Endoscopic Colorectal Cancer Screening: a Cost-Saving Analysis

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Background: **Comprehensive analyses have shown that screening for cancer usually induces net costs. In this study, the possible costs and savings of endoscopic colorectal cancer screening are explored to investigate whether the induced savings may compensate for the costs of screening.** ***Methods:*** **A simulation model for evaluation of colorectal cancer screening, MISCAN–COLON, is used to predict costs and savings for the U.S. population, assuming that screening is performed during a period of 30 years. Plausible baseline parameter values of epidemiology, natural history, screening test characteristics, and unit costs are based on available data and expert opinion. Important parameters are varied to extreme but plausible values.** ***Results:*** **Given the expert opinion-based assumptions, a program based on every 5-year sigmoidoscopy screenings could result in a net savings of direct health care costs due to prevention of cancer treatment costs that compensate for the costs of screening, diagnostic follow-up, and surveillance. This result persists when costs and health effects are discounted at 3%. The "break-even" point, the time required before savings exceed costs, is 35 years for a screening program that terminates after 30 years and 44 years for a screening program that continues on indefinitely. However, net savings increase or turn into net costs when alternative assumptions about natural history of colorectal cancer, costs of screening, surveillance, and diagnostics are considered.** ***Conclusions:*** **Given the present, limited knowledge of the disease process of colorectal cancer, test characteristics, and costs, it may well be that the induced savings by endoscopic colorectal cancer screening completely compensate for the costs. [J Natl Cancer Inst 2000;92:557–63]**

In the past, it has often been asserted that preventive medical services, including screening, are cost saving. The use of preventive services has sometimes been promoted to reduce health care costs. However, this claim generally has not been supported by detailed analysis. For instance, most well-conducted cost-effectiveness analyses of breast and cervical cancer screening find that the costs of screening tests, of diagnostic follow-up, and of treatment are much larger than the savings in treatment costs *(1–3)*.

Colorectal cancer is an important health problem in industrialized countries and comprises 11% of all cancer incidence and 13% of all cancer mortality in the United States *(4)*. Several modalities have been proposed to screen for this disease, including fecal occult blood test, flexible sigmoidoscopy, double-contrast barium enema, and colonoscopy *(5,6)*. Three fecal occult blood test trials using Hemoccult tests have shown a reduction in colorectal cancer mortality *(7–10)*. Economic evaluations linked to two of these trials have concluded that screening by fecal occult blood test is likely to be cost-effective but not cost saving *(11,12)*. Cost-effective means that the incremental cost of obtaining a unit of health effect from screening compared with no screening is below an accepted benchmark, while cost-saving interventions result in a net economic savings as well as a savings in quality-adjusted life-years *(13)*. The efficacy [i.e., the extent to which medical interventions achieve health improvement under ideal circumstances *(13)*] of endoscopic or barium enema screening has not yet been demonstrated by randomized controlled trials, although several case–control studies *(14–18)* suggest that endoscopic screening is associated with a substantial reduction in mortality from colorectal cancer. One reason that screening by endoscopy has been proposed as a supplement or alternative to fecal occult blood test screening is that the preventive effect of the former is likely to be larger. Invasive cancer and its associated high-treatment costs may be prevented through detecting and removing noninvasive adenomas that are generally believed to be precursors of colorectal cancer. The results of ongoing endoscopic trials are expected to become available in several years and will provide more definitive information on the magnitude of this preventive effect *(19–21)*. In this study, we estimate the costs and savings of endoscopic screening by use of a simulation approach.

Methods

The results are based on simulation outcomes of a detailed model for evaluation of colorectal cancer screening (MISCAN–COLON) that has been developed by the Department of Public Health at the Erasmus University Rotterdam, The Netherlands, in cooperation with the National Cancer Institute (NCI) in the United States *(22)*. The model is an adapted version of a microsimulation model previously used for the evaluation of breast and cervical cancer screening *(1,23–26)*. At two expert meetings at the NCI on June 5–7, 1996, and May 12–13, 1997, a model structure was devised in agreement with the currently accepted model of the adenoma–carcinoma sequence (*see* "Appendix" section for the participants of the expert meetings). The validity of this "expert" model is based on observational data, such as clinical incidence and mortality from colorectal cancer *(27)* and the size distribution of adenomas in autopsy studies *(28–32)*. The validity of this model has not been tested on a large longitudinal dataset because that is currently unavailable. A sensitivity analysis has been carried out for important uncertain parameters. If no published data are available for an estimate of a parameter, the estimate has been decided on by the expert panel during the two working meetings that were followed by an e-mail discussion. Using the MISCAN–COLON model *(22)*, it is possible to track costs and induced savings in a hypothetical screening program over an extended period of time.

In the following section, the structure of the expert model, the initial model parameter values, and the assumptions in the alternative variants are presented.

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See "Notes" following "References."

Expert Model

Structure of the model. In the microsimulation model, persons are simulated in whom one or more colorectal neoplastic lesions may develop. Each lesion is simulated separately, enabling each lesion to have its own natural history. Every lesion is located at a specific site in the colorectal tract, thus enabling simulation of the reach of endoscopic tests.

The disease stages that are distinguished in the adenoma–carcinoma sequence are shown in Fig. 1. The adenomas are categorized into size categories: less than or equal to 5 mm, 6–9 mm, and greater than or equal to 10 mm. Most of the adenomas will never grow into cancer in a lifetime. Progressive adenomas will grow into preclinical cancer and will eventually be clinically diagnosed, but a person may die of other causes before that age of clinical diagnosis. The preclinical and clinical invasive cancer stages are subdivided into American Joint Committee on Cancer/International Union Against Cancer stages I–IV *(33).* Clinical stage refers to the stage of cancer that is assigned on clinical detection. Preclinical stage refers to the stage that would be assigned on screen detection for a screen-detectable cancer, whether or not screening actually takes place.

Model of the situation in the absence of screening. It is assumed that all cancers are preceded by adenomas. The expert panel agreed on an estimate of the average sojourn time (i.e., the duration between onset of a progressive adenoma and the clinical diagnosis of subsequent cancer) of 20 years. The average duration of cancer in preclinical stages I–IV is 2 years, 1 year, 1.5 years, and 0.8 year, respectively, which results in a total average duration of 3.6 years because not every cancer reaches stage IV before clinical diagnosis. These sojourn times are based on the ratio between the stage-specific detection rate at first screening in fecal occult blood test trials and the background incidence, accounting for a 60% sensitivity of fecal occult blood test for all cancer stages *(9,10).* All durations are governed by an exponential probability distribution. Durations in each of the invasive cancer stages as well as durations in the stages of the noninvasive adenomas are assumed to be 100% associated with each other, but the durations in invasive stages as a whole are independent of durations in noninvasive adenoma stages that may precede cancer. These assumptions result in an exponential distribution of the total duration of progressive noninvasive adenomas and of the total duration of preclinical cancer, which has also been used in other cancer screening models *(34,35).* It is assumed that 30% of the cancers arise from adenomas of 6–9 mm and that 70% arise from larger adenomas.

The preclinical incidence of progressive adenomas has been chosen to reproduce the colorectal cancer incidence by age, stage, and localization in the United States in 1978 *(27).* During this period, almost no screening was performed. The size distribution of adenomas over all ages is assumed to be 56% for stages less than or equal to 5 mm, 24% for stages 6–9 mm, and 20% for stages greater than or equal to 10 mm *(28–32).* The preclinical incidence of nonprogressive adenomas that will never grow into cancer has varied until the simulated prevalence of all adenomas was about 15% in age group 50–59 years, 27% in age group 60–69 years, and 33% in age group 70 or more years, in agreement with data from the Kaiser study in Northern California *(36)* and with data from autopsy and colonoscopy studies *(28–32).* A good agreement with these data is achieved when 86% of the adenomas that arise before age 65 years are nonprogressive and the percentage of nonprogressive adenomas arising after age 65 years decreases gradually to 63% at age 75 years and to 4% at age 100 years. Each individual is assumed to have one level of risk to develop both progressive and nonprogressive adenomas. This risk index follows a gamma distribution where the variance is twice the mean, which results in an adenoma frequency distribution found in autopsies *(37).*

The anatomic site distribution of both progressive and nonprogressive adenomas and thus of preclinical and clinical cancers is assumed to be equal to the site distribution of colorectal cancers in the United States in 1978 *(27).* The mortality from other causes is assumed to be constant across the simulated years and equal to the mortality in the United States from 1989 through 1991. The stage-specific survival after the clinical diagnosis of colorectal cancer is taken from the Surveillance, Epidemiology, and End Results[1] registry data from 1975 through 1993 *(27).*

Characteristics of screening, surveillance, and diagnostic tests. The reach of screening sigmoidoscopy and surveillance colonoscopy is modeled by use of data from the Kaiser Northern California screening program *(38).* The sensitivity of surveillance colonoscopy for each lesion within realized reach is assumed to be 80% in adenomas less than or equal to 5 mm, 85% in adenomas 6–9 mm, and 95% in adenomas greater than or equal to 10 mm and cancers *(39,40).* The expert panel decided to assume the same sensitivity for sigmoidoscopy in lesions within reach of the test, except for a slightly lower value of 75% test sensitivity in adenomas less than or equal to 5 mm. After a positive test, all lesions will be removed within a short time. The percentage of the population without adenomas or cancer but with hyperplastic polyps, lipomas, or other lesions that lead to polypectomy and pathology after sigmoidoscopy or colonoscopy has been estimated from Kaiser data *(38):* 5% for sigmoidoscopy and 10% for colonoscopy. These percentages are assumed to be independent of the screening round.

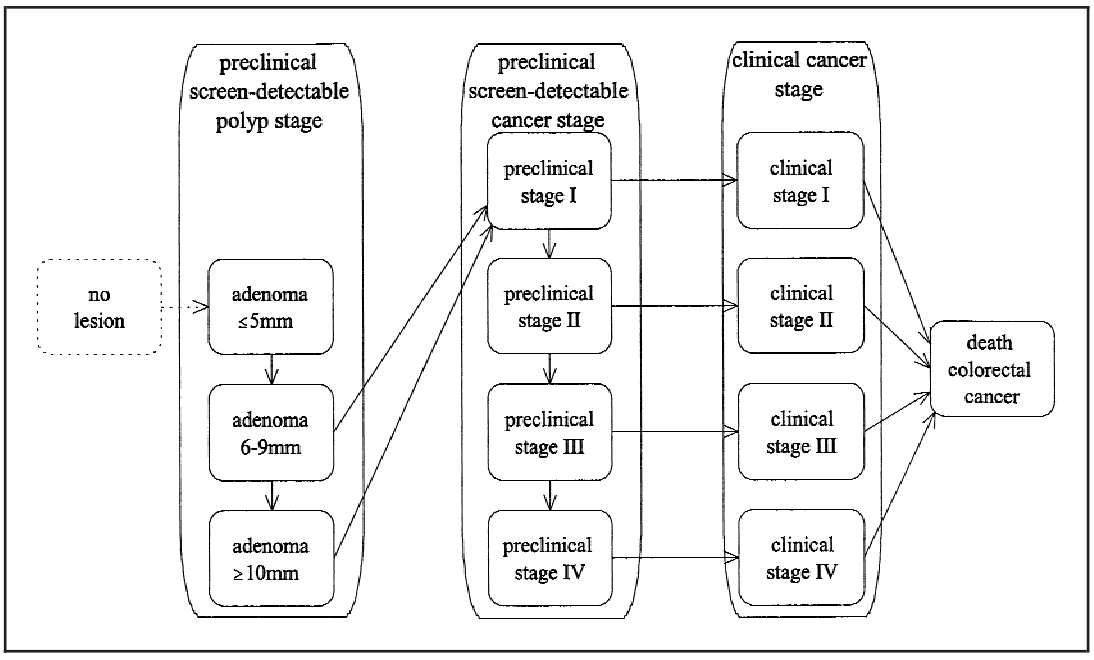

Fig. 1. Adenoma and cancer stages in the MISCAN–COLON microsimulation model. Cancer stages correspond to the American Joint Committee on Cancer/International Union Against Cancer staging system for colorectal cancer. Adenomas are categorized by size. The size-specific prevalence of adenomas as well as the proportion of adenomas that ever develop into cancer is dependent on age. In the expert model, it is assumed that the proportion of progressive adenomas increases from 16% at age 65 years, to 37% at age 75 years, and 96% at age 100 years. In the expert model, it is assumed that 50% of nonprogressive adenomas will remain in the 6- to 9-mm stage until death and 50% will progress to the greater than or equal to 10-mm stage. For progressive adenomas, it is assumed that 30% will develop through the sequence less than or equal to 5-mm adenoma→6- to 9-mm adenoma→preclinical stage I cancer and that 70% will develop through the sequence less than or equal to 5-mm adenoma→6- to 9-mm adenoma→greater than or equal to 10-mm adenoma→preclinical stage I cancer. The mean duration time for progressive adenomas is assumed to be 16.4 years (with an exponential distribution). The mean duration time for cancer is assumed to be 2 years (stage I), 1 year (stage II), 1.5 years (stage III), and 0.8 year (stage IV).

Survival after screen detection. The stage-specific survival of patients with screen-detected cancer is assumed to be the same as the survival of patients with cancers clinically diagnosed in the same stage *(9)*. Removal of an adenoma always prevents development of any subsequent cancer that may have arisen from this adenoma. The mortality from, but not the cost associated with, complications after colonoscopy is assumed to be negligible, because data indicate that this mortality is very low *(41)*.

Unit costs. Published estimates of the cost of screening flexible sigmoidoscopy range from $58 *(42)* to $150 *(43)*. The cost of sigmoidoscopy is assumed in this model to be $100. Estimates of colonoscopy without polypectomy range from $150 *(12,44)* to $1000 *(45)*, while estimates of the cost of colonoscopy with polypectomy and pathology range from $150 *(12)* to $1500 *(43)*. The lower estimates reflect unit cost as measured in organized European screening programs or in particular U.S. practices that have placed a premium on achieving efficient delivery of endoscopic procedures. The higher estimates are based on submitted charges in conventional practice settings, a source of data that are generally believed to overstate true costs. In this model, the cost of colonoscopy without polypectomy is assumed to be $300 and the cost of colonoscopy with polypectomy and pathology is $400. The rate of nonfatal complications by bowel perforation is assumed to be two per 1000 colonoscopies performed *(45,46)*, and a perforation induces $30 000 extra costs *(41,43)*.

The treatment costs of cancer are divided into three categories: 1) the costs for primary cancer treatment in the first 6 months ($25 000), 2) the costs of continuous care after primary treatment ($2200 per year), and 3) the costs of terminal care before death from colorectal cancer ($16 000 in the last 6 months) on the basis of health maintenance organization data *(47)*. Treatment costs of adenomas found during screening or surveillance are assumed to consist only of costs for polypectomy and pathology, thus incorporated in costs of diagnostic or surveillance colonoscopy. All costs are expressed, in real terms, in 1993 U.S. dollars; therefore, future costs are not inflated. Discounting, to convert future expenditures to present value, is performed at an annual discount rate of 3%, as recommended by the Panel on Cost-Effectiveness in Health and Medicine; i.e., dollars expended n years in the future are discounted by a factor of : $1/(1.03)^n$ *(13,48)*.

Screening strategy. Calculations are made for sigmoidoscopy screening, delivered at 5-year intervals between the ages of 50 and 75 years, i.e., six screenings. All positive screening tests are followed by a diagnostic colonoscopy. If no lesions or only adenomas less than or equal to 5 mm are found, a person will again be screened by sigmoidoscopy after 5 years. Persons in whom adenomas greater than or equal to 6 mm are found are invited for surveillance colonoscopy after 5 years, and surveillance is repeated until no lesions are found. Thereafter, one is screened according to the normal screening strategy.

Costs and savings. Costs and savings are calculated per person in a simulated dynamic population. The screening program is in operation from 1993 through 2023. Before 1993, individuals are simulated as described previously in the paragraph entitled "Model of the situation in the absence of screening." The simulated 1993 age distribution corresponds to the U.S. 1993 age distribution *(27)*. No births take place after 1993. All screening effects are accounted for by continuing the simulation until all individuals have died. The savings of primary treatment, continuous care, and terminal treatment are calculated as the difference in total costs of treatment of clinically diagnosed and screen-detected cancer in the situation with and without screening.

Model Variants

The impact of changes in major model assumptions on results is assessed in a sensitivity analysis (Table 1). It is not clear whether all cancers are preceded by adenomas or if some lesions grow directly into cancer without a preceding adenoma. Furthermore, the mean and variance of the dwelling time between onset of a progressive adenoma and clinical cancer are uncertain. Therefore, in one model variant, no variation is assumed in duration between the onset of a progressive adenoma and the clinical diagnosis of cancer, i.e., a fixed sojourn time of 20 years. In the other model, the average duration between the onset of a progressive adenoma and the clinical diagnosis of cancer of 20 years is changed to 10 years, and the percentage of cancers preceded by adenomas is decreased from 100% to 70%. The preclinical incidence of nonprogressive adenomas has been chosen to simulate the same adenoma prevalence and colorectal cancer incidence as in the basic expert model. The costs of screening and surveillance procedures are varied to 50% and 200% of the expert estimate because of the large range of published cost estimates.

RESULTS

In the first years of the screening program starting in 1993, approximately 50 individuals per 1000 in the U.S. population are screened, and the induced costs of sigmoidoscopy screening are $8500 per year per 1000 individuals in the population. Screening reduces the incidence in 2023 in the age group 50–84 years from 198 to 105 cases per 100 000 person-years, while mortality is reduced from 83 to 37 per 100 000 person-years. In the first years, the induced savings are negligible, and extra treatment costs are induced by the early detection of cancer. Later, treatment costs are saved because of prevention of cancers by removal of adenomas during screening. From the 5th year of the program onward, the yearly treatment costs with screening are lower than the treatment costs without screening. When the screening program finishes in year 30, "break-even" occurs by year 35: Cumulative undiscounted costs will be balanced by savings (Fig. 2). In the years after cessation of the program, screening costs have stopped, while treatment costs will still be saved. However, in a program of continuing screening, the break-even point will not be reached until the 44th year of the program, as shown in Fig. 2.

Table 2, A, shows that the 3% discounted costs of a 30-year program of every 5-year sigmoidoscopy screenings in the U.S. population are compensated by induced savings in a population setting, resulting in net costs of −$5 per person in the 1993 U.S. population. The costs involved in screening primarily consist of the costs of screening sigmoidoscopies, diagnostic colonoscopy after a positive test, and costs of surveillance after polypectomy. A large amount of costs are saved by the removal of a high-risk noninvasive adenoma and the prevention of subsequent cancer. For example, for a cohort of 50-year-old persons screened until death, the average undiscounted costs of every 5-year sigmoidoscopy screenings are $743 per person: $508 generated by screening tests, $179 by diagnostic tests, and $56 by surveillance. The average per-person savings in treatment are $1121: $629 saved in primary therapy, $271 in continuous care, and $221 in palliative care. Table 2, A, shows comparable results, averaged across all individuals in the entire U.S. population and discounted at 3% per year. Discounted per person costs averaged over the entire population are as follows: $129 generated by screening tests, $67 by diagnostic tests, and $12 by surveillance, for a total cost of $208. Savings in treatment are $213: $128 saved in primary therapy, $39 in continuous care, and $46 in palliative care.

Table 1. Assumptions in expert model and assumptions in alternative models

	Expert model	Alternative assumption
Dwelling time probability distribution type	Exponential	Constant
Mean dwelling time between onset and clinical diagnosis of cancer	20 y	10 y
Percentage of cancers preceded by an adenoma	100%	70%
Unit cost of sigmoidoscopy	$100	$50, $200
Unit cost of colonoscopy without polypectomy	$300	$150, $600
Unit cost of colonoscopy with polypectomy	$400	$200, $800

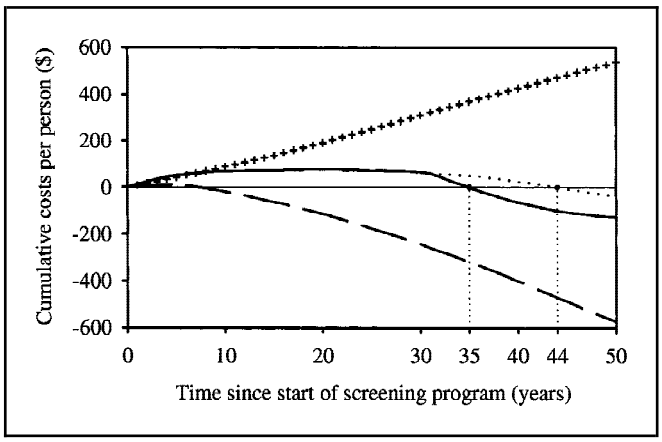

Fig. 2. Expert model results of every 5-year sigmoidoscopy screenings: cumulative undiscounted costs and savings as a function of program years of operation. Break-even (costs = savings) occurs at year 35 for a program that terminates screening at year 30. Break-even occurs at year 44 for a program that continues screening indefinitely. +++++ = cumulative costs of screening, diagnostics, and surveillance of an ongoing program; — — = cumulative difference in treatment costs for screening compared with no screening; ····· = net total costs of an ongoing program; and —— = net total costs of a program that terminates screening after year 30.

Table 2. Three percent discounted induced costs and savings of every 5-year sigmoidoscopy screening in age group 50–75 years from 1993 through 2023 per person in the total U.S. population in 1993*

A. Expert model results

Costs of screening, $	129	
Costs of colonoscopic diagnostics during screening, including polypectomy and complications, $	67	
Costs of surveillance, including polypectomy and complications, $	12	
Total induced costs, $ (95% CI)		208 (207–208)
Savings of primary treatment costs, $	128	
Savings of continuous care, $	39	
Savings of terminal treatment, $	46	
Total induced savings, $ (95% CI)		213 (221–210)
Net costs, $ (95% CI)		−5 (−13 to −2)
Life-years gained per 1000 persons		28

B. Results of alternative models

Variant	Total costs, $	Total induced savings, $	Net costs, $
Expert model	208	213	−5
Alternative models			
Constant dwelling time	200	437	−236
10 y of dwelling time of progressive lesions and 70% of cancers preceded by adenomas	195	137	+58
Low screening and surveillance costs	103	213	−110
High screening and surveillance costs	386	213	+173

*95% CI = 95% confidence interval (because of stochastic output).

Table 2, B, shows the 3% discounted costs and savings of alternative model variants. Compared with the expert model, the savings of treatment in the variant with a constant sojourn time (20 years) are doubled, resulting in increased cost savings from screening from $5 to $236. This is caused by the absence of fast-growing adenomas that have only a small chance to be detected by screening. In the expert model with exponentially distributed sojourn times, 26% become cancerous within 5 years. In contrast, with a constant sojourn time assumption (an extreme example of a situation with less variability in dwelling times than in the expert model), all progressive lesions are present as noninvasive adenomas for 16 years. In these years, an adenoma can be detected by up to three screening opportunities.

In the variant that assumes a mean value of 10 years for the exponentially distributed sojourn time and assumes that only 70% of the cancers are preceded by an adenoma, the induced savings of treating cancers are lower than in the expert model because sigmoidoscopy has less chance to detect a precancerous lesion before it develops into preclinical cancer. In this variant, 70% of the costs of screening, surveillance, and diagnostic tests are compensated for by induced savings, and the net costs are positive (+$58). Clearly, the outcomes are sensitive to assumptions about the natural history of the adenoma–cancer sequence.

In the variant with lower unit costs of screening, surveillance, and diagnostic tests, the total induced costs are lower than those in the expert model, resulting in increased cost savings compared with the base case. In the variant with higher screening costs, the total induced costs are almost doubled, and only 55% of the induced costs by screening, surveillance, and diagnostic tests are compensated for by the induced savings.

DISCUSSION

The results of this study are meaningful because similar analyses of screening programs for breast and cervical cancers *(1,2)* have not demonstrated potential cost savings under any reasonable set of assumptions. The different results for colorectal cancer screening follow for at least two reasons. First, the cost of colorectal cancer treatment is much higher than an endoscopic procedure during which adenomas can be removed. Therefore, the potential savings for an individual in whom colorectal cancer is prevented because of endoscopy are large, in contrast with breast cancer screening where all targeted lesions are cancerous and require extensive cancer treatment. Second, the incidence of colorectal cancer is relatively high and thus the number of preventable cancers is considerable, unlike the case of cervical cancer, where the background incidence is low, at least in industrialized countries where screening is most active.

In screening, costs are induced a number of years before the potential savings in treatment. Discounting reduces the weight of future savings of preventive measures relative to the costs of the intervention. Therefore, discounted net cost savings are achieved only if the undiscounted savings are considerably larger than the costs. Endoscopic colorectal cancer screening might be one instance of secondary prevention where the 3% discounted induced savings are of the same magnitude or even larger than the induced costs. A discount rate of 3% is recommended by the Panel on Cost-Effectiveness in Health and Medicine. The net costs per person in the baseline model change to −$146 with 0% discounting and to $28 with 5% discounting.

Our analysis assumes stability of important model parameters over an extended period of time. If changes in

screening test characteristics or the costs and benefits of treatment occur in the future, the economic implications of the screening policy would need to be reconsidered. If screening test characteristics improve or screening tests become cheaper, net savings would increase, while better or cheaper treatment would make screening less worthwhile. Individual health-care provider organizations might find the prospect of cost savings in the relatively distant future less compelling, especially if the cost savings are likely to be realized by a public program such as Medicare rather than the private health provider who finances screening. However, these problems of time horizon of health benefits are shared by other preventive health programs as well. Furthermore, even if colorectal cancer screening does not save costs from the perspective of private health-care provider organizations, it may still be worthwhile because the effects are likely to be large and the costs relatively small, resulting in a favorable cost-effectiveness ratio.

The results should be seen as preliminary because considerable uncertainty currently exists about the progression of precursor lesions. Better estimates of the distribution of the sojourn time of progressive adenomas and the sensitivity of endoscopic tests will be available after analysis of the results of endoscopic screening trials *(19,20,49)* in coming years. Meanwhile, the assumptions in the presented model are being validated against data from other colorectal cancer screening studies, such as the Minnesota Cancer Control Study of Fecal Occult Blood Screening *(7)*, the Kaiser program of sigmoidoscopy screening in Northern California *(36)*, and the National Polyp Study of Colonoscopic Surveillance *(50,51)*. The validation studies are expected to provide more information about the natural history of colorectal cancer and thus about the potential savings in treatment costs that are brought about by removal of the preceding adenoma.

The present results also depend on the relatively low unit costs of sigmoidoscopy and colonoscopy. We believe that these unit cost assumptions are plausible, especially within the context of a screening program designed to be based on dedicated screening and follow-up clinics, as in the Prostate, Lung, Colorectal and Ovarian Cancer Screening Trial of the NCI *(52)*. When screening is introduced on a large scale, the tests could also be delivered by mid-level health professionals *(53)*. In our baseline model, cost saving no longer occurs at procedure costs that are double our base case, of similar magnitude to those incurred in a traditional low-volume office setting *(42)*. This result underlines the need to investigate the true cost of sigmoidoscopy and colonoscopy in organized high-volume settings *(19,36,52)*. Our results are based on an idealized screening policy with 100% screening compliance of the population. If compliance is lower, screening induces the same amount of costs and savings per screenee as in the 100% compliance model, as long as compliers do not differ systematically. If noncompliers occasionally comply, the balance of costs and savings is more favorable because less intensive screening results in a more favorable cost-savings balance. We have not considered the out-of-pocket and time costs incurred by individuals to undergo screening and diagnostic procedures, as recommended by Gold et al. *(13)* or the perhaps considerable savings of such costs due to avoidance of cancer treatment for some screened individuals. Nor have we considered the costs associated with the promotion of screening. In an efficiently designed screening program, such costs should be a fraction of the costs of the initial screening procedures costs; however, there is, to date, little documented information on the actual magnitude of promotional costs for colorectal cancer screening.

The diagnostic follow-up and surveillance protocols incorporated into the expert model are consistent with the results of the National Polyp Study *(50)* and current practice guidelines *(6)*. These are areas of continuing clinical controversy, and it is likely that current practice is more aggressive than is assumed in our model. However, there is little documentation of the variation in current practice. Future modeling work, taking advantage of emerging data in this area *(53)*, may be useful in clarifying the trade-off between economic savings and clinical risk when comparing alternative approaches to diagnostic follow-up and surveillance. We have not attempted to determine what an optimally efficient program might be in terms of different ages of initiating and terminating screening, differential recruitment of higher risk populations, or combinations of several endoscopic screening modalities by age. More detailed modeling may possibly reveal a screening strategy that is more efficient under baseline assumptions than the one we have modeled.

The costs of colorectal cancer screening have also been assessed in other models *(11,12,41,43,54,55)*, two of which assessed the costs and savings of sigmoidoscopy screening. None of these studies found negative costs of screening, and all concluded that screening may be cost-effective. Our conclusions about the potential cost savings of endoscopic screening are not inconsistent with other modeling results when differences in assumptions and structure are taken into account.

According to the model of the Office of Technology Assessment of the U.S. Congress *(41,55)*, every 5-year sigmoidoscopy screenings after age 50 years generate 5% discounted net costs of $378 per screened person, assuming that only 70% of the cancers are preceded by adenomas and that the mean duration of progressive adenomas is 10 years. This percentage is higher than our 3% discounted net costs estimate of $58 per person in the whole population when we assume the same percentage of cancers preceded by adenomas and the same mean duration of progressive adenomas. If we use the same discount rate of 5% and calculate the costs per person in the screening ages, our estimate is $271. Furthermore, in the Office of Technology Assessment model, more latent cancers (i.e., preclinical cancers that would never have been clinically diagnosed) are detected by screening than in our model. Lieberman *(43)* assessed the costs of sigmoidoscopy screening at age 55 years followed by another sigmoidoscopy at age 60 years if the first screening was negative. He found net costs of this screening program of $1355 per screenee compared with $677 costs of colorectal cancer treatment without screening, resulting in $678 net costs of screening. These net costs are high compared with our estimated net costs and are explained by the high unit costs in the Lieberman model: $1000 for colonoscopy without polypectomy, $1500 with polypectomy, and $150 for screening sigmoidoscopy.

This study shows that endoscopic colorectal cancer screening has the potential to be cost saving. The preliminary results of this study support the importance of ongoing and newly initiated endoscopic screening trials.

APPENDIX

Participants in MISCAN–COLON Expert Model Meetings: Marjolein van Ballegooijen, Rob Boer, J. D. F. Habbema, Franka Loeve (Erasmus University, Rotterdam, The Netherlands); Martin L. Brown, Eric J. Feuer, Julie Legler (National Cancer Institute, Bethesda, MD); Timothy R. Church (University of Minnesota, Minneapolis); Chris J. Colby, Joseph V. Selby (Kaiser Permanente, Northern California); Paul A. Fishman, Margaret Mandelson (Center for Health Studies, Group Health Cooperative of Puget Sound); Matthew Gable, Nicole Urban (Fred Hutchinson Cancer Research Center, Seattle, WA); Bernard Levin (The University of Texas M. D. Anderson Cancer Center, Houston); David A. Lieberman (Portland Veterans Administration Medical Center, OR); Scott Ramsey (University of Washington, Seattle); Judith L. Wagner (Congressional Budget Office); and Ann G. Zauber (Memorial Sloan-Kettering Cancer Center, New York, NY).

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NOTES

[1]SEER is a set of geographically defined, population-based, central cancer registries in the United States, operated by local nonprofit organizations under contract to the National Cancer Institute (NCI). Registry data are submitted electronically without personal identifiers to the NCI on a biannual basis, and the NCI makes the data available to the public for scientific research.

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