Published in final edited form as:

Ann Intern Med. 2013 March 5; 158(5 0 1): 301–311. doi:10.7326/0003-4819-158-5-201303050-00002.

An Automated Intervention With Stepped Increases in Support to Increase Uptake of Colorectal Cancer Screening:

A Randomized Trial

Beverly B. Green, MD, MPH, Ching-Yun Wang, PhD, Melissa L. Anderson, MS, Jessica Chubak, PhD, MBHL, Richard T. Meenan, PhD, Sally W. Vernon, PhD, and Sharon Fuller, BA

Group Health Research Institute, Group Health Physicians, University of Washington School of Medicine, Fred Hutchinson Cancer Center, and University of Washington School of Public Health, Seattle, Washington; Center for Health Research, Kaiser Permanente Northwest, Portland, Oregon; and University of Texas School of Public Health, Houston, Texas

Abstract

Background—Screening decreases colorectal cancer (CRC) incidence and mortality, yet almost half of age-eligible patients are not screened at recommended intervals.

Objective—To determine whether interventions using electronic health records (EHRs), automated mailings, and stepped increases in support improve CRC screening adherence over 2 years.

Design—4-group, parallel-design, randomized, controlled comparative effectiveness trial with concealed allocation and blinded outcome assessments. (ClinicalTrials.gov: NCT00697047)

Setting—21 primary care medical centers.

Patients—4675 adults aged 50 to 73 years not current for CRC screening.

Intervention—Usual care, EHR-linked mailings (“automated”), automated plus telephone assistance (“assisted”), or automated and assisted plus nurse navigation to testing completion or refusal (“navigated”). Interventions were repeated in year 2.

Measurements—The proportion of participants current for screening in both years, defined as colonoscopy or sigmoidoscopy (year 1) or fecal occult blood testing (FOBT) in year 1 and FOBT, colonoscopy, or sigmoidoscopy (year 2).

Results—Compared with those in the usual care group, participants in the intervention groups were more likely to be current for CRC screening for both years with significant increases by intensity (usual care, 26.3% [95% CI, 23.4% to 29.2%]; automated, 50.8% [CI, 47.3% to 54.4%]; assisted, 57.5% [CI, 54.5% to 60.6%]; and navigated, 64.7% [CI, 62.5% to 67.0%]; $P < 0.001$ for all pair-wise comparisons). Increases in screening were primarily due to increased uptake of FOBT being completed in both years (usual care, 3.9% [CI, 2.8% to 5.1%]; automated, 27.5% [CI,

© 2013 American College of Physicians

Requests for Single Reprints: Beverly B. Green, MD, MPH, Group Health Research Institute, 1730 Minor Avenue, Suite 1600, Seattle, WA 98101-1466; green.b@ghc.org.

Potential Conflicts of Interest: Disclosures can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M12-2071.

Reproducible Research Statement: *Study protocol:* Available from reference 10 or from Dr. Green (green.b@ghc.org). *Statistical code:* Available from Ms. Anderson (anderson.melissa@ghc.org). *Data set:* Available from Dr. Green (green.b@ghc.org).

Current author addresses and author contributions are available at www.annals.org.

24.9% to 30.0%]; assisted, 30.5% [CI, 27.9% to 33.2%]; and navigated, 35.8% [CI, 33.1% to 38.6%]).

Limitation—Participants were required to provide verbal consent and were more likely to be white and to participate in other types of cancer screening, limiting generalizability.

Conclusion—Compared with usual care, a centralized, EHR-linked, mailed CRC screening program led to twice as many persons being current for screening over 2 years. Assisted and navigated interventions led to smaller but significant stepped increases compared with the automated intervention only. The rapid growth of EHRs provides opportunities for spreading this model broadly.

Primary Funding Source—National Cancer Institute, National Institutes of Health.

The lifetime risk for colorectal cancer (CRC) is more than 5% in the United States, where it remains the second-highest cause of death from cancer despite recent decreases in incidence and mortality (1). Better treatments have improved survival rates, but achieving higher uptake and adherence to CRC screening could more rapidly reduce morbidity and mortality (2). However, fewer than 60% of Americans aged 50 to 75 years report being current for screening, well below screening rates for breast cancer (72%) and cervical cancer (83%) (3).

The U.S. Preventive Services Task Force strongly recommends CRC screening (4, 5) and, on the basis of microsimulation models, found that similar reductions in morbidity and mortality could be achieved by annual high-sensitivity fecal occult blood testing (FOBT), flexible sigmoidoscopy every 5 years combined with an interval FOBT, or colonoscopy every 10 years, assuming optimal adherence to recommended intervals (6).

Systematic reviews of multiple effectiveness trials provide strong evidence that client reminders, 1-on-1 education, and reduction of structural barriers increase CRC screening rates (7-9). However, few trials have tested the incremental benefits of a stepped approach and none has tested whether these improve adherence to screening over time; this factor is particularly important for patients choosing FOBT, which must be done annually. The SOS (Systems of Support to Increase Colorectal Cancer Screening) trial tested whether a centralized CRC screening program that leveraged electronic health record (EHR) data and stepped-intensity interventions would lead to higher CRC screening uptake and adherence to CRC screening annually during the 2-year study.

Methods

The study design (10) and recruitment (11) details have been previously published. The Group Health Institutional Review Board, Seattle, Washington, approved all study procedures.

Setting and Participants

Participants aged 50 to 73 years were recruited between August 2008 and November 2009 from 21 primary care clinics of Group Health Cooperative, a large nonprofit health care delivery system in Washington (Figure 1). Patients were identified using EHRs and were eligible if they were not current for CRC screening, defined as not having undergone colonoscopy within 9 years, flexible sigmoidoscopy (sigmoidoscopy) within 4 years, or FOBT within 9 months. Exclusions were previous CRC diagnosis or active treatment of another cancer, inflammatory bowel disease, or serious chronic or life-threatening disease (for example, dementia and renal failure). The institutional review board required verbal but not written consent, so potential participants received a letter about the study and were

called to confirm eligibility and give verbal consent, followed by a mailed confirmation that included a telephone number to call to withdraw consent.

Randomization

A computer program developed by the study statistician generated random allocation sequences; participants were stratified by clinic, age group (aged 50 to 64 years and 65 to 73 years), and self-reported previous CRC testing. Seven days after consent, the study database automatically assigned patients in each stratum by using a permuted block design with a block size of 8, where each of the 4 randomization groups allocated 2 participants.

Interventions

Usual Care—Group Health Cooperative recommended FOBT yearly, sigmoidoscopy every 5 years with or without interval FOBT, or colonoscopy every 10 years after shared decision making discussing potential benefits and harms. Usual care at Group Health Cooperative involved services to promote CRC screening, including evidence-based guidelines; patient handouts; and an annual systems-delivered, patient-tailored “birthday letter” with previous completion and subsequent due dates for immunizations, screening tests, and long-term care tests (such as influenza shots, CRC screening, or hemoglobin A_{1c} tests).

During this study in fall 2009, all Group Health Cooperative– owned primary care clinics implemented a patient-centered medical home (PCMH) model that included interventions to improve quality of care in prevention and chronic disease (12). As part of the model, medical assistants (MAs) or nurses used the Group Health Cooperative patient registry and EHR to complete a form before a patient visit to identify unmet immunization, chronic condition, and prevention needs (for example, influenza shots and CRC screening). At the visit, when the patient was “in reach,” the MA gave the form to the physician.

Patients overdue for CRC screening received an FOBT kit before the visit or after a physician discussion, depending on physician preference. Medical assistants also reviewed their physicians’ list of patients the month after the birthday letter was sent to identify those with unmet chronic condition or prevention needs, provide outreach by telephone or secure e-mail (through a patient Web portal), order needed tests (such as hemoglobin A_{1c} tests), and mail FOBT kits if CRC screening was overdue.

Because patients participating in the SOS trial were recruited between August 2008 and November 2009, approximately half were exposed to the PCMH model in year 1 and all were exposed in year 2. Birthday letters were sent throughout the study. The in-reach component of the PCMH model was fully in place early in implementation, whereas outreach occurred more gradually.

Usual Care Plus Automated Care—In addition to usual care, patients in the “automated” group received interventions through a study database registry linked to the EHR. The registry tracked when screening was due and automatically generated mailings. Patients in the automated group received a letter informing them that they were due for CRC screening and an informational pamphlet about the tests and different screening options.

Patients were informed that FOBT kits would be mailed soon but that they could call the SOS trial telephone line if they preferred another screening test. Patients who called were instructed by a research assistant to call their physician’s office and specifically request a sigmoidoscopy or colonoscopy. Patients not requesting alternative testing were mailed FOBT kits with simplified pictorial instructions and a postage-paid return envelope.

If there was no evidence of FOBT completion after 3 weeks, patients received a reminder letter to complete the test or inquire about other screening options. Electronic health record evidence of completion of FOBT or other CRC tests stopped SOS trial interventions until the next due date. Interventions were repeated in year 2 for participants due for screening in year 2, with the cycle starting 12 months after FOBT completion or, if no CRC screening tests were done in year 1, 12 months after study entry. Study-generated FOBT results appeared in the EHR and physician inboxes similar to other tests.

Usual Care Plus Automated Interventions Plus Assisted Care—In addition to automated support, patients in the “assisted” group received automated support and telephone assistance from an MA to complete CRC screening. Assisted interventions were delivered by 3 part-time MAs working a combined 15% full-time equivalents weekly. Medical assistants worked from their usual clinic but had protected time to provide assisted care. Because participants came from all 21 of Group Health Cooperative’s western Washington primary care clinics, the study MA was rarely part of the patients’ care team.

Medical assistants used the study registry to view lists of patients who had called to request alternate screening or had not completed FOBT screening 3 weeks after the mailing. The MA made up to 3 contact attempts to determine patient screening intent (for example, whether the patient planned to do FOBT soon, preferred sigmoidoscopy or colonoscopy, or did not want to complete screening). Medical assistants could review materials sent to the patient to help patients make a choice or complete FOBT.

If the patient wanted a sigmoidoscopy or colonoscopy, the MA forwarded the request to the patient’s primary care physician and recontacted the patient about the decision and instructions. No other ongoing care was provided. The MA documented all communications in the patient’s EHR and updated the study registry.

Usual Care Plus Automated Interventions Plus Assisted Interventions Plus Navigated Care—In addition to automated plus assisted support, patients in the “navigated” group received support from a registered nurse (RN). Two part-time RNs working a combined 10% full-time equivalents weekly delivered navigated interventions. Similar to MAs, RNs worked from their usual clinic, provided care to patients from all clinics, and were rarely part of the patient’s health care team.

The RNs directly contacted patients who had called with questions or requests for an FOBT alternative. An MA contacted navigated patients who did not request an alternative test or complete FOBT after mailings and made up to 2 attempts to determine screening intent. The RNs contacted patients who preferred colonoscopy or sigmoidoscopy, needed assistance in making a screening choice, intended to do FOBT but had no FOBT laboratory results after 3 weeks, or could not be contacted by the MA.

Registered nurse care included assessing patient CRC risk; reviewing procedural risk; providing motivational counseling to assist patients in defining their screening intent; creating a patient-shared screening action plan; assisting with referrals, appointments, and preparation for endoscopy; and tracking testing completion. If the RN could not reach the patient, a letter or secure e-mail was sent reiterating the importance of CRC screening, including the RN’s telephone number for further assistance. Similar to the MAs, the RNs had protected time from other duties and used study registry lists to track CRC screening care.

Blinding

Group allocation and outcome assessments were concealed until all data were collected. Because of the nature of the intervention, MAs, RNs, and physicians could not be blinded to group assignments.

Outcome Measures

Two primary outcomes were designated before analysis: receiving any CRC test and being current for CRC testing in years 1 and 2. Because all patients were overdue for CRC testing at baseline, *current for CRC testing* was defined using U.S. Preventive Services Task Force screening guidelines (receipt of a colonoscopy or flexible sigmoidoscopy in year 1, FOBT in years 1 and 2, or FOBT in year 1 and sigmoidoscopy or colonoscopy in year 2). Secondary outcomes included completion rates for FOBT or any type of CRC test in year 1 and separately in year 2 for participants still eligible for screening and the proportion who received any FOBT, colonoscopy, or sigmoidoscopy during either study year.

Primary and secondary outcomes were based on evidence from the EHR or claims data of CRC test completion. Because these administrative data sources did not contain sufficient information to distinguish between screening and diagnostic tests, outcome measures were based on CRC testing regardless of indication.

Intervention Cost Assessment

Intervention costs were defined as the value of resources used to implement and operate the interventions over the 2-year trial and were measured from the perspective of a sponsoring health care system. Research-related costs were excluded, as were study registry development costs, because organizations often have, and EHRs increasingly support, registries for monitoring and managing populations (such as patients with diabetes).

Intervention costs were calculated for each study group by using microcosting techniques (13). Intervention components were classified as labor (for example, MA calls) or nonlabor (for example, mailed FOBT kits). Cost data were collected from expense reports and retrospective labor estimates. Unit cost multipliers (for example, MA wage rate plus fringe) were applied to resource quantities (for example, MA follow-up calls of mean duration). Joint resources (for example, hotline monitoring by a project manager) were shared across groups.

Year 2 wage rates were increased by 3%. Resource values (total unit cost $\times$ resource quantities) were then summed on the basis of intervention costs alone and intervention costs plus induced CRC costs. For each intervention group, the incremental cost per incremental person screened for CRC was then estimated relative to each less intensive group.

Statistical Analysis

The planned sample size (5000 total, 1250 per study group) provided 80% power to detect an 8% difference in the proportion screened between any 2 study groups, assuming 20% loss to follow-up and adjusting the 5% type I error rate to account for 6 possible pair-wise between-group comparisons. Analyses used Stata statistical software, version 12.0 (StataCorp, College Station, Texas).

All participants were included in primary outcomes analyses according to their randomization group assignment (Figure 1) except for participants who left Group Health Cooperative before ($n = 10$) or withdrew consent after ($n = 1$) randomization. Primary outcomes for patients who died ($n = 23$), were diagnosed with CRC ($n = 10$), or disenrolled ($n = 391$) were based on their screening currency status at the time of the event. For the

primary outcome, being current in years 1 and 2, participants disenrolling during year 1 were required to be current in year 1 only. Participants disenrolling during year 2 were required to be current in both years. Participants disenrolling during year 1 were excluded from year 2 secondary analyses.

Primary and secondary outcomes were reported as binary measures of CRC testing completion. Logistic regression models with terms for age, sex, race or ethnicity, and education and robust SEs to account for clustering of patients within clinics were used to find predictive margins. Predictive margins are presented as probabilities adjusted across the covariate distribution in the sample. Predictive margins were found using the margins command in Stata. The analysis used a complete-case approach, and participants with missing covariates ($n = 30$) were excluded from adjusted models. On the basis of the Bonferroni correction for multiple comparisons, only P values below a significance threshold of 0.0083 ($\alpha = 0.05$ of 6 possible pair-wise group comparisons) denoted statistically significant results (14).

Subgroup analyses assessed effect modification by age at randomization (49 to 63 years and 64 to 72 years), sex, self-reported ever or never having CRC screening, education level, and race or ethnicity. Interaction terms between these variables and intervention groups were included in multivariable models to estimate separate intervention effects within each subgroup. Exploratory analyses similarly assessed effect modification by clinic to determine any heterogeneity in intervention effects across clinics.

Results

Study Participants

Invitation letters were sent to 15 451 patients aged 50 to 73 years who were not current for CRC screening based on automated data (Figure 1). Of these, 6% (929 of 15 451) could not be contacted, 10.5% (1629 of 15 451) were ineligible for self-report of sigmoidoscopy within the past 4 years or colonoscopy within 9 years, and 10.2% (1581 of 15 451) were ineligible for other reasons. Of 11 312 potentially eligible patients, 41.3% (4675 of 11 312) completed the recruitment survey and provided verbal consent, with 46.3% self-reporting that they had never had any type of CRC testing (Table 1).

Comparisons between SOS trial participants and nonparticipants have been described (11). Trial participants were more likely than nonparticipants to be white and more educated and to engage in other preventive behaviors (for example, being current for other types of cancer screening). Disenrollment over the 2-year study was 8.4% (391 of 4664), with no significant difference across study groups (usual care, 8.2%; automated, 9.2%; assisted, 8.1%; and navigated, 8.0%; $P = 0.68$).

Primary Outcomes

Participants in all 3 intervention groups were more likely to be current for screening in both years comparing the usual care group (26.3% [95% CI, 23.4% to 29.2%]), automated group (50.8% [CI, 47.3% to 54.4%]), assisted group (57.5% [CI, 54.5% to 60.6%]), and navigated group (64.7% [CI, 62.5% to 67.0%]) ($P < 0.001$ for all pair-wise comparisons). The assisted group was significantly more likely to be current than the automated group ($P = 0.001$), and the navigated group was significantly more likely to be current than both the automated and assisted groups (both $P < 0.001$) (Table 2). Among participants current for CRC screening, incremental increases were primarily due to completion of FOBT in both years 1 and 2 (Figure 2).

Most participants had at least 1 CRC test during the 2-year intervention, with incremental increases by intervention (72.5% [CI, 69.9% to 75.1%] for the automated group, 77.9% [CI, 75.2% to 80.6%] for the assisted group, and 82.6% [CI, 80.2% to 85.1%] for the navigated group vs. 57.4% [CI, 53.5% to 61.3%] for the usual care group; $P < 0.001$ for all pair-wise comparisons).

Secondary Outcomes

In all study groups, CRC testing rates were lower in year 2 than in year 1 for participants still eligible for screening. However, increases in CRC testing by intervention intensity persisted (Table 3). By the end of year 2, the usual care group (26.0% [CI, 22.8% to 29.2%]) and the navigated group (25.6% [CI, 23.2% to 28.0%]) were significantly more likely to have completed a colonoscopy (for any indication) than the automated group (20.7% [CI, 17.4% to 24.0%]; both $P < 0.001$) but not the assisted group (23.0% [CI, 19.8% to 26.2%]; $P = 0.06$ [vs. usual care group] and 0.11 [vs. navigated group]).

Among patients who completed an FOBT in year 1, those in the intervention groups were 3 times more likely to complete an FOBT in year 2 than those in the usual care group (70.4% vs. 20.8%; adjusted risk ratio, 3.37 [CI, 2.62 to 4.34]; data not shown). We used specific codes to distinguish study FOBTs from Group Health Cooperative FOBTs. Of the FOBTs completed in years 1 and 2 by the automated, assisted, and navigated groups, 83.1% (3153 of 3784) were study FOBTs and 16.9% were Group Health Cooperative-generated FOBTs.

Subgroup Analyses

Automated interventions were more effective than usual care for all patient subgroups (Appendix Table 1, available at www.annals.org). Compared with the automated group, the assisted group had significantly higher rates of being current for CRC testing in both years, but only for men, those aged 50 to 64 years, and white persons. The magnitude of effect of the assisted intervention varied, particularly among racial subgroups (Appendix Table 2, available at www.annals.org). Compared with the automated group, the navigated group had significantly higher rates for being current for CRC testing in both years regardless of sex, education, and previous CRC testing, except for those aged 65 to 73 years and nonwhite persons. Patients who reported no previous CRC testing had lower CRC testing rates overall.

The automated intervention was effective in almost all clinics, with 17 of 21 having at least a 20% or greater (range, 20.0% to 39.4%) net increase in being current for CRC testing in both years compared with usual care. Incremental effectiveness of assisted compared with automated interventions and navigated compared with assisted interventions varied more among clinics. However, the navigated intervention was more effective than the automated intervention, with 14 of 21 clinics having an approximate 10% net increase (range, 11.7% to 35.1%) for being current for CRC testing in both years.

Process Measures

Patients in the assisted group received MA telephone assistance only if CRC testing was not completed after the mailed interventions, with 54.3% (630 of 1161) in year 1 and 52.9% (558 of 1055) in year 2 eligible to receive this assistance. Medical assistants were able to contact more than 70% of these patients within 3 telephone attempts. Patients in the navigated group received RN navigation if they did not complete CRC testing after mailed and assisted interventions, with 41.6% (488 of 1173) in year 1 and 39.2% (410 of 1047) in year 2 eligible. Registered nurses were able to contact most of these patients by telephone or secure e-mail.

Adverse Events

Participants were monitored for death or hospitalization within 30 days of a colonoscopy. No hospitalizations or deaths were found to be related to study participation or study-induced CRC tests.

Intervention Costs

Two-year program costs per participant (excluding CRC test costs) were \$94 for the automated, \$98 for the assisted, and \$103 for the navigated interventions. Incremental costs per person screened (combined program and CRC test costs) were -\$89 for the automated compared with the usual care group \$371 for the assisted compared with the automated group, and \$557 for the navigated compared with the assisted group. The combined program and CRC testing costs of the automated intervention were lower than those of usual care because the automated program generated fewer colonoscopies, which more than offset the increased FOBT costs. Increased combined costs for the assisted and navigated interventions were from incremental increases in colonoscopies, with small differences having a large effect on cost.

Discussion

This randomized trial demonstrated that automated EHR data systems can be used to deliver an inexpensive and effective CRC screening program. Automated interventions led to twice as many people being current for CRC testing in both study years and were effective in all population subgroups. Compared with automated interventions, the stepped-intensity interventions led to smaller but significant incremental increases in CRC testing uptake and being current for CRC testing in both study years.

Increases in CRC testing were mainly due to increased FOBT. Compared with usual care, patients in the automated group were modestly but significantly less likely to have a colonoscopy, with rates similar among the usual care, assisted, and navigated groups. Patients in the intervention groups were sent information on CRC screening test choices and a telephone number to call to request a colonoscopy or sigmoidoscopy, with FOBT kits mailed 3 weeks later if no request was made. However, only 61 patients called before the default FOBT to request an alternative.

Recent studies suggest that U.S. physicians are more likely to offer colonoscopy, whereas patients often prefer FOBT (15). Inadomi and colleagues (16) found that, compared with offering colonoscopy alone, providing patients with a choice of FOBT or colonoscopy led to almost twice as many people completing screening.

Several studies have shown that direct mailing of FOBT kits increases screening rates similar to our results (17-21). Effective components include mailing an advance letter (22, 23), including a postage-paid return envelope (20, 21), and providing a follow-up reminder letter (24). The SOS trial is the first CRC screening effectiveness trial to use these components as part of a repeated approach. Providing FOBT at clinic visits (25) or at the time of influenza shots (26) also increases FOBT uptake compared with not receiving interventions.

Results from interactive voice recognition (27, 28), telephone (17, 29), and e-mail (30) reminders to increase FOBT uptake have varied, probably because patients have to “opt in” rather than receiving mailed FOBT kits as the default option. Trials focusing on physicians (30-33), clinic practices (25, 32, 34-38), and use of patient decision tools (39-45) have had variable or null effects; required more clinic staff or patient time; and, when evaluated, were expensive to implement (31, 46-49).

The SOS trial occurred during implementation of a PCMH model (12), with usual care receiving both inreach and outreach interventions that included efforts to increase CRC screening. Interventions from the SOS trial were still more effective than usual care, possibly because of variation in execution of PCMH procedures or because interventions occurred exactly when the patient was due rather than opportunistically throughout the year.

Compared with usual care, the automated intervention alone led to higher CRC testing rates in all population subgroups. Compared with the automated intervention, navigated intervention led to significantly higher CRC testing rates for all subgroups except those aged 65 to 73 years and nonwhite persons. Older adults were less likely to benefit because they were more adherent to mailed interventions and had less opportunity to be exposed to the more intense steps. In contrast, people without prior testing were more responsive to the greater-intensity stepped interventions.

Small sample size limited our ability to interpret the effects of the assisted and navigated interventions on racial or ethnic groups and had lower response to the automated intervention but greater response to the more intensive assisted and navigated interventions than those who had previous testing. Compared with the automated intervention, the higher-intensity interventions led to testing increases in white, Asian, and Hispanic subgroups but not in black persons. Studies targeting specific subpopulations with language-concordant and culturally tailored media, health educators, and navigators have successfully increased CRC screening uptake (19, 50-58). Our interventions were designed for patients with low literacy but were not culturally tailored. Additional research is needed to understand why some people never undergo screening and to determine the best ways to integrate patient-tailored strategies into routine care.

Observational studies (59-61) have assessed organized centralized programs that mail FOBT kits directly to patients, including those delivered nationwide. Kaiser Permanente Northern California reported that a centralized outreach program of mailed single-sample fecal immunochemical tests substantially increased Healthcare Effectiveness Data and Information Set (National Committee for Quality Assurance, Washington, DC) CRC screening rates, with proportional increases in CRC detection, primarily of early-stage disease (62). The SOS trial achieved similar FOBT screening rates by using a high-sensitivity 3-sample guaiac-based FOBT that included instructions for avoiding red meat, aspirin, and nonsteroidal antiinflammatory medications. Higher rates might be achievable using fecal immunochemical tests that require fewer samples and pose no dietary restrictions (63, 64).

Few studies on CRC screening effectiveness have assessed intervention costs (31, 46-49, 65). When CRC test costs were added to our program costs, costs for usual care exceeded total automated intervention costs because the automated intervention generated fewer colonoscopies. Longer-term assessments are needed to compare 10-year costs, because screening colonoscopy is needed less frequently than annual FOBT.

Our study has limitations. Volunteers were required to provide verbal consent and were more likely than nonparticipants to be educated and white and to practice other preventive behaviors (11). Thus, the magnitude and relative effect of our results may not generalize to other populations. Study patients also had health insurance, access to follow-up testing, and no or low copays related to screening or diagnostic testing completion. Higher out-of-pocket costs might lead to lower uptake rates.

Although most CRC tests were probably done for screening, some were for diagnosis, surveillance, or treatment. We did not audit charts to determine indication. Thus, receiving CRC tests and being current for CRC testing were proxies for uptake and adherence to CRC

screening. Lastly, most patients chose FOBT, which is recommended annually, and we do not know whether adherence would be maintained in the long term.

In conclusion, to the best of our knowledge, this is the first randomized, controlled trial to demonstrate that EHR-linked data can be used efficiently, effectively, and repeatedly to deliver interventions that led to twice as many people being current for CRC screening over 2 years. A stepped approach of providing brief assistance or navigation only when patients did not respond to lowerintensity interventions led to progressive increases in CRC testing. The rapid growth of EHRs provides opportunities for spreading this model more broadly and testing whether EHR-linked mailings and stepped levels of support can be used to maintain long-term adherence to screening.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors thank Robert S. Thompson, MD, Group Health Physicians, Group Health Permanente, study design; Kim Riddell, MD, Group Health Permanente, laboratory support; Peggy Rogers, Group Health Cooperative, laboratory support; David Carrell, PhD, Group Health Research Institute, programmer; Kathryn Horner, MS, San Francisco General Hospital; Ed Wagner, MD, MPH, Group Health Research Institute, McColl Center, conceptual model, advisor; Stephen Taplin, MD, MPH, National Cancer Institute, study design; Jackie St. John, BS, Group Health Research Institute, project manager; Andy Bogart, MS, Group Health Research Institute, biostatistician; Mary Lyons, BFA, Group Health Research Institute, research specialist; Kris Hansen, BA, Group Health Research Institute, research specialist; Chris Tachibana, PhD, Group Health Research Institute, scientific editor; Camille Campbell, BA, Group Health Research Institute, administrative support; and Annie Shaffer, BA, Group Health Research Institute, administrative support.

Grant Support: By grant R01CA121125 from the National Cancer Institute of the National Institutes of Health.

Role of the Funding Source

The study was supported by the National Cancer Institute of the National Institutes of Health.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

1. Siegel R, Naishadham D, Jemal A. Cancer statistics, 2012. *CA Cancer J Clin*. 2012; 62:10–29. [PubMed: 22237781]
2. Vogelaar I, van Ballegooijen M, Schrag D, Boer R, Winawer SJ, Habbema JD, et al. How much can current interventions reduce colorectal cancer mortality in the U.S.? Mortality projections for scenarios of risk-factor modification, screening, and treatment. *Cancer*. 2006; 107:1624–33. [PubMed: 16933324]
3. Joseph DA, King JB, Miller JW, Richardson LC. Centers for Disease Control and Prevention (CDC). Prevalence of colorectal cancer screening among adults—Behavioral Risk Factor Surveillance System, United States, 2010. *MMWR Morb Mortal Wkly Rep*. 2012; 61(Suppl):51–6. [PubMed: 22695464]
4. U.S. Preventive Services Task Force. Screening for colorectal cancer: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med*. 2008; 149:627–37. [PubMed: 18838716]
5. Whitlock EP, Lin JS, Liles E, Beil TL, Fu R. Screening for colorectal cancer: a targeted, updated systematic review for the U.S. Preventive Services Task Force. *Ann Intern Med*. 2008; 149:638–58. [PubMed: 18838718]

6. Zuber AG, Lansdorp-Vogelaar I, Knudsen AB, Wilschut J, van Ballegooijen M, Kuntz KM. Evaluating test strategies for colorectal cancer screening: a decision analysis for the U.S. Preventive Services Task Force. *Ann Intern Med.* 2008; 149:659–69. [PubMed: 18838717]
7. Task Force on Community Preventive Services. Recommendations for client and provider-directed interventions to increase breast, cervical, and colorectal cancer screening. *Am J Prev Med.* 2008; 35:S21–5. [PubMed: 18541184]
8. Baron RC, Rimer BK, Breslow RA, Coates RJ, Kerner J, Melillo S, et al. Task Force on Community Preventive Services. Client-directed interventions to increase community demand for breast, cervical, and colorectal cancer screening: a systematic review. *Am J Prev Med.* 2008; 35:S34–55. [PubMed: 18541187]
9. Sabatino SA, Lawrence B, Elder R, Mercer SL, Wilson KM, DeVinney B, et al. Community Preventive Services Task Force. Effectiveness of interventions to increase screening for breast, cervical, and colorectal cancers: nine updated systematic reviews for the guide to community preventive services. *Am J Prev Med.* 2012; 43:97–118. [PubMed: 22704754]
10. Green BB, Wang CY, Horner K, Catz S, Meenan RT, Vernon SW, et al. Systems of support to increase colorectal cancer screening and follow-up rates (SOS): design, challenges, and baseline characteristics of trial participants. *Contemp Clin Trials.* 2010; 31:589–603. [PubMed: 20674774]
11. Green BB, Bogart A, Chubak J, Vernon SW, Morales LS, Meenan RT, et al. Nonparticipation in a population-based trial to increase colorectal cancer screening. *Am J Prev Med.* 2012; 42:390–7. [PubMed: 22424252]
12. Hsu C, Coleman K, Ross TR, Johnson E, Fishman PA, Larson EB, et al. Spreading a patient-centered medical home redesign: a case study. *J Ambul Care Manage.* 2012; 35:99–108. [PubMed: 22415283]
13. Luce, B.; Manning, W.; Siegel, J.; Lipscomb, J. Cost-Effectiveness in Health and Medicine. New York: Oxford Univ Pr; 1996. Estimating costs in cost-effectiveness analysis; p. 176–213.
14. Dunn OJ. Multiple Comparisons among Means. *Journal of the American Statistical Association.* 1961; 56:52–64.
15. Hawley ST, McQueen A, Bartholomew LK, Greisinger AJ, Coan SP, Myers R, et al. Preferences for colorectal cancer screening tests and screening test use in a large multispecialty primary care practice. *Cancer.* 2012; 118:2726–34. [PubMed: 21948225]
16. Inadomi JM, Vijan S, Janz NK, Fagerlin A, Thomas JP, Lin YV, et al. Adherence to colorectal cancer screening: a randomized clinical trial of competing strategies. *Arch Intern Med.* 2012; 172:575–82. [PubMed: 22493463]
17. Church TR, Yeazel MW, Jones RM, Kochevar LK, Watt GD, Mongin SJ, et al. A randomized trial of direct mailing of fecal occult blood tests to increase colorectal cancer screening. *J Natl Cancer Inst.* 2004; 96:770–80. [PubMed: 15150305]
18. Hoffman RM, Steel SR, Yee EF, Massie L, Schrader RM, Moffett ML, et al. A system-based intervention to improve colorectal cancer screening uptake. *Am J Manag Care.* 2011; 17:49–55. [PubMed: 21348568]
19. Coronado GD, Golovaty I, Longton G, Levy L, Jimenez R. Effectiveness of a clinic-based colorectal cancer screening promotion program for underserved Hispanics. *Cancer.* 2011; 117:1745–54. [PubMed: 21472722]
20. Freedman JD, Mitchell CK. A simple strategy to improve patient adherence to outpatient fecal occult blood testing. *J Gen Intern Med.* 1994; 9:462–4. [PubMed: 7965243]
21. Miller MF, Wong JG. Reducing financial barriers enhances the return rate of stool Hemoccult packets. *Am J Med Sci.* 1993; 306:98–100. [PubMed: 8362899]
22. van Roon AH, Hol L, Wilschut JA, Reijerink JC, van Vuuren AJ, van Ballegooijen M, et al. Advance notification letters increase adherence in colorectal cancer screening: a population-based randomized trial. *Prev Med.* 2011; 52:448–51. [PubMed: 21457725]
23. Cole SR, Smith A, Wilson C, Turnbull D, Esterman A, Young GP. An advance notification letter increases participation in colorectal cancer screening. *J Med Screen.* 2007; 14:73–5. [PubMed: 17626705]

24. Lee JK, Reis V, Liu S, Conn L, Groessl EJ, Ganiats TG, et al. Improving fecal occult blood testing compliance using a mailed educational reminder. *J Gen Intern Med.* 2009; 24:1192–7. [PubMed: 19774423]
25. Thompson NJ, Boyko EJ, Dominitz JA, Belcher DW, Chesebro BB, Stephens LM, et al. A randomized controlled trial of a clinic-based support staff intervention to increase the rate of fecal occult blood test ordering. *Prev Med.* 2000; 30:244–51. [PubMed: 10684748]
26. Potter MB, Walsh JM, Yu TM, Gildengorin G, Green LW, McPhee SJ. The effectiveness of the FLU-FOBT program in primary care a randomized trial. *Am J Prev Med.* 2011; 41:9–16. [PubMed: 21665058]
27. Mosen DM, Feldstein AC, Perrin N, Rosales AG, Smith DH, Liles EG, et al. Automated telephone calls improved completion of fecal occult blood testing. *Med Care.* 2010; 48:604–10. [PubMed: 20508529]
28. Simon SR, Zhang F, Soumerai SB, Ensroth A, Bernstein L, Fletcher RH, et al. Failure of automated telephone outreach with speech recognition to improve colorectal cancer screening: a randomized controlled trial. *Arch Intern Med.* 2010; 170:264–70. [PubMed: 20142572]
29. Levy BT, Daly JM, Xu Y, Ely JW. Mailed fecal immunochemical tests plus educational materials to improve colon cancer screening rates in Iowa Research Network (IRENE) practices. *J Am Board Fam Med.* 2012; 25:73–82. [PubMed: 22218627]
30. Sequist TD, Zaslavsky AM, Marshall R, Fletcher RH, Ayanian JZ. Patient and physician reminders to promote colorectal cancer screening: a randomized controlled trial. *Arch Intern Med.* 2009; 169:364–71. [PubMed: 19237720]
31. Khankari K, Eder M, Osborn CY, Makoul G, Clayman M, Skripkauskas S, et al. Improving colorectal cancer screening among the medically underserved: a pilot study within a federally qualified health center. *J Gen Intern Med.* 2007; 22:1410–4. [PubMed: 17653808]
32. Ornstein S, Nemeth LS, Jenkins RG, Nietert PJ. Colorectal cancer screening in primary care: translating research into practice. *Med Care.* 2010; 48:900–6. [PubMed: 20808257]
33. Ferreira MR, Dolan NC, Fitzgibbon ML, Davis TC, Gorby N, Ladewski L, et al. Health care provider-directed intervention to increase colorectal cancer screening among veterans: results of a randomized controlled trial. *J Clin Oncol.* 2005; 23:1548–54. [PubMed: 15735130]
34. Ganz PA, Farmer MM, Belman MJ, Garcia CA, Streja L, Dietrich AJ, et al. Results of a randomized controlled trial to increase colorectal cancer screening in a managed care health plan. *Cancer.* 2005; 104:2072–83. [PubMed: 16216030]
35. Lane DS, Messina CR, Cavanagh MF, Chen JJ. A provider intervention to improve colorectal cancer screening in county health centers. *Med Care.* 2008; 46:S109–16. [PubMed: 18725822]
36. Ling BS, Schoen RE, Trauth JM, Wahed AS, Eury T, Simak DM, et al. Physicians encouraging colorectal screening: a randomized controlled trial of enhanced office and patient management on compliance with colorectal cancer screening. *Arch Intern Med.* 2009; 169:47–55. [PubMed: 19139323]
37. Roetzheim RG, Christman LK, Jacobsen PB, Schroeder J, Abdulla R, Hunter S. Long-term results from a randomized controlled trial to increase cancer screening among attendees of community health centers. *Ann Fam Med.* 2005; 3:109–14. [PubMed: 15798035]
38. Baker AN, Parsons M, Donnelly SM, Johnson L, Day J, Mervis A, et al. Improving colon cancer screening rates in primary care: a pilot study emphasising the role of the medical assistant. *Qual Saf Health Care.* 2009; 18:355–9. [PubMed: 19812097]
39. Wei EK, Ryan CT, Dietrich AJ, Colditz GA. Improving colorectal cancer screening by targeting office systems in primary care practices: disseminating research results into clinical practice. *Arch Intern Med.* 2005; 165:661–6. [PubMed: 15795343]
40. Miller DP Jr, Spangler JG, Case LD, Goff DC Jr, Singh S, Pignone MP. Effectiveness of a web-based colorectal cancer screening patient decision aid: a randomized controlled trial in a mixed-literacy population. *Am J Prev Med.* 2011; 40:608–15. [PubMed: 21565651]
41. Pignone M, Winquist A, Schild LA, Lewis C, Scott T, Hawley J, et al. Effectiveness of a patient and practice-level colorectal cancer screening intervention in health plan members: the CHOICE trial. *Cancer.* 2011; 117:3352–62. [PubMed: 21319147]

42. Pignone M, Harris R, Kinsinger L. Videotape-based decision aid for colon cancer screening. A randomized, controlled trial. *Ann Intern Med.* 2000; 133:761–9. [PubMed: 11085838]
43. Ruffin MT 4th, Fetter MD, Jimbo M. Preference-based electronic decision aid to promote colorectal cancer screening: results of a randomized controlled trial. *Prev Med.* 2007; 45:267–73. [PubMed: 17689600]
44. Smith SK, Trevena L, Simpson JM, Barratt A, Nutbeam D, McCaffery KJ. A decision aid to support informed choices about bowel cancer screening among adults with low education: randomised controlled trial. *BMJ.* 2010; 341:c5370. [PubMed: 20978060]
45. Vernon SW, Bartholomew LK, McQueen A, Bettencourt JL, Greisinger A, Coan SP, et al. A randomized controlled trial of a tailored interactive computerdelivered intervention to promote colorectal cancer screening: sometimes more is just the same. *Ann Behav Med.* 2011; 41:284–99. [PubMed: 21271365]
46. Lairson DR, DiCarlo M, Myers RE, Wolf T, Cocroft J, Sifri R, et al. Cost-effectiveness of targeted and tailored interventions on colorectal cancer screening use. *Cancer.* 2008; 112:779–88. [PubMed: 18098272]
47. Misra S, Lairson DR, Chan W, Chang YC, Bartholomew LK, Greisinger A, et al. Cost effectiveness of interventions to promote screening for colorectal cancer: a randomized trial. *J Prev Med Public Health.* 2011; 44:101–10. [PubMed: 21617335]
48. Shankaran V, Luu TH, Nonzee N, Richey E, McKoy JM, Graff Zivin J, et al. Costs and cost effectiveness of a health care provider-directed intervention to promote colorectal cancer screening. *J Clin Oncol.* 2009; 27:5370–5. [PubMed: 19826133]
49. Wolf MS, Fitzner KA, Powell EF, McCaffrey KR, Pickard AS, McKoy JM, et al. Costs and cost effectiveness of a health care provider-directed intervention to promote colorectal cancer screening among Veterans. *J Clin Oncol.* 2005; 23:8877–83. [PubMed: 16314648]
50. Tu SP, Taylor V, Yasui Y, Chun A, Yip MP, Acorda E, et al. Promoting culturally appropriate colorectal cancer screening through a health educator: a randomized controlled trial. *Cancer.* 2006; 107:959–66. [PubMed: 16865681]
51. Aragonés A, Schwartz MD, Shah NR, Gany FM. A randomized controlled trial of a multilevel intervention to increase colorectal cancer screening among Latino immigrants in a primary care facility. *J Gen Intern Med.* 2010; 25:564–7. [PubMed: 20213208]
52. Katz ML, Fisher JL, Fleming K, Paskett ED. Patient activation increases colorectal cancer screening rates: a randomized trial among low-income minority patients. *Cancer Epidemiol Biomarkers Prev.* 2012; 21:45–52. [PubMed: 22068288]
53. Basch CE, Wolf RL, Brouse CH, Shmukler C, Neugut A, DeCarlo LT, et al. Telephone outreach to increase colorectal cancer screening in an urban minority population. *Am J Public Health.* 2006; 96:2246–53. [PubMed: 17077394]
54. Dietrich AJ, Tobin JN, Cassells A, Robinson CM, Greene MA, Sox CH, et al. Telephone care management to improve cancer screening among low-income women: a randomized, controlled trial. *Ann Intern Med.* 2006; 144:563–71. [PubMed: 16618953]
55. Fiscella K, Humiston S, Hendren S, Winters P, Idris A, Li SX, et al. A multimodal intervention to promote mammography and colorectal cancer screening in a safety-net practice. *J Natl Med Assoc.* 2011; 103:762–8. [PubMed: 22046855]
56. Lasser KE, Murillo J, Medlin E, Lisboa S, Valley-Shah L, Fletcher RH, et al. A multilevel intervention to promote colorectal cancer screening among community health center patients: results of a pilot study. *BMC Fam Pract.* 2009; 10:37. [PubMed: 19480698]
57. Percac-Lima S, Grant RW, Green AR, Ashburner JM, Gamba G, Oo S, et al. A culturally tailored navigator program for colorectal cancer screening in a community health center: a randomized, controlled trial. *J Gen Intern Med.* 2009; 24:211–7. [PubMed: 19067085]
58. Walsh JM, Salazar R, Nguyen TT, Kaplan C, Nguyen LK, Hwang J, et al. Healthy colon, healthy life: a novel colorectal cancer screening intervention. *Am J Prev Med.* 2010; 39:1–14. [PubMed: 20547275]
59. Chao HH, Schwartz AR, Hersh J, Hunnibell L, Jackson GL, Provenzale DT, et al. Improving colorectal cancer screening and care in the Veterans Affairs Healthcare system. *Clin Colorectal Cancer.* 2009; 8:22–8. [PubMed: 19203893]

60. Malila N, Palva T, Malminiemi O, Paimela H, Anttila A, Hakulinen T, et al. Coverage and performance of colorectal cancer screening with the faecal occult blood test in Finland. *J Med Screen*. 2011; 18:18–23. [PubMed: 21536812]
61. Zavoral M, Suchanek S, Zavada F, Dusek L, Muzik J, Seifert B, et al. Colorectal cancer screening in Europe [Editorial]. *World J Gastroenterol*. 2009; 15:5907–15. [PubMed: 20014454]
62. Levin TR, Jamieson L, Burley DA, Reyes J, Oehrli M, Caldwell C. Organized colorectal cancer screening in integrated health care systems. *Epidemiol Rev*. 2011; 33:101–10. [PubMed: 21709143]
63. Vart G, Banzi R, Minozzi S. Comparing participation rates between immunochemical and guaiac faecal occult blood tests: a systematic review and meta-analysis. *Prev Med*. 2012; 55:87–92. [PubMed: 22634386]
64. Rabeneck L, Rumble RB, Thompson F, Mills M, Oleschuk C, Whibley A, et al. Fecal immunochemical tests compared with guaiac fecal occult blood tests for population-based colorectal cancer screening. *Can J Gastroenterol*. 2012; 26:131–47. [PubMed: 22408764]
65. Sequist TD, Franz C, Ayanian JZ. Cost-effectiveness of patient mailings to promote colorectal cancer screening. *Med Care*. 2010; 48:553–7. [PubMed: 20473196]

Context

Interventions to increase adherence to recommendations for colorectal cancer screening are needed.

Contribution

This 2-year randomized trial found that, compared with usual care, patients completed recommended screening more often when electronic health record–linked reminders and fecal occult blood testing kits were sent to them. Follow-up telephone calls by medical assistants and, if required, nursing assistance each resulted in additional but smaller incremental improvements in adherence.

Caution

Whether improved adherence would persist beyond 2 years is not known.

Implication

Sending automated electronic health record–linked reminders and fecal occult blood testing kits can improve colorectal cancer screening rates.

—The Editors

Figure 1. Study flow diagram

CRC = colorectal cancer.

* Provided written request to be withdrawn from the study and to have data removed from study databases.

Figure 2. Type of colorectal testing completed for those current for testing, both years 1 and 2
Current is defined as receiving a FS or CS in year 1 or FOBT in year 1 plus FOBT, colonoscopy, or flexible sigmoidoscopy in year 2. Patients with FOBT in year 1 and who were ineligible in year 2 (death, colorectal cancer, or disenrollment in year 1) were defined as *current for the primary analysis* ($n = 68$). CS = colonoscopy; FOBT = fecal occult blood test; FS = flexible sigmoidoscopy.

Table 1**Baseline Characteristics, by Randomization Group**

Characteristic *	Usual Care Group (n = 1166), n (%)	Automated Group[†] (n = 1169), n (%)	Assisted Group[‡] (n = 1159), n (%)	Navigated Group[§] (n = 1170), n (%)
Age group at baseline				
50–64 y	992 (85.1)	1002 (85.7)	986 (85.1)	994 (85.0)
65–73 y	174 (14.9)	167 (14.3)	173 (14.9)	176 (15.0)
Women	653 (56.0)	629 (53.8)	615 (53.1)	647 (55.3)
Race/ethnicity ^{//}				
Hispanic	43 (3.7)	27 (2.3)	35 (3.0)	49 (4.2)
Non-Hispanic				
Black	44 (3.8)	53 (4.6)	64 (5.6)	67 (5.8)
Asian	64 (5.5)	62 (5.3)	53 (4.6)	58 (5.0)
White	950 (82.3)	941 (80.8)	926 (80.5)	919 (78.8)
Other	54 (4.7)	82 (7.0)	73 (6.3)	73 (6.3)
General health [¶]				
Excellent/very good	722 (62.0)	735 (62.9)	728 (63.0)	750 (64.2)
Good	338 (29.0)	365 (31.2)	354 (30.6)	334 (28.6)
Fair/poor	104 (8.9)	69 (5.9)	74 (6.4)	85 (7.3)
Married or living with partner	837 (72.0)	870 (74.4)	866 (74.9)	866 (74.1)
Education				
High school graduate, GED, or less	191 (16.4)	168 (14.4)	173 (14.9)	168 (14.4)
Some college, 2-y degree, or vocational training	368 (31.6)	364 (31.2)	353 (30.5)	382 (32.7)
Bachelor's degree or higher	605 (52.0)	635 (54.4)	633 (54.6)	620 (53.0)
Never been screened for CRC	539 (46.2)	543 (46.5)	539 (46.5)	539 (46.1)
First-degree relative with CRC	55 (4.8)	50 (4.3)	51 (4.5)	59 (5.1)

CRC = colorectal cancer.

* Missing data for race/ethnicity (n = 27), general health status (n = 6), marital status (n = 7), education (n = 4), and family history (n = 73). Age and sex were collected from electronic data; other questions were captured by self-report at baseline.

[†] Usual care plus automated.

[‡] Usual care plus automated plus assisted.

[§] Usual care plus automated plus assisted plus navigated.

// For participants with >1 category for race/ethnicity, coding precedence was Hispanic, black, Asian, other, and white, in that order.

// Assessed using question 1 from the Short Form-36 health-related quality-of-life survey, version 2 (www.qualitymetric.com/WhatWeDo/SFHealthSurveys/SF36v2HealthSurvey/tabid/185/Default.aspx).

Primary Outcomes for the SOS Trial

Table 2

Primary Outcome	Proportion Tested*			Adjusted Difference Between Groups		
	Usual Care Group	Automated Group	Assisted Group	Navigated Group	Automated Minus Usual Care	Assisted Minus Automated
Current for screening, years 1 and 2†						
Patients, <i>n</i>	1166	1169	1159	1170	–	–
Adjusted percentage (95% CI)	26.3 (23.4–29.2)	50.8 (47.3–54.4)	57.5 (54.5–60.6)	64.7 (62.5–67.0)	24.5 (20.6–28.4)	6.7 (2.7–10.7)
<i>P</i> value‡					<0.001§	<0.001§
Any CRC screening¶						
Patients, <i>n</i>	1166	1169	1159	1170	–	–
Adjusted percentage (95% CI)	57.4 (53.5–61.3)	72.5 (69.9–75.1)	77.9 (75.2–80.6)	82.6 (80.2–85.1)	15.1 (11.7–18.6)	5.4 (2.2–8.6)
<i>P</i> value‡					<0.001§	0.002§

CRC = colorectal cancer; SOS = Systems of Support to Increase Colorectal Cancer Screening and Follow-up Rates.

* Models are adjusted for age, sex, race, and education and account for clustering by clinic.

† Receiving flexible sigmoidoscopy or colonoscopy in year 1 or fecal occult blood testing in year 1 plus fecal occult blood testing, colonoscopy, or sigmoidoscopy in year 2.

‡ Reported *P* values should be interpreted while considering the 6 pairwise test performed for each outcome. Applying a strict Bonferroni cutoff would provide a threshold of 0.0083 (i.e., 0.05 of 6).

§ Significant *P* value.

¶ Receiving flexible sigmoidoscopy, colonoscopy, or fecal occult blood testing in either year 1 or 2.

Table 3

Secondary Outcomes for the SOS Trial

Secondary Outcome	Proportion Tested*				Adjusted Difference Between Groups		
	Usual Care Group	Automated Group	Assisted Group	Navigated Group	Automated Minus Usual Care	Assisted Minus Automated	Navigated Minus Automated
Year 1							
Patients, <i>n</i>	1166	1169	1159	1170	–	–	–
FOBT							
Adjusted percentage (95% CI)	25.8 (21.5 to 30.0)	56.4 (53.2 to 59.6)	60.2 (57.4 to 63.0)	65.9 (62.8 to 69.0)	30.6 (26.2 to 35.0)	3.8 (–0.2 to 7.9)	5.7 (2.0 to 9.4)
<i>P</i> value†					<0.001‡	0.06	0.003‡
Any CRC screening							
Adjusted percentage (95% CI)	39.4 (35.4 to 43.5)	62.3 (59.6 to 65.1)	68.1 (64.7 to 71.5)	74.8 (72.0 to 77.5)	22.9 (18.3 to 27.6)	5.7 (1.5 to 9.9)	6.7 (2.4 to 11.0)
<i>P</i> value†					<0.001‡	0.008‡	0.002‡
Year 2§							
Patients, <i>n</i>	893	915	898	891	–	–	–
FOBT							
Adjusted percentage (95% CI)	19.9 (15.0 to 24.8)	47.2 (43.9 to 50.6)	51.7 (48.5 to 55.0)	57.3 (54.7 to 59.9)	27.3 (23.2 to 31.4)	4.5 (0.7 to 8.3)	5.6 (1.9 to 9.3)
<i>P</i> value†					<0.001‡	0.020	0.002‡
Any CRC screening							
Adjusted percentage (95% CI)	31.8 (27.2 to 36.4)	53.9 (50.0 to 57.7)	59.8 (57.3 to 63.4)	66.1 (63.5 to 68.7)	22.0 (18.6 to 25.5)	6.0 (2.0 to 10.0)	6.3 (3.1 to 9.5)
<i>P</i> value†					<0.001‡	0.003‡	<0.001‡
Year 1 or 2							
Patients, <i>n</i>	1166	1169	1159	1170	–	–	–
FOBT							
Adjusted percentage (95% CI)	37.0 (31.6 to 42.4)	64.0 (60.6 to 67.5)	67.2 (64.1 to 70.3)	71.2 (68.4 to 74.0)	27.1 (22.0 to 32.1)	3.2 (–1.1 to 7.4)	4.0 (0.9 to 7.0)
							7.1 (3.6 to 10.7)

Secondary Outcome	Proportion Tested*			Adjusted Difference Between Groups		
	Usual Care Group	Automated Group	Assisted Group	Navigated Group	Automated Minus Usual Care	Assisted Minus Automated
Colonoscopy						
Adjusted percentage (95% CI)	26.0 (22.8 to 29.2)	20.7 (17.4 to 24.0)	23.0 (19.8 to 26.2)	25.6 (23.2 to 28.0)	−5.3 (−8.2 to −2.3)	2.3 (−1.6 to 6.1)
P value [†]					<0.001 [‡]	0.15
						0.01
						<0.001 [‡]
Flexible sigmoidoscopy						
Adjusted percentage (95% CI)	5.3 (3.5 to 7.0)	5.1 (3.2 to 6.9)	6.5 (4.1 to 8.9)	5.5 (3.7 to 7.3)	−0.2 (−1.4 to 0.9)	1.4 (−0.0 to 2.9)
P value [†]					0.69	0.05
						0.10
						0.39

CRC = colorectal cancer; FOBT = fecal occult blood testing; SOS = Systems of Support to Increase Colorectal Cancer Screening and Follow-up Rates.

* Models are adjusted for age, sex, race, and education and account for clustering by clinic.

[†] Reported *P* values should be interpreted while considering the 6 pairwise test performed for each outcome. Applying a strict Bonferroni cutoff would provide a threshold of 0.0083 (i.e., 0.05 of 6).

[‡] Significant *P* value.

[§] Those who in year 1 had colonoscopy (*n* = 686), had flexible sigmoidoscopy (*n* = 201), had CRC diagnosis (*n* = 1), died (*n* = 11), disenrolled (*n* = 161), or had positive FOBT results (*n* = 7) were excluded from year 2 analysis. Exclusion sample sizes were applied sequentially, so no previous exclusion was present.