

Special Report: Critical Appraisal of CT Colonography Cost-Effectiveness Analyses



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Executive Summary

Background

Computed tomographic (CT) colonography, also known as “virtual colonoscopy,” is an imaging technique of the colon involving helical computed tomography and computer software to generate high-resolution 2-dimensional and 3-dimensional images of the inner surface of the colon. These images are then interpreted by a radiologist to determine the presence of several types of abnormalities of the colon. CT colonography has been investigated as a technique for colon cancer screening. Concerns about its effectiveness and costs have been raised. This Special Report is a companion piece to the latest clinical TEC Assessment on CT colonography.

Objective

To review and critically appraise cost-effectiveness analyses of CT colonography, specifically to compare CT colonography and colonoscopy.

Search Strategy

Studies that examine cost-effectiveness of CT colonography with adequate methodology and with a comparison with colonoscopy. Studies needed to reveal sufficient data on assumptions, calculate overall life-expectancy or life-year benefits of different strategies, and allow a calculation of an incremental cost-effectiveness ratio.

Main Results

Seven published studies were selected. Two studies completely simulate assumptions that are consistent with current diagnostic capability of CT colonography and recommended practice guidelines. CT colonography was a dominant or cost-effective option only in the one study that added CT colonography’s benefit of detection of aortic aneurysm and extracolonic cancers. Without this set of study results, in general, colonoscopy was generally the more effective screening test, and its incremental cost-effectiveness ratio was consistent with a reasonable value for its benefits. The quantity of health benefit afforded by either test is fairly similar.

Authors’ Comments and Conclusions

Due to differing assumptions, current cost-effectiveness studies vary in their evaluation of the comparative costs and effects of CT colonography and colonoscopy with currently available data and practice guidelines. Overall benefit without consideration of costs appears to be similar between the two tests regarding colon cancer prevention. Most studies did not consider the potential benefits of aortic aneurysm detection and extracolonic cancer detection, CT colonography was generally more expensive and in many studies less effective as a screening strategy than colonoscopy, and in other studies only slightly more effective. Thus it generally was either dominated by colonoscopy or had a very unfavorable incremental cost-effectiveness ratio.

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Depending on the study, at a cost of CT colonography relative to that for colonoscopy within the range of 0.22 to 0.52, CT colonography had reasonable incremental cost-effectiveness ratio compared to colonoscopy. The relative costs of CT colonography and colonoscopy are extremely critical parameters for this analysis. None of the aforementioned studies included the costs of anesthesia; costs for colonoscopy may be particularly high when anesthesiologists provide pain control. More solid information is needed on the relative costs of the two procedures.

Only one study incorporated health benefits of aortic aneurysm detection, extracolonic cancer detection, and long-term radiation effects. This benefit was calculated to account for up to 20% of the total health benefit achieved. Most of the benefit was estimated to be from early detection of aortic aneurysms. Screening for aneurysm using ultrasound has been demonstrated to be effective in older (i.e., age 65 or older) men and has been recommended for older male smokers. Screening for the other cancers assumed to be detected has not been shown to be effective. Further research is needed to bolster the data supporting considerable benefit of CT colonography regarding aortic aneurysm, especially in older individuals, and extracolonic cancer detection, as well as the costs and potential health risks of false-positive findings.

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Objective

There are currently several accepted methods of screening for prevention and detection of colon cancer, including fecal occult blood testing, flexible sigmoidoscopy, and colonoscopy. There has been much interest and several recent studies supporting the effectiveness of computed tomographic (CT) colonography as a method of screening. These studies have specifically examined the capability of CT colonography to detect cancers and cancer precursors in comparison to colonoscopy. Recent studies using trained interpreters and the latest multi-row detector CT equipment have shown high sensitivity (i.e., greater than 90%) for polyps of significant size (i.e., 1 cm or larger) (Johnson et al. 2008).

Based solely on the sensitivity and specificity of CT colonography to detect polyps, it may be reasonable to conclude that CT colonography can detect and prevent some colon cancers, but it is more complicated to try to calculate more precisely its relative efficacy compared to colonoscopy. Even more difficult, given its different costs and proposed frequency of use in a longitudinal screening program, is to determine its costs relative to colonoscopy. Decision analysis and cost-effectiveness analysis are analytic techniques used to try to calculate such relative effects and costs when there is no single comprehensive study that evaluates the complete chain of events under consideration.

The purpose of this Report is to present and critically review existing published cost-effectiveness analyses of CT colonography. This Report is intended to accompany the latest clinical TEC Assessment on CT colonography. Only analyses meeting generally recognized criteria for technical adequacy and with data reasonably consistent with current performance and practice will be reviewed. This Report will concentrate on the comparison between the effects and costs of CT colonography and colonoscopy. Other screening tests, such as sigmoidoscopy, have also been evaluated in some of these studies, but these results will not be presented in order to streamline the discussion. Critical parameters of each study and important assumptions of the studies will be presented and compared. The results of certain studies relative to other studies may be partially explainable by differences in critical assumptions. Certain older studies may include assumptions that are no longer valid

given subsequent published research or a change in practice patterns. Even though the studies differ on many visible and undetectable assumptions, it may be possible to reach some broad conclusions regarding the comparative efficacy and costs of CT colonography versus colonoscopy.

Background

Overview of Colon Cancer Modeling

The technique of analysis involves constructing a quantitative model of the natural history of cancer development, and then superimposing the effects of different colon cancer screening programs. For colon cancer, this involves estimating the rate of polyp growth over time and the probability of cancer developing from polyps. The data underlying these aspects of the model are complex and difficult to compare across studies. Introducing a test that detects polyps and leads to their removal interrupts this process and prevents cancer from developing. The underlying natural history of cancer development is assumed to be the same regardless of which screening test is used, but the different tests have different capabilities of detecting polyps and are used at differing frequencies.

Since the purpose of the non-colonoscopy screening test is to appropriately refer patients to colonoscopy, and thus to be sensitive and specific for cancer and polyps, the essential parameter to know about any screening test is its sensitivity and specificity for cancer and polyps. The results of a one-time screening program could be estimated based on these parameters. However, screening programs must be evaluated from a longitudinal time horizon, where the risks of missing polyps (generally greater in the non-colonoscopy screening tests) weigh against the risks of interval cancers (possibly greater in colonoscopy, with a longer 10-year interval between tests). This is the central trade-off regarding the comparison of colonoscopy with other colon cancer screening tests. Add to this trade-off all the other quantifiable effects such as complications and adherence, and colonoscopy or another strategy may produce more favorable overall outcomes.

Follow-up care could differ between different screening tests and result in different outcomes. However for colon cancer screening, the protocols for care have become somewhat

standardized beyond the initial referral for colonoscopy if polyps are found. Most screening tests, if positive, result in referral for colonoscopy. Once patients receive a colonoscopy, generally they are no longer subject to the proscribed time frames of the original screening program and receive colonoscopic screenings at indicated intervals pertinent to their own cases for the rest of their lives.

Methods

Search Methods

Cost-effectiveness studies of CT colonography were identified through search of the MEDLINE® database (via PubMed) through January 2009. The search strategy included the terms “virtual colonoscopy,” “computed tomography colonoscopy OR colonography OR CT colonography” and “cost-effectiveness OR economics.” Abstracts and review articles were reviewed in order to find additional references that met study criteria.

Study Selection

Studies were included for review if they performed a cost-effectiveness analysis of CT colonography with a comparison to colonoscopy using generally recognized techniques for such an analysis. Such an analysis needed to include a longitudinal perspective including more than one round of screening, calculation of life-expectancy or life-year benefits of screening strategies, and either presentation of or the raw numbers needed to calculate an incremental cost-effectiveness ratio. Studies simply comparing polyp detection rates or evaluating only one round of screening were not included in the Report (see Appendix). One other study (Sonnenberg et al. 1999) was excluded because of lack of sufficient information regarding the sensitivity of CT colonography and the criteria for referral for colonoscopy.

Medical Advisory Panel Review

This Special Report was first reviewed by the Blue Cross and Blue Shield Association Medical Advisory Panel (MAP) on February 18, 2009, and tabled for additional revision and review. A revised draft was submitted to the Panel for electronic review and vote in May 2009. In order to maintain the timeliness of the scientific information in this Special Report, literature searches were performed subsequent to the Panel’s review (see “Search Methods”). If the search updates identified any additional

studies that met the criteria for detailed review, the results of these studies were included in the tables and text where appropriate. There were no studies that would change the conclusions of this Special Report.

Review

Key Parameters of CT Colonography Cost-Effectiveness Studies

For this particular clinical question, parameters of the analysis that can usually be found in published cost-effectiveness studies and are essential to compare across studies include:

- Sensitivity and specificity of CT colonography for polyps (polyp size-specific)
- Sensitivity and specificity of colonoscopy (polyp size-specific)
- Screening interval for each test
- Polyp size referral threshold for CT colonography
- Age of population starting screening
- Cost of CT colonography
- Cost of colonoscopy/polypectomy
- Cost of colon cancer care at different stages of disease

Other issues that some analyses may have incorporated into the analysis, although they may have a minor quantitative impact on the study results, include 1) estimation of radiation exposure consequences; 2) estimation of consequences of detection of extracolonic findings of CT colonography; 3) perforation rates and outcomes and costs of colonic perforation due to colonoscopy.

Another complex issue not generally considered in the base models of these studies was differences in patient adherence. Sometimes these were considered in sensitivity analyses, but the issues are complex. Some considered adherence only as an assumption regarding the initial acceptance of a screening test, but screening in a longitudinal program also involves continuing adherence to the screening program.

Current Performance Characteristics of CT Colonography and Practice Guidelines

The technology and practice of CT colonography has changed over time. Cost-effectiveness studies published a few years ago may not reflect the capabilities of the current technology nor the current recommendations for use. In this section, we will present what is

thought to be the current performance characteristics of CT colonography and the current recommendations for frequency of use and referral thresholds.

The most recent large-scale screening study of CT colonography is the ACRIN trial (Johnson et al. 2008). In this study, CT colonography had a sensitivity of 90% for polyps 10 mm or larger in size and a specificity of 86%, with lower sensitivity for smaller polyps. Similar sensitivity for polyps had previously been demonstrated in a screening population in a study by Pickhardt et al. (2003) using similar technology. These two studies reporting the best sensitivity for CT colonography probably represent what is currently possible with the latest multi-row detector scanners and with strict protocols for training and interpretation of scans.

The latest guidelines of the American Cancer Society on colon cancer screening propose guidelines on how frequent and at what size threshold of polyp patients should be referred for colonoscopy (Levin et al. 2008). The guideline states that after a negative CT colonography, the next screening examination should occur at 5 years. They also state that patients should be referred for colonoscopy if a polyp 6 mm or larger is detected and that polyps smaller than that should not be reported. Such a guideline vastly reduces the number of patients being referred for colonoscopy, but the trade-off is that small polyps are not detected and removed.

Key Assumptions and Characteristics of Selected Cost-Effectiveness Studies

Table 1 shows the 7 cost-effectiveness studies that provided adequate data and perspective to include in this Report. Several of the studies had several different base case models based on different performance characteristics of CT colonography, differing polyp size referral thresholds, and screening intervals. Four of the studies share some common authorship among them. Pickhardt is a co-author on Vijan and co-workers' (2007) study, Hassan is a co-author on Pickhardt and co-workers' (2007) study, and Pickhardt is a co-author on Hassan and co-workers' (2008) study.

Table 1 shows the key assumptions and characteristics of the selected cost-effectiveness studies on CT colonography. Aside from the underlying incidence, prevalence, and rates of

progression of polyps (not shown), the studies all have slightly different assumptions for sensitivity and specificity of CT colonography and colonoscopy, screening interval, polyp size referral threshold, and other assumptions. However, Hassan et al. (2007), Pickhardt et al. (2007), and Hassan et al. (2008) all assumed the identical diagnostic characteristics for CT colonography. They probably used the same diagnostic characteristics for colonoscopy, as it is not plausible for colonoscopy to have less than 100% specificity, but it is reported as 90% in 2 of the studies. The study that has the most radical assumption is the study by Hassan et al. (2008), which incorporates the capability of CT colonography to detect aortic aneurysm and extracolonic cancers. This study is also the only one that estimated adverse outcomes due to radiation exposure of CT colonography. These and other differences make it difficult to compare the results of the studies directly. Several of the studies use values for diagnostic performance of CT colonography consistent with recent studies showing greater than 90% sensitivity for the detection of polyps 10 mm or larger. The study by Zauber et al. (2009) is notable in that the analysis was performed using 3 different models of the natural history of polyp growth and cancer development. The study by Scherer et al. (2008) used one of the same models of polyp growth and transition (SimCRC) as the Zauber study.

The cost of CT colonography was less than that of colonoscopy in all studies except two (Ladabaum et al. 2004; Scherer et al. 2008), and the ratio of the cost used in the analysis varied between 0.68 to 0.98 of colonoscopy (without polypectomy) in the rest of the studies. Medicare reimbursements were generally used as the basis to estimate costs for colonoscopy and other cancer care. The studies tend to be vague regarding how the cost of CT colonography is determined. The only study that specifically mentions how cost is determined for CT colonography is Vijan et al. (2007), who stated that their cost is assumed to be the same as an abdominal and pelvic CT scan. The ratio is reported rather than the actual cost due to differences in absolute cost and currency used in various studies and for simplicity. Each study must also assign costs to a large number of medical interventions representing all possible cancer outcomes, but these are too numerous to show in this Report.

Table 1. Selected Parameters and Characteristics of Cost-effectiveness Analyses of CT Colonography (CTC) versus Colonoscopy

Study CTC type	Sensitivity CTC (≥10 mm)	Sensitivity Colonoscopy (≥10 mm)	Specificity CTC	Specificity Colonoscopy	Screening Interval(s) CTC	Polyp Size Referral Threshold	Beginning Age Screening	Cost of CTC/Cost of Colonoscopy
Ladabaum et al. 2004	94%	NR	85%	100%	10	all referred	50 years	1
Vijan et al. 2007								
2-D	82%	95%	91%	100%	5, 10	all referred	50 years	0.86
3-D	91%							
Hassan et al. 2007	85%	90%	86%	90%	10	all referred	50 years	0.68
Pickhardt et al. 2007	85%	90%	86%	90%	10	≥6 mm all referred	50 years	0.69
Hassan et al. 2008 ^a	85%	90%	86%	99%	10 (5 in sensitivity analysis)	≥6 mm	50 years	0.76
Scherer et al. 2008	93.8%	95%	79.6% ^b 96% ^c	90%	5, 10	≥6 mm ≥10 mm	50 years	1
Zauber et al. 2009 ^d MISCAN model	92.2%	95%	79.6%	90%	5	≥6 mm	65 years	0.98
Zauber et al. 2009 ^d SimCRC model	92.2%	95%	79.6%	90%	5	≥6 mm	65 years	0.98
Zauber et al. 2009 ^d CRC-SPIN model	92.2%	95%	79.6%	90%	5	≥6 mm	65 years	0.98

^a Hassan et al. 2008 is the only study that incorporates the benefits of extracolonic findings, particularly aortic aneurysm, and the radiation effects of CTC

^b Specificity at a 6-mm referral threshold

^c Specificity at a 10-mm referral threshold

^d Sensitivity and specificity for only 1 of 2 base cases tested in the report. The other base case sensitivity and specificity analyzed was always less effective and more costly.

Key Results of Selected Cost-Effectiveness Studies

Effects. When looking at effectiveness on colon cancer death prevention only, without regard for costs, the preponderance of the findings showed that colonoscopy was the more effective strategy. This is not too surprising, given that for most of the studies, the frequency of screening with CT colonography was set at 10 years, identical to colonoscopy, and the sensitivity of CT colonography was assumed to be lower than colonoscopy. Unless there are sufficient adverse effects of colonoscopy screening that outweigh the better capability to detect polyps, if the frequency of screening is the same, colonoscopy will always be more effective than CT colonography.

There were 4 scenarios in which CT colonography was the more effective strategy. In Vijan et al. (2007), using 3-D CT colonography every 5 years, in which CT colonography sensitivity is greater than 90%, CT colonography produces a benefit slightly greater than colonoscopy every 10 years. In the study by Scherer et al. (2008), in the one scenario where the screening interval was 5 years and the threshold for colonoscopy referral was 6 mm or larger, CT colonography was just slightly more effective than colonoscopy. In the study by Hassan et al. (2008), benefits of using CT colonography to detect extracolonic disease, particularly aortic aneurysm and cancer, produced benefits that were greater than colonoscopy at both a 10-year screening interval (base case analysis) and a 5-year screening interval (sensitivity analysis). These benefits were quite considerable as estimated in this study, amounting to almost 20% of the total life-years gained with CT colonography versus no screening. If these benefits are ignored, the colon cancer prevention benefits of CT colonography are less than colonoscopy in this study (numbers not reported in manuscript text, but can be estimated from tables).

In most studies, regardless of which strategy was more effective, the quantity of the benefit was comparable. The ratio of lives saved or life-expectancy benefit between the two strategies compared to no screening was generally between .90 and 1.10, indicating that benefits of either strategy are within 10% of the other.

Costs and Effects. When examining costs and effects, the first step is to determine whether one strategy is both more effective and less expensive—or dominates—the other. If the

more expensive strategy is more effective, the critical number to examine is the incremental cost-effectiveness ratio (ICER) between the two strategies. The lower the value of the ICER, the better the value the more effective strategy represents in terms of additional health benefit per quantity spent.

There is no established cut-off value for ICER that represents those improvements that are worth the value versus those that are too expensive, but the literature will commonly cite values between \$20,000 to \$100,000 (Laupacis et al. 1992). ICER values below \$20,000 are thought to be improvements that are well within the range of commonly accepted medical practice, and ICER values above \$100,000 are often thought to be too expensive. Context also plays a role in determining whether a particular ICER value is a good cutoff value. Some have proposed that ICER cutoff values for preventive screening activities should be lower than that for potentially life-saving therapeutic interventions, in that we should try to be more certain that screening interventions are worth the cost (Laupacis et al. 1992). In the U.K., the governmental technology assessment entity (the National Institute for Health and Clinical Excellence, or “NICE”) has a variable cost-effectiveness acceptability threshold between 20,000 to 30,000 pounds (McCabe et al. 2008).

In most of the studies where colonoscopy was the more effective strategy, it either was a dominant strategy (better outcomes lower costs) or was below \$30,000 per life-year saved compared to CT colonography, indicating a reasonable expenditure for the additional benefit (Table 2). However, the study by Pickhardt et al. (2007) represents an exception, in which the ICER value of colonoscopy was \$42,000 and \$64,000, depending on the polyp size referral threshold for CT colonography. However, these numbers were not the focus of the original study nor were they even calculated. The purpose of the study was actually a comparison between polyp size referral thresholds for CT colonography. For this analysis, the result was that a strategy of CT colonography in which all polyps are referred was not cost-effective compared to a 6-mm polyp size threshold because the ICER was \$118,000 in the former case. From this perspective, then, the strategy of referring all polyps should be ignored because it is dominated (by extension) by colonoscopy, and the only value that counts is the ICER of \$64,000.

Table 2. Results of Base Case and Other Selected Scenarios of Cost-Effectiveness Studies of CT Colonography (CTC) versus Every-10-Year Colonoscopy

Study CTC-specific scenario within study (screening interval, referral threshold, other characteristic)	Life-years gained CTC, aggregate population or increase in life expectancy versus no screening ^a	Life-years gained colonoscopy, aggregate population or increase in life expectancy versus no screening ^a	More effective	CTC/colonoscopy Ratio of health benefits	Incremental cost- effectiveness ratio of more effective to less effective test, or dominates
Ladabaum et al. 2004 all lesions referred every 10 years	5.563	6.185	Colonoscopy	0.90	dominates
Vijan et al. 2007 all lesions referred 2-D every 5 years	0.0523	0.0531	Colonoscopy	0.98	dominates
Vijan et al. 2007 all lesions referred 3-D every 5 years	0.0551	0.0531	CTC	1.04	\$155,000 per life-year
Vijan et al. 2007 all lesions referred 3-D every 10 years	0.044	0.0531	Colonoscopy	0.83	\$7,692 per life-year
Hassan et al. 2007 all lesions referred every 10 years	3.589	3.821	Colonoscopy	0.94	15,091 Euro per life-year
Pickhardt et al. 2007 ≥6-mm referral every 10 years	4,266	4,641	Colonoscopy	0.92	\$64,000 per life-year
Pickhardt et al. 2007 all lesions referred every 10 years	4,372	4,641	Colonoscopy	0.94	\$42,380 per life-year (colonoscopy dominates by extension if 6-mm referral is available)

^a Magnitude of numbers varies because studies varied in size of simulated population, or calculated benefit as increase in life expectancy for a single person

Table 2. Results of Base Case and Other Selected Scenarios of Cost-Effectiveness Studies of CT Colonography (CTC) versus Every-10-Year Colonoscopy (cont'd)

Study CTC-specific scenario within study (screening interval, referral threshold, other characteristic)	Life-years gained CTC, aggregate population or increase in life expectancy versus no screening ^a	Life-years gained colonoscopy, aggregate population or increase in life expectancy versus no screening ^a	More effective	CTC/colonoscopy Ratio of health benefits	Incremental cost- effectiveness ratio of more effective to less effective test, or dominates
Hassan et al. 2008 ≥6-mm referral every 10 years INCLUDE extracolonic finding benefits	12,127	10,669	CTC	1.13	dominates
Hassan et al. 2008 ≥6-mm referral every 5 years INCLUDE extracolonic finding benefits	13,567	10,669	CTC	1.27	\$30,987 per life-year
Hassan et al. 2008 ≥6-mm referral every 10 years EXCLUDE extracolonic finding benefits	9,835	10,669	Colonoscopy	0.92	\$18,280 per life-year (Estimated, not reported in study)
Scherer et al. 2008 ≥6-mm referral every 5 years	118.5	116.8	CTC	1.01	\$630,700 per life-year
Scherer et al. 2008 ≥10-mm referral every 5 years	103.7	116.8	Colonoscopy	0.89	dominates
Scherer et al. 2008 ≥6-mm referral every 10 years	107.3	116.8	Colonoscopy	0.92	dominates
Scherer et al. 2008 ≥10-mm referral every 10 years	84.2	116.8	Colonoscopy	0.72	dominates

^a Magnitude of numbers varies because studies varied in size of simulated population, or calculated benefit as increase in life expectancy for a single person

Table 2. Results of Base Case and Other Selected Scenarios of Cost-Effectiveness Studies of CT Colonography (CTC) versus Every-10-Year Colonoscopy (cont'd)

Study CTC-specific scenario within study (screening interval, referral threshold, other characteristic)	Life-years gained CTC, aggregate population or increase in life expectancy versus no screening ^a	Life-years gained colonoscopy, aggregate population or increase in life expectancy versus no screening ^a	More effective	CTC/colonoscopy Ratio of health benefits	Incremental cost- effectiveness ratio of more effective to less effective test, or dominates
Zauber et al. 2009 CTC 1 ≥10-mm referral every 5 years MISCAN model	85.3	86.7	Colonoscopy	0.94	dominates
Zauber et al. 2009 CTC 1 ≥10-mm referral every 5 years SimCRC model	92.0	93.8	Colonoscopy	0.98	dominates
Zauber et al. 2009 CTC 1 ≥10-mm referral every 5 years CRC-SPIN model	101.2	105.5	Colonoscopy	0.96	dominates

^a Magnitude of numbers varies because studies varied in size of simulated population, or calculated benefit as increase in life expectancy for a single person

In the studies in which CT colonography was the more effective strategy, ICER values varied widely. The study by Vijan et al. (2007) had an ICER of \$155,000 per life-year for 3-D screening every 5 years, indicating a very expensive strategy for the amount of gain. In the study by Scherer et al. (2008), the ICER was \$630,700 per life-year, also an expensive strategy for the amount of gain. Because the study by Hassan et al. (2008) showed so much additional benefit of CT colonography due to aneurysm and extracolonic cancer detection, CT colonography at a 10-year screening interval dominated colonoscopy at a 10-year screening interval, and was potentially cost-effective at a 5-year screening interval with an ICER of about \$31,000 per life-year. Without these additional benefits of CT colonography, CT colonography was no longer the more effective screening strategy.

Discussion and Conclusions

This review of cost-effectiveness analysis comparisons between CT colonography and colonoscopy shows the whole spectrum of results, from colonoscopy being a dominant strategy to CT colonography being a dominant strategy, and everything in between. There were two studies that completely simulated current performance capabilities (greater than 90% sensitivity for CT colonography) and current recommended practices for CT colonography screening (6 mm or larger threshold for referral, 5-year screening interval). In the study by Scherer et al. (2008), CT colonography was just slightly more effective than colonoscopy, but was much more expensive, resulting in an extremely large ICER of \$630,700 per life-year. In the study by Zauber et al. (2009), colonoscopy was slightly more effective AND less expensive than CT colonography.

These studies are roughly consistent with each other in showing that CT colonography is more expensive than colonoscopy. The studies differ only in that one shows CT colonography is very slightly more effective and that the other shows it is slightly less effective than colonoscopy; in neither case is CT colonography cost-effective.

The authors of both studies recognized that the relative cost of CT colonography and colonoscopy were critical parameters in the analysis and explored this issue in sensitivity analyses. In the study by Scherer et al, a sensitivity analysis in which the cost of CT

colonography was 0.36 that of colonoscopy resulted in CT colonography being less expensive. At other cost ratios ranging from 0.42 to 0.52, CT colonography had reasonable incremental cost-effectiveness ratio compared to colonoscopy. In the study by Zauber et al., cost ratios ranging from 0.22 to 0.47 resulted in cost-effectiveness ratios similar to colonoscopy and other accepted colon cancer screening techniques. Thus both studies demonstrate that CT colonography may be both effective and cost-effective if its cost is less than half of that of colonoscopy. The costs of either procedure may vary according to market area and provider practice. For example, colonoscopy may be much more expensive than estimated in these reviewed study areas where sedation and pain control is provided by anesthesiologists. Specific data regarding the relative costs of the two procedures, especially varying by locales and settings, are necessary to more firmly establish the economic consequences of these two screening strategies.

The one study (Hassan et al. 2008) that incorporates potential CT colonography benefits of aortic aneurysm and extracolonic cancer detection boost the benefits of CT colonography by a huge amount up to 20% of life-years saved, making CT colonography either a dominant or cost-effective strategy. In this study, the benefit was largely due to detection of aortic aneurysm rather than extracolonic cancers. The cancers estimated to be detected with CT colonography included lung, liver, pancreatic, renal, and ovarian cancer. Screening is not generally recommended for these cancers and has not been proven to be effective for any of them. On the other hand, the effectiveness of screening for aortic aneurysm has been demonstrated in clinical trials (Cosford and Leng 2007). The U.S. Preventive Services Task Force recommends a one-time screening with ultrasound among male smokers between the ages of 65 and 75 years. Given the potentially large effect of this benefit, a more careful examination of the assumptions on which it is based is necessary. The costs and potential health effects of false-positive extracolonic findings needs further data support as well.

Without this study, or by estimating this study's findings subtracting these benefits, the results between studies are much more consistent. With one exception (Pickhardt et al. 2007), the studies would either demonstrate colonoscopy to be the dominant strategy, or colonoscopy

is cost-effective in that the ICER of using colonoscopy instead of CT colonography would be less than \$30,000 per life-year, or that the additional benefit of CT colonography (if it is a more effective strategy) is extremely expensive. Overall, the quantity of benefit provided by either screening strategy is not different by a large amount.

It would be useful to know the results of studies if all the pertinent parameters consistent with current practice were tried in all of these models. In addition, better documentation of the costs of CT colonography and colonoscopy would provide greater confidence in the economic results. Because the results of these analyses are extremely sensitive to the consideration of the potential benefits of aortic aneurysm detection and extracolonic cancers and this was considered only in one study, additional analysis utilizing different assumptions (e.g., regarding utilities of extracolonic findings) is needed to determine whether such modeled benefits are reasonable.

Other Issues to be Addressed

Some other issues regarding the two technologies have not been clearly addressed in the current cost-effectiveness literature. The potential importance of flat and depressed colorectal neoplasms has been raised recently (Soetikno et al. 2008). These lesions are difficult to detect with both colonoscopy and CT colonography (Park et al. 2006), but special training can improve the ability of colonoscopists to detect such lesions (Soetikno et al. 2008). Current

decision models essentially ignore this issue, but this may not matter if neither technique is good at detecting flat lesions. However, awareness of these lesions may bring about improvements in detection for both techniques. If one technology (e.g., colonoscopy with training) is demonstrated to be superior to the other in detecting these lesions, then decision models will likely show a greater benefit to that particular screening technique.

The initial acceptance of a particular screening strategy and the subsequent adherence over time to the requirements of the screening program are complicated issues also not well addressed in the current literature. Most studies simply assume acceptance of the particular screening strategy. In the simplest case of examining acceptance of a screening strategy, the effectiveness of a screening strategy is simply “diluted” by the proportion of persons who do not accept the screening strategy. For example, if 50% of persons accept colonoscopy and 50% choose not to be screened, the results of a decision analysis simply combine the outcomes of those who were screened and those who were not. It is more complicated to model the possibilities if there are multiple screening options. Another layer of complication is to examine the “decay” of adherence over time when differing screening strategies require follow-up tests and different testing frequencies over time. The empirical data supporting varying acceptance and adherence rates between screening strategies appear to be weak, and much more solid support is needed before incorporating these issues into analyses.

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Appendix

Cost-effectiveness studies of CT colonography not included in report, reasons noted

Sonnenberg A, Delco F, Bauerfeind P. (1999). Is virtual colonoscopy a cost-effective option to screen for colorectal cancer? *Am J Gastroenterol*, 94:2268-2274.

CT colonography sensitivity cited as 80%, but no size-specific diagnostic capabilities cited or stated.

Arneson RB, Ginnerup-pedersen B, Poulsen PB et al. (2007). Cost-effectiveness of computed tomographic colonography: a prospective comparison with colonoscopy. *Acta Radiol*, 48:259-266.

Single screening episode only.

Heitman SJ, Manns BJ, Hilsden RJ et al. (2005). Cost-effectiveness of computerized tomographic colonography versus colonoscopy for colorectal cancer screening. *CMAJ*, 175:877-81.

Single screening episode only.



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