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The Value of Colonoscopic Colorectal Cancer Screening of Adults Aged 50 to 64

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Colorectal cancer (CRC) is a common and lethal cancer. In the United States, for those cancers that affect both genders, it is the third most common cancer and the second most common cause of cancer-related deaths. In 2009, the incidence rate for CRC was 42.5 cases per 100,000 population, and the mortality rate was 15.7 per 100,000 population.[1] Fortunately, many cases of CRC and CRC-related deaths are preventable through screening and early detection activities.

Screening and prevention activities for CRC have evolved over the past 2 decades. The first US guidelines for CRC screening were published in 1989.[2] In 2012, the American College of Physicians published a synthesis of guidance statements from other organizations,[3] and a multi-specialty society task force published a consensus update for surveillance after screening and polypectomy.[4]

The natural history of CRC is that approximately 85% of CRC cases arise from adenomas—benign lesions of the colon—and these adenomas leading to CRC take approximately 10 years to grow and progress to localized CRC.[2] From localized CRC, average progression to regional CRC takes approximately 2 years, and from regional to distant (metastatic) takes an additional 2 years.[5]

Screening for CRC is valuable because detection and removal of adenomas and localized CRC interfere with this natural history, preventing CRC and CRC-related deaths. Several techniques have been recommended for CRC screening. Guaiac or fecal immunochemical testing for occult blood in the stool (FOBT) is based on the fact that CRC and adenomas may bleed, and fecal DNA testing is based on the fact that CRC may shed abnormal genetic material into the stool. Virtual colonoscopy using low-dose computed tomography (CT) is an advanced imaging technique that relies on the distortion of colonic lining by CRC or adenomas. Endoscopic techniques (sigmoidoscopy and colonoscopy) are based on direct observation of the colon for CRC and adenomas. Colonoscopy is the only screening and detection technique that examines the entire colon, and simultaneously enables removal of adenomas.

Colonoscopy screening programs have been shown to decrease CRC mortality. The National Polyp Study showed that colonoscopy with removal of adenomatous polyps could prevent subsequent CRC.[6] Long-term follow-up of these patients found a 53% reduction in CRC mortality compared with that expected based on Surveillance Epidemiology and End Results Program (SEER) data for CRC mortality in the general population.[7]

A decision analysis commissioned to inform US Preventive Services Task Force (USPSTF) guidelines used 2 microsimulation models to estimate life-years gained from colonoscopy screening relative to no screening. The decision analysis was from a societal perspective, studied effects over the entire lifetime of

individuals, and did not include costs of screening or treatment. This analysis supported CRC screening with colonoscopy every 10 years starting at age 50 years.[8]

The Healthy People 2020 target is that 70.5% of adults aged 50 to 75 years be up-to-date with this recommended cancer screening. As of 2010, the National Health Interview Survey found that 62% reported ever having a colonoscopy or sigmoidoscopy, and 13% reported home-based FOBT in the previous 2 years.[9] Similarly, in 2011, Healthcare Effectiveness Data and Information Set (HEDIS) measures of CRC screening showed that 62.4% of the commercially insured health maintenance organization (HMO) population had been appropriately screened, and 54.6% of the commercial preferred provider organization population had been appropriately screened, based on USPSTF recommendations.[10]

The purpose of this study was to determine the value of life-years saved due to CRC screening with colonoscopy for the population aged 50 to 64 years. Our price perspective is that of a commercial payer (including amounts paid by patients), while our value perspective includes survival past age 65 years, when most of the US population is insured by Medicare. We used recent adjudicated commercial claims data to calculate the cost of CRC screening and cost of patients for the 4 years after CRC diagnosis by stage. We focused on colonoscopy because it is not only diagnostic but also therapeutic; because positive results on other screening tests generally are followed up with colonoscopy; and to build on previous study results that colonoscopy is ultimately more cost-effective than other screening, even considering its expense.[8,11]

STUDY DATA AND METHODS

Our model was designed to estimate the cost and cost-benefit of CRC screening with colonoscopy for US adults aged 50 to 64 years—those among the working-age population for whom CRC screening is recommended. This target population consists of about 23% of the 158 million US individuals who are commercially insured and aged less than 65 years (approximately 36 million people). We applied standard actuarial methods that are often used when evaluating insurance features or coverage. Population details were derived from 2010 and earlier US Census Bureau projections.

Data Sources and Methods for Cost of Colonoscopy

We used Truven Health MarketScan Research Databases 2010-2011, a large commercial database of paid health benefits claims, to develop the cost of colonoscopy. (See the **eAppendix** [available at **www.ajmc.com**] for the colonoscopy codes used.) The cost of a screening colonoscopy can include professional fees for both the procedure and anesthesia, as well as facility fees, laboratory/pathology services, and supplies. To capture costs comprehensively, we selected patients aged 50 to 64 years undergoing a colonoscopy and tabulated all costs occurring on the day of the colonoscopy. We did not include any follow-up costs that may have occurred on subsequent days. (See **Table 1** for the cost of colonoscopy.)

Data Sources and Methods for Cost, Incidence, and Mortality of Colorectal Cancer by Stage

We developed the cost of CRC for 3 stages to approximate the SEER categorization into local, regional, and distant, where local is the most curable and distant (metastatic) is the most fatal. We used Truven

Health MarketScan Research Databases 2007-2011 to develop CRC costs by stage. Because cancer stage is not directly identified in standard claims coding, we used treatment surrogates to categorize the stage at diagnosis. (See the eAppendix for the algorithm used.) CRC cases were identified as new if the individual had no claims coded with cancer in the 12 months prior to diagnosis. All costs of new cases by each of the 3 stages were tabulated by month from diagnosis for up to 4 years. Because the database does not distinguish death from other causes of insurance termination, we composited the monthly costs using a survivorship function developed from SEER data. Table 1 shows the cost of CRC by stage and year from index diagnosis date. Mortality by year following diagnosis for each stage was developed by incident age from SEER data. **Table 2** shows the CRC mortality rates.

Mortality rates for people without CRC were obtained from the CDC National Vital Statistics Reports. Costs for people without CRC were developed from Truven Health MarketScan Research Databases data by age and sex.

Shifting the stage of detection from later stages of CRC to earlier stages is one of the values of screening. Underlying the calculation of stage shifting is a model of the natural history of CRC development in the absence of interference. Specifically, we make assumptions that localized CRC arises from adenomas that, on average, have been present 10 years, and that the time from local to regional CRC is 2 years and from regional to distant CRC is 2 years.[2,5] The time in each stage is referred to as the "sojourn time."

Because colonoscopic adenoma removal reduces the incidence of CRC by stage, we developed incidence rates with and without colonoscopy by age, sex, and stage. CRC incidence rates by stage from 1975-1977 SEER[12] were assumed to reflect CRC incidence for individuals who had not had colonoscopy, as it was not recommended for screening in those years. Based on the literature, about 15% of CRC does not emerge from adenomas.[2] Incidence rates of cancer not arising from adenoma consisting of 15% of the 1975-1977 SEER incidence rates could be thought of as representing a "theoretical best" incidence outcome of colonoscopy, if colonoscopy could detect and remove all adenomas before cancer developed. However, colonoscopy may miss some CRC cases that are exceptionally fast-growing, or the patient may have inadequate preparation where some adenomas may be missed, so we needed to develop "best practical" incidence rates. SEER CRC incidence from 2007-2009[12] shows much lower rates of regional and distant cancers than 1975-1977 data and reflects widespread, although incomplete, use of screening. We assumed that the 2007-2009 incidence reflects a blend of "best practical" and 1975-1977 incidence rates caused by the impact of about 50% screening. The 50% screening assumption is close to that reported by HEDIS in 2009.[10] **Table 3** shows incidence rates from 1975-1977 SEER,[12] as well as our "best practical" incidence rates.

USPSTF recommendations call for screening colonoscopies every 10 years starting at age 50 years for the normal risk population. For the working-age population, this means screening at ages 50 and 60 years, which is assumed in our model. According to these guidelines, individuals with adenomas should obtain a follow-up screening in 5 years, and we developed the portion of colonoscopies receiving this follow-up based on findings from the literature.[13]

All costs were trended to 2013 levels using a 5% annual trend, which reflects recent commercial unit price increases.[14]

Simulation Methods

Estimates for the impact of screening on incidence of CRC, aggregate cost of colonoscopies and CRC, and life-years, were developed through Monte Carlo simulation. Fifteen successive annual cohorts of men and women turning age 50 years starting in 1998 were processed in the model for up to 15 years to produce a typical US population aged 50 to 64 years in 2013. No individuals who reached age 65 years were included in the model. Individuals were randomly assigned to be screened (or not screened) at ages 50 and 60 years. Separate runs of the simulation tested different screening scenarios, ranging from 0% to 100%. Based on adenoma incidence rates identified in the screening colonoscopy claim data analysis, a portion of the individuals screened at age 50 years were randomly assigned to an adenoma group to receive an additional screening at age 55 years following recommendations.[4] Individuals were attributed with CRC (by stage) or no CRC by applying incidence probabilities. The incidence probabilities by stage varied depending on whether the individual had received screening or not.

Annual costs and annual life or death determinations (including for those 65 years and older) were assigned to each individual. The costs for people without cancer varied depending on the person's age and sex. For people with cancer, costs varied by stage and years since diagnosis. People without CRC were assigned average costs based on the person's age and sex. People receiving colonoscopy received additional cost in the year of colonoscopy.

Colonoscopies, cancer diagnoses, and non-cancer costs were assumed to occur at the beginning of the year. Mortality was assumed to occur at the end of the year. Future life expectancies were tabulated using mortality rates that varied by age and sex, stage, and duration of CRC.

The model follows individuals for up to 15 years (for the cohort that turned age 50 years in 1998) and reaches a steady state for spending and cancer incidence in 2013. At this steady state, all ages in the 50-to-64-year-old cohort have been subject to the chosen screening scenario. For each scenario, costs and future life expectancy were tabulated for each individual alive in 2013. Under our assumption that cost trends equal discount rates, for any given screening scenario, all spending would remain constant after 2013, as would the number of cancer cases by stage and the population. Consequently, for cost and cost-benefit analysis, we simply tabulated results for 2013. Neither inflationary adjustments nor discounting was applied or necessary.

RESULTS

Cost/Benefit Analysis

We present the results of the simulation model in **Table 4**, calibrated to a typical health plan with 100,000 commercial members, which would include 23,000 members aged 50 to 64 years. Compared with no screening, 50% adherence (our baseline) with the recommendations for colonoscopy (age 50 and 60 years) would cost $11,562 per life-year saved and result in an additional 4 individuals alive in 2013 who are aged 50 to 64 years. Annual spending for colonoscopies would be $4.07 million and would yield 252 future

life-years saved. Increasing colonoscopies to 70% would increase life-years saved to 348 and would result in 7 more individuals alive than would be the case with no screening. In the screening scenarios, the life-year calculation considers the individuals who are alive and those who will not develop CRC because of screening, as well those whose earlier diagnosis will reduce their mortality.

Sensitivity tests are shown in Table 4. Increasing or decreasing cancer costs by 10% produced costs per life-year saved of $10,758 or $12,778, respectively. Increasing or decreasing colonoscopy costs by 25% produced costs per life-year saved of $15,853 or $7684, respectively. Reduced or improved screening effectiveness produced costs per life-year saved of $14,816 or $9583, respectively.

Colorectal Cancer Screening Versus Other Cancer Screenings

Table 5 compares the cost per life-year saved of well-established cancer screenings with that of CRC screening. We applied medical inflation adjustments to bring the published figures for cervical, breast, and lung cancer up to the price levels associated with our 2013 estimate for colorectal cancer.[15] This was necessary because prominent studies of the cost effectiveness of cancer screening were conducted more than 10 years ago.

As shown, the cost per life-year saved projected to 2013 dollars was $50,162 to $75,181 for cervical cancer, $31,309 to $51,274 for breast cancer, and $19,805 for lung cancer. In the baseline scenario, the 2013 estimate for the cost per life-year saved was $11,768 for colorectal cancer.

DISCUSSION

We used actuarial techniques to study the value to commercial payers of screening and prevention of CRC using colonoscopy. We found that the cost per life-year saved, assuming that 70% of the population was screened, was $11,768, which is comparable to our estimate for cost per life-year saved for lung cancer screening with low-dose CT scanning.[16,17]

We applied sensitivity testing to our model for several inputs. We found that cost per life-year saved, if the costs of colonoscopy were 25% lower than our baseline scenario, would be $7684, while it would be $15,853 if the costs of colonoscopy were 25% higher. We also found that cost per life-year saved, if the cost of cancer care varied by 10% either way from baseline, would be $10,758 to $12,778. Additionally, changing the effectiveness of screening yielded estimates of cost per life-year saved of $9583 to $14,816.

Previous studies of cost-effectiveness of colorectal screening have also found that screening for CRC is cost-effective compared with no screening. The cost-effectiveness of CRC screening has improved over time, with newer studies showing cost per life-year gained ranging from $19,000 to actually being cost-saving, while older studies have suggested a range of $13,000 to $32,000 cost per life-year gained.[18]

In older studies, the choice of optimal testing strategy was very sensitive to variation in the costs of the screening tests. In 2009 dollars, the costs for colonoscopy in US studies ranged from $460 to $1570. Four studies using Medicare costs used $533 as the cost of colonoscopy[18]; a study from 2000 that analyzed a mixed commercial/Medicare population used a blended rate derived from Truven Health MarketScan

Research Databases and Medicare 5% sample claim data and described the range as $779 to $1192.[19] Another study from 2000 chose $1570, based on information from a regional HMO.[20] The incremental cost of polypectomy in US studies ranged from $162 to $480 for Medicare-derived cost,[18] and from $442 to $786 for costs in the regional HMO.[20] Some studies included the costs of treatment of the most common serious complication of colonoscopy—perforation—and those estimates ranged from $342 to $50,193; some models did not include perforation. Cost of care for CRC was also variable across studies, with some assuming that cost did not vary by stage; others input actual costs from HMO or Medicare, depending on state of disease and type of care.[21]

Our approach to costs was to use actual costs of medical care based on a database of claims paid by commercial health insurers in 2011. We captured all costs on the day of the screening colonoscopy, not simply the professional component of the procedure. Likewise, we based the costs of treatment of CRC diagnosed at the various SEER stages (local, regional, distant) on actual claims data. Furthermore, we placed the costs of CRC prevention, screening, and treatment in the context of the total spending by commercial health insurers. We did not consider the societal impact of life-years saved, such as productivity, taxes, or benefits. We did tabulate life-years saved beyond age 65, but we did not consider that screening the population aged 65 years or less will reduce the burden of CRC on the federal Medicare program.

Limitations

Our methodology and model have several limitations. No single source provided all necessary data, so we relied on multiple sources that may be confounding. For example, we applied sojourn times between CRC stages from the literature, but the studies were not based solely on people aged 50 to 64 years. Additionally, for the cost of CRC treatment, we assigned CRC stage based on treatment. Because some patients may not receive guideline-concordant treatment, this may lead to some level of stage misclassification.

We used SEER data for incidence and mortality estimates by age and sex, and these data include individuals who may not have commercial insurance. Any differences in population incidence and mortality for CRC by source of healthcare funding would not be accounted for.

While statistics on the risk reduction of many interventions exist from randomized controlled trials, no such figures are available for the stage shift or incidence reduction associated with full adherence to the colonoscopy regimen. The “best practice” incidence rates we developed were based on mathematical processes applied to the historical changes in CRC incidence rates, which we associated with the implementation of CRC screening.

For ease of modeling, we considered only colonoscopies, but other modalities are also recommended, including screening for fecal occult blood, visualization with sigmoidoscopy, or virtual colonoscopy with low-dose CT. We assumed the current reported CRC adherence rate of about 50%, which is defined to include screening modalities other than colonoscopy and a fairly loose definition of adherence. It is likely that truly effective screening is lower than 50%, which could mean the opportunity for reducing incidence

and stage shifting is larger than we report. We note that the ability of colonoscopy to both reduce incidence of CRC and to detect CRC earlier means our results could be seen as showing somewhat greater impact than if other methods were used.

Our findings are based on a model that has reached a "steady state," which has advantages in transparency in that it avoids the need for inflationary or present value (discounting) adjustments. It is also relatively clear for its application to payers; however, it has disadvantages in that it tabulates only future life-years saved (including life-years after age 65 years), not life-years saved in the past. It also does not consider the past investment needed to produce the "steady-state" results, only the ongoing costs. This is, in effect, a "snapshot analysis" that parallels typical health plan annual fiscal reporting.

Our scenarios assume that screened individuals obtain colonoscopies at ages 50 and 60 years. Of course, in reality, people do not always get screened on schedule. We made no explicit allowance for the many variations that can occur that could reduce colonoscopy effectiveness, such as inadequate bowel preparation, polyps that were missed by the colonoscopist, or complications from colonoscopy. Some of these variations are implicitly captured by our model's calibration to the 2007-2009 incidence rates and the assumption that those rates reflect about 50% adherence to recommended CRC screening.

Some individuals with adenomas are diagnosed with villous type where the recommendation for additional screening is 3 years versus the 5-year recommendation for nonvillous type. Because the incidence of villous adenoma is not reported by age in the literature, we assumed a 5-year surveillance screening colonoscopy for every adenoma detected at the age 50 years colonoscopy screening. This could cause our CRC screening costs to be somewhat underestimated. However, along with 3-year screening there would likely be reduced CRC costs with earlier detection of colon cancer. The cost per life-year saved ($11,768; again, assuming 70% of the population was screened), is lower than most estimates of cost per life-year saved for breast and cervical cancer.[22-24]

CONCLUSIONS

CRC is a disease associated with substantial medical and economic burden, and it is in large part preventable or diagnosable at a localized stage with screening colonoscopy and resection of adenomas. In our investigation of CRC screening for the US population aged 50 to 64 years, using actual screening and treatment costs, we found that both the cost of screening and the cost per life-year saved compare favorably with published rates for other cancer screenings. Under the Affordable Care Act (ACA), preventive services including colonoscopy are considered essential health benefits for fully insured groups, including group and individual products offered on or off the healthcare exchanges, and require no patient cost sharing. While some of the self-insured population covered under Administrative Services Only plans may not be subject to the same ACA requirements and obligations as fully insured groups, employers utilizing these arrangements should note the overall relative value of screening and consider the enhanced benefits of encouraging colorectal cancer screening among employees. In this context, commercial insurers, as well as employers, should continue to consider CRC screening with colonoscopy to be of substantial value.

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