 years would require 16.3 million sigmoidoscopies and colonoscopies in 2014 and 18 to 19 million sigmoidoscopies and colonoscopies annually by 2030. The continuation of currently observed test-use patterns with 80% participation would require 23 million colonoscopies annually by 2030.

The required colonoscopy capacity with either FIT or colonoscopy screening with 100% participation was

**TABLE 1.** Current and Potential Number of Colonoscopies: 2012 Survey of Endoscopic Capacity II

| | Total (SE) |
|---|---|
| No. of facilities[a] | 5858 (202.6) |
| No. of current weekly colonoscopies (mean) | 51.1 (2.5) |
| Colonoscopies performed for screening, % | 43.2 (0.6) |
| No. of potential maximum weekly colonoscopies (mean) | 87.0 (5.4) |
| Current annual volume (in millions)[b] | 15.0 (1.2) |
| Potential annual volume (in millions)[b] | 25.5 (2.4) |
| Available annual capacity (in millions)[b] | 10.5 (2.6) |

Abbreviation: SE, standard error.
[a] Facilities included hospitals, ambulatory surgery centers, and physician offices where colonoscopies were performed for the purpose of colorectal cancer screening of adults.
[b] Assuming 50 work weeks per year.

approximately one-third higher than the capacity needed for the base case of 80% assumed participation. The 100% FIT scenario would require 14.3 million colonoscopies in 2014 and would require 68 million FIT procedures and 6.9 million colonoscopies annually by 2030. The 100% colonoscopy scenario would require 14.1 million colonoscopies in 2014 and 17 million colonoscopies annually by 2030.

### *Survey*

Of the 1269 facilities included in the final analysis, 767 (60.4%) were hospital departments, 403 (31.8%) were ambulatory endoscopy or surgery centers, 98 (7.7%) were physician practices, and 1 was unknown (data not shown). The majority of survey respondents identified themselves as nurse administrators/managers (60.2%). The majority of sites were classified as urban (68.2%). After weighting, there were an estimated 5988 facilities (95% confidence interval, 5832-6144) in the United States that performed any lower endoscopy in 2012. Of these facilities, 5858 (97.8%) reported performing colonoscopy, and 1831 (30.6%) reported performing sigmoidoscopy.

Survey respondents estimated that 51.1 colonoscopies (95% confidence interval, 46.1-56.1) were performed per week (Table 1). Respondents estimated that 43.2% of colonoscopies were performed for screening. The total mean potential maximum number of colonoscopies that could be performed per week was 87.

Survey responses were weighted to determine national estimates for the current and potential capacity to provide colonoscopies in the United States. In 2012, approximately 15 million total colonoscopies were performed (Table 1). Respondents reported they could increase their colonoscopy volume to 25.5 million annually for an available capacity of 10.5 million colonoscopies annually.

## DISCUSSION

This report estimates the number of colonoscopies that would be needed to screen 80% of the eligible population and compares this need to estimates of colonoscopy capacity. The Microsimulation Screening Analysis microsimulation model estimated that 13.4 million colonoscopies would be needed in the first year of a population CRC screening program with FIT, and this would gradually decline to 5.2 million colonoscopies with full implementation of the program after 10 years. A colonoscopy program implemented over 10 years would require 16.2 million colonoscopies in the first year and 12 to 13 million colonoscopies annually with full implementation. According to the survey, in 2012, 15 million colonoscopies were performed, and respondents estimated that 42.3% of these colonoscopies (6.3 million) were performed for screening. Respondents indicated that an additional 10.5 million colonoscopies could be performed per year, and this suggests that the increased demand for screening colonoscopy could be absorbed. The FIT screening program would require no screening colonoscopies, and the demand for diagnostic and surveillance colonoscopies could presumably be met by shifting currently available resources. The colonoscopy screening program would require approximately 7 million screening colonoscopies and 5 million surveillance colonoscopies annually. Under the assumption of no change in the available capacity, the increased demand for screening and surveillance colonoscopies could be matched by the currently available colonoscopy capacity as reported. Because a colonoscopy screening program is, for a given participation level, the strategy with the highest colonoscopy demand, there would also be sufficient capacity to meet colonoscopy demand for most of the scenarios modeled in the sensitivity analysis (FIT only or colonoscopy only with 100% participation and annual gFOBT, CTC every 10 years, or FSIG every 5 years with 80% participation). If recently observed CRC test-use patterns continued with 80% participation, the estimated capacity could meet the need for colonoscopy within the estimated standard error (22-24 million needed annually vs an estimated annual capacity of 23.1-27.9).

The percentage of the adult population that is up-to-date with CRC screening has steadily increased over the past decade, primarily through increased use of colonoscopy.[20-22] Our data do not show a concomitant increase in the number of colonoscopies performed

annually. Although the SECAP survey is cross-sectional and may not have captured a true rise in the number of colonoscopies performed, at least 1 other study found that the use of screening colonoscopy increased before the recent economic recession and then subsequently declined.[23] After rapid growth from 2000 to 2006, a decline in the number of colonoscopies performed per Medicare beneficiary has also been noted.[24]

The Microsimulation Screening Analysis microsimulation model estimated that approximately 13.7 million colonoscopies were performed in 2012 for screening and follow-up; an analysis of the 2012 Behavioral Risk Factor Surveillance System[25] and the 2010 NHIS[3] estimated that 14.9 million people and 11.4 million people, respectively, had undergone colonoscopy within the past year. The 2012 SECAP estimate of 15 million colonoscopies performed closely matches these estimates. Notably, the number of adults who were 50 years old or older and reported sigmoidoscopy or colonoscopy within the previous year remained largely unchanged from the 2003 NHIS (11.3 million) to the 2010 NHIS (11.8 million) despite a substantial increase in the proportion of adults in this age group who reported being up-to-date with CRC screening by colonoscopy within 10 years.[3]

In the base case analysis, it was estimated that a national CRC screening program with either FIT or colonoscopy, with 80% participation of the eligible population, would need 5 to 16 million colonoscopies annually. These model projections included only colonoscopies performed for screening, diagnostic, or surveillance purposes and assumed no underuse or overuse of screening and, therefore, may have underestimated actual test needs in these scenarios. The 2012 SECAP survey estimated that 43.2% of colonoscopies were performed for screening purposes, and this was consistent with previous estimates of 38% to 49.7%.[23,26] Surveillance colonoscopies have accounted for up to one-quarter of colonoscopies performed, and this suggests that a substantial proportion of colonoscopies are performed for reasons other than screening or surveillance (ie, diagnosis).[26,27] Several studies of the Medicare population have found overuse and underuse of both screening and surveillance colonoscopies.[28-34] In our sensitivity analysis, the continuation of current CRC test-use patterns, reflecting current patterns of underuse and overuse, required substantially more colonoscopies than even the colonoscopy-only scenario. The modeled colonoscopy need may also have been overestimated because we assumed 80% adherence to screening and surveillance. Despite concerted efforts to increase CRC screening rates in the population, rates remain well below 80% because of a variety of patient-, provider-, and system-level factors.[21,22,35] Among those who are screened for CRC with FIT or other tests that require follow-up with colonoscopy, adherence to follow-up is well below 100%.[36,37]

Full implementation of a national CRC screening program with FIT would require approximately 5 million diagnostic and surveillance colonoscopies annually. Although the number of colonoscopies required is practically achievable, a national FIT program would also require nearly 60 million FIT procedures annually by 2040. FIT does not require many resources on the part of the patient (it can be done at home and does not require bowel preparation or dietary changes), but a complete FIT screening program can require substantial additional resources to ensure that test kits are distributed to the eligible population, to remind people to complete and return the kits, to ensure complete follow-up for those with positive results, to process all returned kits in the provider's office or in the laboratory, and to ensure that all eligible adults repeat the test annually.[38,39] It is unknown whether adequate resources exist to implement a FIT screening program on such a large scale. Our model estimates that a national colonoscopy screening program would require substantially more colonoscopies annually than a FIT program. It is unknown whether it is feasible to shift resources toward more screening and surveillance and whether sufficient capacity would remain to perform colonoscopies needed for other reasons.

This study is subject to some other limitations. First, our model estimates of future test need for a national CRC screening program were based on recent population projections, currently available screening methods, and current screening guidelines, which may not apply to the entire time horizon of the study. Second, we could not validate directly the number of colonoscopies that survey respondents indicated they were performing or could perform. Respondents were asked to estimate the number of additional colonoscopies that they could perform without additional resources, but it is unknown whether the estimates truly reflect what could be done without changes to current practice or reflect a shifting of resources away from other procedures. An analysis of additional SECAP questions indicated that there were limiting factors to increasing capacity, and if it were necessary, facilities would invest in additional resources (eg, physicians, nurses, and equipment) to increase their capacity (Supporting Tables 2 and 3). As described earlier, our estimate of the annual colonoscopy volume was consistent with estimates from other sources.[3,25] Third, the survey

sampling frame included facilities that purchased or leased equipment between 2006 and 2010. This excluded facilities that used equipment purchased or leased outside this time frame, and the number of colonoscopies currently performed and the available capacity may have been underestimated. Fourth, the study was not designed to model market forces as they relate to the supply of colonoscopy in response to increasing demand (eg, the market could respond by increasing the supply of endoscopists). Fifth, this study could not account for the geographic distribution of the CRC screening need or colonoscopy capacity. The survey was not designed to estimate colonoscopy capacity at the local level, and simulating future screening needs at this level would require an impractical number of models (to account for population size and past screening behavior for each geographical unit).

CRC screening is conducted with a variety of tests, most commonly colonoscopy and less frequently FOBT or FIT. Although it is unlikely that all eligible adults will be screened with a single test type, this analysis shows that the estimated colonoscopy capacity would be sufficient to screen them with a mix of tests. Future analyses should take into account the geographic distribution of the colonoscopy capacity and screening need to determine whether there is a surplus of capacity in some areas of the country along with an insufficient capacity in others.

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## CONFLICT OF INTEREST DISCLOSURES

Battelle had a contract with the Centers for Disease Control and Prevention for this study.

## AUTHOR CONTRIBUTIONS

**Djenaba A. Joseph:** Writing of original draft and investigation. **Reinier G. S. Meester:** Writing of the original draft, investigation, and data curation. **Ann G. Zauber:** Writing of the original draft and investigation. **Diane L. Manninen:** Writing of the original draft and investigation. **Linda Winges:** Writing of the original draft and investigation. **Fred B. Dong:** Data curation and review and editing. **Brandy Peaker:** Review and editing and investigation. **Marjolein van Ballegooijen:** Investigation, data curation, and review and editing.

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