ORIGINAL INVESTIGATION

The Appropriateness of More Intensive Colonoscopy Screening Than Recommended in Medicare Beneficiaries
A Modeling Study

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IMPORTANCE Many Medicare beneficiaries undergo more intensive colonoscopy screening than recommended. Whether this is favorable for beneficiaries and efficient from a societal perspective is uncertain.

OBJECTIVE To determine whether more intensive colonoscopy screening than recommended is favorable for Medicare beneficiaries (ie, whether it results in a net health benefit) and whether it is efficient from a societal perspective (ie, whether the net health benefit justifies the additional resources required).

DESIGN, SETTING, AND PARTICIPANTS Microsimulation modeling study of 65-year-old Medicare beneficiaries at average risk for colorectal cancer (CRC) and with an average life expectancy who underwent a screening colonoscopy at 55 years with negative results.

INTERVENTIONS Colonoscopy screening as recommended by guidelines (ie, at 65 and 75 years) vs scenarios with a shorter screening interval (5 or 3 instead of 10 years) or in which screening was continued to 85 or 95 years.

MAIN OUTCOMES AND MEASURES Quality-adjusted life-years (QALYs) gained (measure of net health benefit); additional colonoscopies required per additional QALY gained and additional costs per additional QALY gained (measures of efficiency).

RESULTS Screening previously screened Medicare beneficiaries more intensively than recommended resulted in only small increases in CRC deaths prevented and life-years gained. In comparison, the increases in colonoscopies performed and colonoscopy-related complications experienced were large. As a result, all scenarios of more intensive screening than recommended resulted in a loss of QALYs, rather than a gain (ie, a net harm). The only exception was shortening the screening interval from 10 to 5 years, which resulted in 0.7 QALYs gained per 1000 beneficiaries. However, this scenario was inefficient because it required no less than 909 additional colonoscopies and an additional $711,000 per additional QALY gained. Results in previously unscreened beneficiaries were slightly less unfavorable, but conclusions were identical.

CONCLUSIONS AND RELEVANCE Screening Medicare beneficiaries more intensively than recommended is not only inefficient from a societal perspective; often it is also unfavorable for those being screened. This study provides evidence and a clear rationale for clinicians and policy makers to actively discourage this practice.
All guidelines for colorectal cancer (CRC) screening recommend a screening interval of 10 years for colonoscopy screening in average-risk individuals. Moreover, the US Preventive Services Task Force and the American College of Physicians recommend against routine screening in adults older than 75 years with an adequate screening history. Whereas CRC screening is well known to be underused by many Medicare beneficiaries, recent studies have also demonstrated that many beneficiaries undergo more intensive colonoscopy screening than recommended: 1 in 5 beneficiaries with a negative screening colonoscopy result undergoes a repeated screening colonoscopy within 5 years' time instead of after 10 years. Furthermore, 1 in 4 beneficiaries with a negative screening colonoscopy result at 75 years or older receives yet another screening colonoscopy at an even more advanced age. Although the reasons for these practices vary, on some occasions they are likely to result from the beneficiary's or doctor's perception that screening should occur more frequently than recommended. However, whether such practices are actually favorable for Medicare beneficiaries (ie, whether they result in a net health benefit) is uncertain: The low risk for CRC after a negative screening colonoscopy result limits the life-years (LYs) that can be gained by applying a shorter screening interval than recommended, whereas the high risk for other-cause mortality at advanced age limits the LYs that can be gained by continuing screening beyond 75 years. On the other hand, both practices will substantially increase the number of colonoscopies performed and, hence, the number of colonoscopy-related complications experienced. Moreover, continuing screening beyond 75 years might substantially increase overdiagnosis and overtreatment of CRC (ie, the detection and treatment of cancers that would not have been diagnosed without screening). As a result, more intensive screening than recommended might be associated with a balance among benefits, burden, and harms that is unfavorable for Medicare beneficiaries: it might negatively affect health.

If more intensive screening than recommended is favorable for Medicare beneficiaries, the subsequent question is whether it is efficient from a societal perspective (ie, whether the net health benefit justifies the additional colonoscopies and financial resources required). This is important because both colonoscopy capacity and financial resources are constrained.

The objective of this study was to determine whether more intensive colonoscopy screening than recommended is favorable for Medicare beneficiaries and, if so, whether it is efficient from a societal perspective. In a prior analysis, we already demonstrated that applying a screening interval of 5 instead of 10 years and continuing screening beyond 75 years result in a small increase in LYs gained relative to the increase in colonoscopies performed in those starting screening at 50 years. In this study, we extend this work by determining the net health benefit and cost-effectiveness of screening. Moreover, in our current analysis, we focus on the Medicare population. Analyses were performed using the microsimulation model MISCAN-Colon (Microsimulation Screening Analysis–Colon).

Methods

MISCAN-Colon

MISCAN-Colon is a well-established microsimulation model for CRC developed at the Department of Public Health of the Erasmus University Medical Center (Rotterdam, the Netherlands). The model's structure, underlying assumptions, and calibration are described in eAppendix 1 in the Supplement. In brief, MISCAN-Colon simulates the life histories of a large population of persons from birth to death. As each simulated person ages, 1 or more adenomas may develop. These adenomas can progress from small (<5 mm in diameter) to medium (6-9 mm) to large size (≥10 mm). Some adenomas can develop into preclinical cancer, which may progress through stages I to IV. During each stage, CRC may be diagnosed because of symptoms. Survival after clinical diagnosis is determined by the stage at diagnosis, the localization of the cancer, and the person's age.

Screening will alter some of the simulated life histories: Some cancers will be prevented by the detection and removal of adenomas; other cancers will be detected in an earlier stage with a more favorable chance of survival. However, screening can also result in serious complications and overtreatment of CRC. By comparing all life histories with screening with the corresponding life histories without screening, MISCAN-Colon quantifies the effectiveness and efficiency of screening.

MISCAN-Colon was calibrated to the age-specific, stage-specific, and localization-specific incidence of CRC as observed before the introduction of screening and the age-specific prevalence and multiplicity distribution of adenomas as observed in autopsy studies. The preclinical duration of CRC and the adenoma dwell time were calibrated to the rates of interval cancers and surveillance-detected cancers observed in randomized clinical trials evaluating screening using guaiac fecal occult blood tests and a once-only sigmoidoscopy.

Model Inputs

Populations Simulated

We simulated 2 cohorts of 10 million 65-year-old Medicare beneficiaries. In the first cohort, all beneficiaries had received a negative screening colonoscopy result at 55 years (ie, were up-to-date with screening recommendations). In the second cohort, all beneficiaries were previously unscreened. For both cohorts, we assumed the average population risk for CRC and an average life expectancy.

Screening Scenarios

In both cohorts we simulated “recommended screening” (ie, colonoscopy screening at 65 and 75 years), as well as 2 scenarios in which a shorter screening interval was applied: (1) screening at a 5-year interval (screening at 65, 70, and 75 years) and (2) screening at a 3-year interval (screening at 65, 68, 71, and 74 years). Furthermore, we simulated 2 scenarios of continued screening beyond 75 years: (1) screening up to 85 years (screening at 65, 75, and 85 years) and (2) screening up to 95 years (screening at 65, 75, 85, and 95 years). Beneficia-
Figure 1. Model Inputs: Age-Specific Risks for Complications Associated With Colonoscopies With Polypectomy

Derived by performing additional statistical analyses on Medicare data used in a study by Warren et al.\textsuperscript{16} (eAppendix 2 in the Supplement). Only complications necessitating hospitalization or an emergency department visit were considered.

- Perforations, gastrointestinal bleeding, or complications necessitating transfusions; risk per colonoscopy = 1/(exp\(9.09053 - 0.06105 \times \text{Age}\) + 1).
- Paralytic ileus, nausea and vomiting, dehydration, abdominal pain; risk per colonoscopy = 1/(exp\(8.81404 - 0.05903 \times \text{Age}\) + 1).
- Myocardial infarction or angina, arrhythmias, congestive heart failure, cardiac or respiratory arrest, syncope, hypotension, or shock; risk per colonoscopy = 1/(exp\(9.09053 - 0.07056 \times \text{Age}\) + 1).
- Other gastrointestinal complications\textsuperscript{b}.
- Cardiovascular complications\textsuperscript{c}.

Costs Associated With Colonoscopy Screening

We assumed a utility loss (ie, a loss of quality of life) equivalent to 2 days of life per colonoscopy (0.0055 quality-adjusted life-years [QALYs]) and 2 weeks of life per complication (0.0384 QALYs).\textsuperscript{11} We also assigned a utility loss to each LY with CRC care.\textsuperscript{40} Assigning utility losses to LYS with CRC care works 2 ways: On the one hand, screening prevents cancers by the detection and removal of adenomas. This reduces LYS with CRC care and, hence, results in a gain of quality of life. On the other hand, screening results in earlier detection and overdiagnosis and overtreatment of cancers. This adds LYS with CRC care and, hence, results in a loss of quality of life. The resulting net impact on quality of life can be either positive or negative.

Outcomes and Analysis

For each scenario of more intensive screening than recommended, we determined the associated increase in CRC cases prevented, CRC deaths prevented, LYs gained, LYs with CRC care prevented, colonoscopies performed, and complications experienced. Subsequently, we determined the resulting increases in QALYS gained; the net health benefit of screening. If more intensive screening resulted in a gain of QALYS, it was considered favorable for Medicare beneficiaries; if it resulted in a loss of QALYS, it was considered unfavorable. In a second step, we determined the increase in costs associated with all scenarios simulated. For those scenarios that were favorable for Medicare beneficiaries, we related the increases in colonoscopies performed and costs to the increase in QALYS gained to determine the efficiency of screening.

We present both undiscounted and discounted results (applying the conventional 3% annual discount rate for both effects and resources required). We based our conclusions on the discounted results. Screening strategies associated with an incremental cost per QALY gained exceeding $100 000 (discounted) were considered inefficient.

Sensitivity Analyses

We repeated our analysis assuming (1) half and twice the base-case utility losses for colonoscopies and colonoscopy-related complications; (2) no utility loss for LYS with continuing care for CRC and a utility loss of 0.12, 0.18, 0.24, and 0.70 QALYS.

The sensitivity of colonoscopy for the detection of adenomas and CRC was obtained from a systematic review on miss rates observed in tandem colonoscopy studies and was 75% for small adenomas (≤5 mm in diameter), 85% for medium-sized adenomas (6-9 mm), and 95% for large adenomas (≥10 mm) and CRC.\textsuperscript{30} We assumed that 95% of all colonoscopies reached the cecum; for the remaining 5%, the reach of the procedure was assumed to be distributed uniformly over colon and rectum.

Complications of Colonoscopy

Age-specific risks for gastrointestinal and cardiovascular complications associated with colonoscopy were derived by performing additional statistical analyses on Medicare data used in a study by Warren and colleagues\textsuperscript{16} (eAppendix 2 in the Supplement). According to these analyses, colonoscopies with polypectomy were associated with an excess risk for complications, whereas colonoscopies without polypectomy were not. The risks associated with colonoscopies with polypectomy increased exponentially with age (Figure 1). Only complications necessitating hospitalization or an emergency department visit were considered. We assumed that 1 of every 30 000 colonoscopies involving a polypectomy resulted in death.\textsuperscript{16-37}

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Results

Previously Screened Beneficiaries

Benefits, Burden, and Harms

Screening Medicare beneficiaries with a negative screening colonoscopy result at 55 years according to current guideline recommendations (ie, colonoscopy screening at 65 and 75 years) resulted in 14.1 CRC cases prevented, 7.7 CRC deaths prevented, and 63.1 LYs gained per 1000 beneficiaries, compared with no screening (ie, a mean of 23.0 days per beneficiary) (Figure 2A-C). Moreover, recommended screening prevented 37.5 LYs with CRC care per 1000 beneficiaries (Figure 2D). To achieve this effect, 2131 colonoscopies had to be performed, causing 8.3 complications (Figure 2E and F).

Compared with screening every 10 years, screening every 5 years resulted in 1.7 additional CRC cases prevented, 0.6 additional CRC deaths prevented, and 5.8 additional LYs gained per 1000 beneficiaries (ie, a mean of 2.1 additional days of life per beneficiary). Moreover, screening every 5 years prevented 10.9 additional LYs with CRC care per 1000 beneficiaries. To achieve this relatively small added benefit, 783 additional colonoscopies had to be performed, causing 1.3 additional complications. Continuing screening up to 85 instead of 75 years resulted in even fewer additional CRC cases prevented, CRC deaths prevented, and LYs gained: 0.2, 0.3, and 1.2 per 1000 beneficiaries (ie, a mean of 0.4 additional days of life per beneficiary), respectively. To achieve this marginal additional benefit, 369 additional colonoscopies had to be performed, causing 2.4 additional complications. Furthermore, instead of preventing additional LYs with CRC care, screening up to 85 instead of 75 years increased the number of LYs with CRC care. Further intensifying screening by reducing the screening interval to 3 years or by continuing screening up to 95 years resulted in even smaller increases in the benefits of screening, also relative to the corresponding increases in burden and harms (Figure 2).

Net Health Benefit

In previously screened beneficiaries, recommended screening resulted in 63.1 LYs gained per 1000 beneficiaries, compared with no screening (Table 2). On top of that, screening resulted in 13.4 QALYs gained per 1000 beneficiaries through lost for each LY with continuing care for stage I, II, III, and IV CRC, respectively; (3) twice the base-case miss rates for LYs with CRC care; (4) twice the base-case miss rates for proximal adenomas and CRC44-47; and (5) twice the base-case miss rates for all adenomas and CRCs. Furthermore, to determine the extent to which our results were driven by more intensive screening rather than more beneficiaries entering surveillance, we repeated our analysis assuming 0% adherence to surveillance (ie, the opportunity costs of spending time on screening or being treated for a complication or CRC) but do not include travel costs, costs of lost productivity, and unrelated health care and non-health care costs in added years of life. We assumed that the value of patient time was equal to the median wage rate in 2012: $16.71 per hour.48 We assumed that colonoscopies and complications used up 8 and 16 hours of patient time, respectively. Patient time costs were already included in the estimates for the costs of LYs with CRC care obtained from a study by Yabroff and colleagues.49 Care for CRC was divided into 3 clinically relevant phases: initial, continuing, and terminal care. The initial care phase was defined as the first 12 months after diagnosis; the terminal care phase was defined as the final 12 months of life; and the continuing care phase was defined as all months in between. In the terminal care phase, we distinguished between CRC patients dying of CRC and CRC patients dying of another cause. For patients surviving less than 24 months, the final 12 months were allocated to the terminal care phase and the remaining months were allocated to the initial care phase. A patient who receives a diagnosis of CRC at 65 years who dies of CRC at 70 years will be in the initial care phase from 65 to 66 years, in the continuing care phase from 66 to 69 years, and in the terminal care phase associated with death of CRC from 69 to 70 years. Patients with CRC who do not die of CRC will be in the continuing care phase from 1 year after diagnosis until 1 year before death of another cause.

Utility losses for LYs with initial care were derived from a study by Ness and colleagues.50 For LYs with continuing care for stage I and II CRC, we assumed a utility loss of 0.05 QALYs; for LYs with continuing care for stage III and IV CRC, we assumed the corresponding utility losses for LYs with initial care. For LYs with terminal care for CRC, we assumed the utility loss for LYs with initial care for stage IV CRC. For LYs with terminal care for another cause, we assumed the corresponding utility losses for LYs with continuing care.

Abbreviations: CRC, colorectal cancer; ellipses, not applicable; LY, life-year; QALY, quality-adjusted life-year.

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Table 1. Model Inputs: Utility Losses and Costs Associated With Colonoscopy Screening

<table>
<thead>
<tr>
<th>Event</th>
<th>Utility Loss, QALY$ab</th>
<th>Cost, $b</th>
<th>Utility Loss, QALY$ab</th>
<th>Cost, $b</th>
<th>Utility Loss, QALY$ab</th>
<th>Cost, $b</th>
<th>Utility Loss, QALY$ab</th>
<th>Cost, $b</th>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without polypectomy and/or biopsy</td>
<td>0.0055</td>
<td>887</td>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>With polypectomy and/or biopsy</td>
<td>0.0055</td>
<td>1096</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Complication of colonoscopy</td>
<td>0.038</td>
<td>6045</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>LY with CRC care$cd</td>
<td>Initial Care</td>
<td>Continuing Care</td>
<td>Terminal Care, CRC Death</td>
<td>Terminal Care, Other-Cause Death</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage I</td>
<td>0.12</td>
<td>36 683</td>
<td>0.05</td>
<td>3050</td>
<td>0.70</td>
<td>63 809</td>
<td>0.05</td>
<td>19 176</td>
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<tr>
<td>Stage II</td>
<td>0.18</td>
<td>49 234</td>
<td>0.05</td>
<td>2870</td>
<td>0.70</td>
<td>63 555</td>
<td>0.05</td>
<td>17 279</td>
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<tr>
<td>Stage III</td>
<td>0.24</td>
<td>59 759</td>
<td>0.24</td>
<td>4021</td>
<td>0.70</td>
<td>67 041</td>
<td>0.24</td>
<td>21 457</td>
</tr>
<tr>
<td>Stage IV</td>
<td>0.70</td>
<td>77 790</td>
<td>0.70</td>
<td>12 178</td>
<td>0.70</td>
<td>88 368</td>
<td>0.70</td>
<td>49 866</td>
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</table>

Downloaded From: http://archinte.jamanetwork.com/pdfaccess.ashx?url=/data/journals/intemed/930927/ on 06/18/2017
Figure 2. Increases in Benefits, Burden, and Harms Associated With More Intensive Colonoscopy Screening Than Recommended in Medicare Beneficiaries With a Negative Screening Colonoscopy Result at 55 Years

A-D, Benefits; E and F, burden and harms. Numbers are per 1000 beneficiaries and undiscounted. CRC indicates colorectal cancer; LY, life-year.

For each scenario, the distribution of additional LYs with CRC care prevented over the different phases of care and stages of CRC is given in eAppendix 3 in the Supplement.

Complications necessitating hospitalization or an emergency department visit were considered.

Preventing LYs with CRC care. However, to achieve these benefits, colonoscopies had to be performed, resulting in a loss of 11.7 QALYs per 1000 beneficiaries. Furthermore, these colonoscopies caused complications, resulting in a loss of another 0.3 QALYs per 1000 beneficiaries. Hence, recommended screening resulted in a net health benefit of $63.1 + 13.4 - 11.7 - 0.3 = 64.5$ QALYs gained per 1000 beneficiaries.

When a screening interval of 5 instead of 10 years was applied, the gain in quality of life by preventing additional LYs with CRC care was exceeded by the loss of quality of life...
due to additional colonoscopies and additional complications. As a result, applying a screening interval of 5 instead of 10 years resulted in fewer QALYs than LYs gained: 3.2 vs 5.8 per 1000 beneficiaries. When screening was continued up to 85 instead of 75 years, the overall loss of quality of life exceeded the associated increase in LYs gained. Hence, continuing screening up to 85 instead of 75 years resulted in a loss of QALYs rather than a gain. Both applying a screening interval of 3 instead of 5 years and continuing screening up to 95 instead of 85 years also negatively affected the number of QALYs gained by screening. Discounting did not change the direction of the effect on QALYs gained for any of the scenarios simulated.

### Table 2. Net Health Benefit of More Intensive Colonoscopy Screening Than Recommended in Medicare Beneficiaries With a Negative Screening Colonoscopy Result at 55 Years

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Per 1000 Beneficiaries</th>
<th>Impact on Quality of Life, QALYs Gained*</th>
<th>Net Health Benefit, QALYs Gained† (A+B+C+D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LYs Gainedb (A)</td>
<td>LYs With CRC Carec (B)</td>
<td>Colonoscopies (C)</td>
</tr>
<tr>
<td>Undiscounted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended screening*</td>
<td>63.1</td>
<td>13.4</td>
<td>−11.7</td>
</tr>
<tr>
<td>Applying shorter screening intervals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 yf,g</td>
<td>5.8</td>
<td>1.8</td>
<td>−4.3</td>
</tr>
<tr>
<td>3 yh</td>
<td>1.6</td>
<td>0.7</td>
<td>−4.3</td>
</tr>
<tr>
<td>Continuing screening beyond 75 y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 85 yl</td>
<td>1.2</td>
<td>0.1</td>
<td>−2.0</td>
</tr>
<tr>
<td>To 95 ym</td>
<td>0.0</td>
<td>−0.0</td>
<td>−0.4</td>
</tr>
<tr>
<td>3% Discounted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended screening*</td>
<td>36.0</td>
<td>7.7</td>
<td>−9.9</td>
</tr>
<tr>
<td>Applying shorter screening intervals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 yf</td>
<td>3.4</td>
<td>1.1</td>
<td>−3.7</td>
</tr>
<tr>
<td>3 yh</td>
<td>1.0</td>
<td>0.5</td>
<td>−3.9</td>
</tr>
<tr>
<td>Continuing screening beyond 75 y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 85 yl</td>
<td>0.5</td>
<td>0.0</td>
<td>−1.1</td>
</tr>
<tr>
<td>To 95 ym</td>
<td>0.0</td>
<td>−0.0</td>
<td>−0.2</td>
</tr>
</tbody>
</table>

### Table 3. Efficiency of More Intensive Colonoscopy Screening Than Recommended in Medicare Beneficiaries With a Negative Screening Colonoscopy Result at 55 Years

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Per 1000 Beneficiaries</th>
<th>Net Health Benefit, QALYs Gainedd (A+B+C+D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>QALYs Gained</td>
<td>Colonoscopies, No.</td>
</tr>
<tr>
<td>Undiscounted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended screening*</td>
<td>64.5</td>
<td>2131</td>
</tr>
<tr>
<td>Applying shorter screening intervals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 yf,g</td>
<td>3.2</td>
<td>783</td>
</tr>
<tr>
<td>3 yh</td>
<td>−2.1</td>
<td>781</td>
</tr>
<tr>
<td>Continuing screening beyond 75 y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To 85 yl</td>
<td>−0.8</td>
<td>369</td>
</tr>
<tr>
<td>To 95 ym</td>
<td>−0.4</td>
<td>69</td>
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<tr>
<td>3% Discounted</td>
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<tr>
<td>Recommended screening*</td>
<td>33.6</td>
<td>1815</td>
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<tr>
<td>Applying shorter screening intervals</td>
<td></td>
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<tr>
<td>5 yf</td>
<td>0.7</td>
<td>675</td>
</tr>
<tr>
<td>3 yh</td>
<td>−2.5</td>
<td>711</td>
</tr>
<tr>
<td>Continuing screening beyond 75 y</td>
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<tr>
<td>To 85 yl</td>
<td>−0.6</td>
<td>203</td>
</tr>
<tr>
<td>To 95 ym</td>
<td>−0.2</td>
<td>28</td>
</tr>
</tbody>
</table>

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Abbreviations: CRC, colorectal cancer; LY, life-year; QALY, quality-adjusted life-year.

* The impact of a screening scenario on quality of life.

† The impact of a screening scenario on quantity of life.

‡ Screening results in a gain of quality of life by preventing LYs with CRC care and a loss of quality of life by adding LYs with CRC care. The net effect can be a gain of quality of life (positive values) or a loss of quality of life (negative values).

§ The impact of a screening scenario on quantity and quality of life incorporated in 1 measure.

¶ Compared with no screening.

** Compared with recommended screening.

‖ Detailed results for this scenario are given in eAppendix 4 in the Supplement.

§§ Compared with applying a screening interval of 5 years.

### Appropriateness of More Colonoscopy Screening

Original Investigation Research

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counted result) (Table 3). To gain these QALYs, 675 additional colonoscopies and an additional $528 000 were required; hence, 909 additional colonoscopies and an additional $711 000 were required per additional QALY gained (discounted results).

**Previously Unscreened Beneficiaries**

In previously unscreened beneficiaries, more intensive screening than recommended was slightly less unfavorable or inefficient; however, screening every 3 instead of 5 years and continuing screening beyond 75 years were still associated with a loss of QALYs rather than a gain and screening every 5 instead of 10 years was still inefficient, necessitating 416 additional colonoscopies and an additional $317 000 per additional QALY gained (discounted results) (eAppendix 5 in the Supplement).

**Sensitivity Analyses**

When the base-case utility losses for colonoscopies and complications were doubled or when a lower risk for CRC or a worse-than-average life expectancy was assumed, screening previously screened beneficiaries every 5 instead of 10 years resulted in a loss of QALYs rather than a gain (Table 4). None of the other sensitivity analyses changed the direction of the effect on QALYs gained for any of the scenarios simulated. Assuming a 25% higher risk for CRC resulted in the least unfavorable efficiency ratios: Screening previously screened beneficiaries every 5 instead of 10 years required 249 additional colonoscopies and an additional $181 000 per additional QALY gained (discounted results) (Table 4). Again, results in beneficiaries without prior screening were slightly less unfavorable (eAppendix 5 in the Supplement): In previously unscreened beneficiaries at 25% increased risk for CRC, screening every 5 instead of 10 years was associated with 174 additional colonoscopies and an additional $121 000 per additional QALY gained.

**Discussion**

Recent studies show that many Medicare beneficiaries undergo more intensive colonoscopy screening than recommended.7,8 Our study shows that the resulting balance among benefits, burdens, and harms is often unfavorable. Screening previously screened Medicare beneficiaries up to 85 instead of 75 years, for example, resulted in only 1.2 additional LYs gained per 1000 beneficiaries, whereas it required 369 additional colonoscopies, causing 2.4 additional complications (undiscounted results). As a result, this practice was associated with a loss of QALYs rather than a gain (ie, a net harm). The only scenario favorable for beneficiaries was screening every 5 instead of 10 years, which required 909 additional colonoscopies and an additional $711 000 per additional QALY gained (discounted results). This well exceeds the conventional thresholds for the willingness to pay per QALY gained of $50 000 and $100 000; and although some researchers regard these thresholds as being too low,9,10 even these researchers suggest a threshold well below $711 000. Results in previously unscreened beneficiaries were slightly less unfavorable. However, screening every 3 instead of 5 years and continuing screening beyond 75 years were still associated with a loss of QALYs rather than a gain; and screening every 5 instead of 10 years still required 416 additional colonoscopies and an additional $317 000 per additional QALY gained.

The small increase in LYs gained by applying a shorter screening interval than recommended is explained by a combination of 2 factors: (1) the high sensitivity of colonoscopy for the detection of adenomas and CRC16 and (2) the low progression rate of adenomas into CRC.29 As a result of the former, adenomas and CRC are unlikely to be prevalent in individuals who just underwent a screening colonoscopy with negative results. As a result of the latter, adenomas that remain undetected during the first colonoscopy at 65 years or newly developed adenomas after this colonoscopy are unlikely to develop into CRC before 75 years, when the next recommended screening colonoscopy takes place. Hence, an additional screening
colonoscopy at 70 years is unlikely to add much benefit. The small increase in LYS gained by continuing screening beyond 75 years is explained by the same 2 factors and by the high risk for other-cause mortality at advanced age, which reduces both the probability that screening will prevent CRC mortality and the number of LYS gained if CRC mortality is prevented. Moreover, the risks for colonoscopy-related complications and overdiagnosis and overtreatment of CRC increase with age, negatively affecting the net health benefit of screening.16

In the analysis underlying the US Preventive Services Task Force recommendation statement on CRC screening,13 we already demonstrated that both applying shorter screening intervals than 10 years and continuing screening beyond 75 years result in a small increase in LYS gained and a large increase in colonoscopies performed in those starting screening at 50 years. However, in that analysis we did not quantify the possible harms of screening (ie, nonlethal colonoscopy-related complications and overdiagnosis and overtreatment of CRC), nor did we explicitly weigh the benefits against the burden and harms. This is one of the strengths of the present study because it allows us to draw conclusions about the net health benefit of screening. Whereas clinicians and patients might be reluctant to apply a relatively long screening interval or to discontinue screening after 75 years on the basis of a certain balance between colonoscopies and LYS gained, they are more likely to respond to evidence demonstrating that more intensive screening than recommended negatively affects health. Furthermore, in our earlier study we did not consider costs, which is necessary to evaluate the appropriateness of screening from a societal perspective.

Our study has 3 main limitations. First, although CRC screening is recommended from 50 years onward, we focused our analysis on the Medicare population; ie, we addressed the appropriateness of more intensive screening than recommended from 65 years onward. We chose to do so because patterns of more intensive screening than recommended have mainly been documented in the Medicare population. Nevertheless, an additional analysis shows that more intensive screening than recommended is also inefficient when started at 50 years (eAppendix 6 in the Supplement). Second, because we aimed to illustrate the impact of more intensive screening than recommended, we assumed 100% adherence to all screening scenarios. However, in reality, a beneficiary with negative results on screening colonoscopies at 65 and 68 years might be unlikely to receive another screening colonoscopy at 71 years. If a lower adherence rate were assumed, the scenarios of more intensive screening than recommended would be more similar to recommended screening. Third, although we did perform a sensitivity analysis on the sensitivity of colonoscopy for adenomas and CRC, we did not perform an analysis assuming low-quality colonoscopies. If a proper colonoscopy cannot be performed because of a bad bowel preparation, for example, an early repeated screening colonoscopy is of course justified.

Our analysis highlights some critical future research directions. First, it shows that continuing screening up to very advanced age can be inefficient or even harmful. This is also likely to be true for surveillance in patients who have had adenomas removed, particularly in those at relatively low risk for CRC. Investigating the appropriateness of surveillance at advanced age is particularly important because a substantial proportion of those being screened eventually enter surveillance. Furthermore, our sensitivity analyses demonstrate that the effectiveness and cost-effectiveness of screening depend on an individual’s life expectancy and, more importantly, risk for CRC, which reinforces the need for research on personalizing CRC screening recommendations. Finally, our study demonstrates the importance of considering effects on quality of life when screening is evaluated. However, data regarding the utility losses associated with CRC screening are sparse or even absent. More research is needed in this area.

Conclusions
Screening Medicare beneficiaries more intensively than recommended is not only inefficient from a societal perspective; often it is also unfavorable for those being screened. This study provides strong evidence and a clear rationale for clinicians and policy makers to actively discourage this practice.

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