

Virtual colonoscopy for primary screening

The future is now

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Virtual colonoscopy (VC) is a minimally invasive tool that utilizes modern CT technology for colorectal evaluation. Since its inception in 1994, VC has continued to rapidly evolve and improve as a diagnostic screening tool. Early success using primary two-dimensional (2D) detection in polyp-rich cohorts was followed by disappointing results in low prevalence populations. Subsequent introduction of the three-dimensional (3D) endoluminal display for primary polyp detection and oral contrast tagging has transformed VC into an effective primary screening tool. This state-of-the-art VC technique has already proven to be a viable enterprise when combined with existing optical colonoscopy practice. More widespread implementation of VC screening faces multiple challenges, but these are all greatly overshadowed by the immediate need for increased participation in effective colorectal screening. Given its relatively noninvasive nature and the wide availability of CT, VC holds significant potential for addressing a very important yet preventable public health concern. This review will cover current VC technique, compare the existing multi-center VC trials, discuss issues related to primary VC screening, and briefly update the progress of our VC screening program.

Key words: Virtual colonoscopy - Colon diseases - Rectum diseases - Computer tomography.

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Virtual colonoscopy (VC), also referred to as CT colonography, is a minimally invasive test for the detection of colorectal polyps and masses. This technique, which combines two-dimensional (2D) and three-dimensional (3D) CT displays, has been rapidly evolving since its inception in 1994.¹ Some of the earlier VC trials involving polyp-rich cohorts demonstrated very encouraging results using a primary 2D approach to polyp detection,^{2, 3} but the initial attempts to study low prevalence populations were rather disappointing.⁴⁻⁶ However, subsequent improvements in VC technique, particularly the use of the 3D endoluminal display for primary polyp detection and oral contrast for tagging of residual fluid and stool, have transformed VC into an effective primary screening tool. These advances culminated in a large multi-center VC screening trial that showed comparable performance to optical colonoscopy (OC).⁷ Clinical implementation of this proven method for VC screening has already been shown to be a viable enterprise, particularly when covered by third-party payers and combined with an exist-

TABLE I.—*Potential challenges to clinical implementation of VC screening.*

— Reimbursement of VC screening from third-party payers (U.S.)
— Development of an acceptable diagnostic screening algorithm
— Identifying the appropriate group of patients for primary VC screening
— Establishing an effective relationship with gastroenterology and colorectal surgery
— Establishing practice guidelines and program accreditation
— Demonstrating cost effectiveness of VC screening
— Dedicated training of enough radiologists and technologists
— Educating patients and referring physicians on the role for VC in screening
— Continued need for colon purgation (and development of non-cathartic alternatives)
— Issue of exposure to ionizing radiation (albeit low dose in adults)
— Assessing the net impact of extracolonic CT findings
— Competing with other screening tools (new and old)
— Flat colorectal lesions

ing OC program.⁸ The dire need for increased colorectal screening is quite apparent, as far too many people are dying from a largely preventable disease.⁹ Although widespread implementation of VC screening faces multiple challenges (Table I), these are clearly overshadowed by the need for increased screening. This review will cover the basic essentials of current VC technique, compare the 3 major multi-center VC trials to date, address some of the relevant issues related to primary VC screening, and provide an update on the status of our VC screening program.

VC technique

The basic concept behind VC is rather simple: by imaging a properly cleaned and distended colon with a modern (multi-detector) CT scanner, clinically significant colorectal polyps can be readily identified. Having said that, there has been considerable variability in the specific techniques used for performing VC. For the purpose of this report, emphasis will be placed on the VC methods that have proven most successful to date.

Colonic preparation

Robust colonic preparation is important for accurate polyp detection.^{7,10} Not only must the fecal matter be adequately removed, but oral contrast material should be used for tagging any retained solid or liquid material. Patient preparation usually begins the day before the examination. We have had great success with a relatively simple low-volume cathartic preparation (less than 400 mL) that combines 3 basic components, all of which are important for complete success: sodium phosphate for catharsis, dilute 2% barium for solid stool tagging, and an ionic water-soluble contrast agent for fluid opacification.¹⁰ In addition to the actual prep components, the patient maintains a clear-liquid diet with liberal hydration throughout the day. Through continued testing, we have refined this prep considerably compared with that used in the multi-center trial.⁷ Now, only single doses of each component are required the evening before the examination (45 mL sodium phosphate, 250 mL 2% barium, and 60 mL gastroview or gastrografin), which greatly simplifies the patient instructions.¹¹ For patients with known or suspected renal or cardiac insufficiency, magnesium citrate is substituted for the sodium phosphate.

Less vigorous preparations for VC are currently under investigation and have shown preliminary success in high-risk groups.¹² The prepless designation sometimes applied to this approach is a misnomer, since a bowel preparation is invariably employed. The terms “non-cathartic” or “minimal” prep are closer to the truth, although most would agree that the use of gastrografin provokes at least a mild cathartic effect. Regardless, important trade-offs with this approach include an expected drop in accuracy in low prevalence populations and inability for same-day polypectomy.¹³ Although non-cathartic preps for VC may ultimately increase overall compliance, I believe it should be primarily reserved for patients who are unwilling to undergo proper cleansing, assuming they understand the consequences. Furthermore, this approach must first be validated in a multi-center trial evaluating an asymptomatic average-risk population. In my opinion, it is

preferable to use a bowel preparation method that allows for the possibility of same-day polypectomy to avoid the need for a second prep. Our patients greatly value this one-stop shop approach to colorectal screening.

Colonic distention

Gaseous distention of the colon, like proper cleansing, is also critical for diagnostic success. Distention may be achieved with either room air or carbon dioxide. The rate and degree of insufflation can be controlled by the patient, controlled by the technologist/physician, or automated. The adequacy of colonic distention prior to scanning is usually gauged on the CT scout view (Figure 1). The 2 best (and safest) techniques for consistent colonic distention are patient-controlled room air insufflation and automated carbon dioxide delivery (PROTOCO₂L, E-Z-EM). Perforations are extremely rare when these techniques are employed and are essentially unheard of in the setting of asymptomatic VC screening. We recently compared patient-controlled room air insufflation *versus* automated carbon dioxide delivery for VC screening in over 200 patients and determined that the latter approach resulted in slightly improved colonic distention and decreased post-procedure discomfort (Shinners FJ, Pickhardt PJ, Taylor AJ, Jones DA, Olsen CH. Colonic distention and patient comfort at screening CT colonography: prospective comparison of patient-controlled room air insufflation *versus* automated carbon dioxide delivery. Submitted). Furthermore, the automated carbon dioxide method was clearly preferred over patient-controlled room air insufflation by the CT technologists obtaining the studies. As a result of these findings, automated carbon dioxide delivery has now become our front-line method for colonic distention. In a small number of patients undergoing primary VC evaluation (2% or less, in our experience), the study may be incomplete due to focal collapse of a colonic segment on both supine and prone views. Because the great majority of nondiagnostic segments involve the sigmoid colon, typically as a result of extensive diverticular disease, we



Figure 1.—Scout image from CT scan performed as part of VC study in 53-year-old woman undergoing colorectal screening. Excellent gaseous distention such as this is reliably obtained from the automated carbon dioxide delivery system (PROTOCO₂L, E-Z-EM). The sigmoid colon, however, often requires extra attention and its adequacy for distention is best evaluated directly on the axial 2D images.

now offer these patients same-day, unsedated flexible sigmoidoscopy to complete their screening evaluation (again, a one-stop shop offering).

CT scanner requirements

While it is true that a multi-detector CT scanner is necessary for acceptable 3D image quality at VC, a four-channel CT scanner will generally suffice. This is due in part to the fact that the gas-filled colon is a relatively static and forgiving structure, but also because the target lesions are sufficiently large (i.e., polyps measuring 5-6 mm or greater in size) and do not require exquisite spatial resolution for detection. Although we now perform all VC exams on eight- and 16-channel CT scanners (with 1.25 mm collimation and 1-mm reconstruction interval), a 4x2.5 mm detector configuration remains adequate for successful examination.^{7,8} Given the nature of the soft tissue-air interface, the CT technique for VC entails significantly lower radiation doses

compared with standard abdominal CT studies. The clear benefit of effective colorectal screening outweighs the small theoretical risk from the low-dose radiation exposure in the adult population.¹⁴

VC software: 2D vs 3D polyp detection

The choice of VC software for interpretation is an absolutely critical factor, greatly outweighing the small differences that exist among different multi-detector CT scanners. Of paramount importance is whether or not effective and time-efficient 3D evaluation is even possible with a given VC software system. Primary 2D evaluation for polyps consists of scrolling through the hundreds of 2D CT images in a manual lumen tracking mode. In my opinion, there are several reasons why this 2D approach has unfortunately become ingrained as the leading search method: 1) high-quality 2D displays were available when VC was first emerging as a nascent technique in the mid-late 1990s; 2) a pre-existing comfort level for interpreting cross-sectional CT images made 2D evaluation for polyps a logical extension for abdominal CT radiologists; 3) effective primary 3D endoluminal evaluation was simply not feasible during early VC development.

Primary 2D polyp detection served well for early proof of concept VC studies that evaluated polyp rich cohorts^{2,3} but performed poorly when applied to low prevalence populations, as discussed below.⁴⁻⁶ Fortunately, effective primary 3D polyp detection became available (V3D Colon, Viatronix) before we embarked upon our multi-center screening trial (Figure 2).^{7,15} The results from our trial (also discussed below) demonstrated that VC with emphasis on 3D detection compared favorably with OC.⁷ When viewed side-by-side, it becomes fairly obvious why 3D polyp detection represents an inevitable successor to 2D polyp detection. In practice, this transition from 2D to 3D polyp detection represents a fundamental reversal in the approach to VC interpretation. The 2D images now primarily serve as source images that are vital for confirming 3D findings, but also have a secondary role in polyp detection.

This interpretation approach is best described as a biphasic examination. The need for high-level 3D-2D correlation requires that CT-trained radiologists interpret these examinations. Although there have been significant recent improvements in the 3D rendering capabilities of many VC software systems, it is unfortunate that very few systems currently allow for accurate and time-efficient primary 3D navigation.¹⁵

The major advantage with using the 3D endoluminal view for primary polyp detection is that the visual search pattern is much simpler compared with 2D.^{15,16} Polyp conspicuity is greatly enhanced and distinguishing polyps from folds is a much easier task on 3D. In comparison, the eye strain and fatigue associated with primary 2D evaluation becomes quite evident when faced with interpreting multiple cases in succession. Approximately 20 000 axial 2D images would need to be viewed for each advanced adenoma that will be encountered in a typical screening population. Furthermore, our experience shows that flat lesions do not represent a significant drawback for VC screening in typical Western populations when state-of-the-art 3D imaging is combined with 2D imaging.¹⁷ Our investigations have also shown that linear polyp measurement on the 3D endoluminal view is significantly more accurate than 2D axial, coronal, or sagittal measurements, both *in vitro* and *in vivo*.¹⁸ This is due to both 2D windowing effects and the fact that the long axis of a polyp is easily measured on 3D but rarely aligns directly with a standard orthogonal 2D view. Optimizing the linear 2D size by obtaining all 3 orthogonal measurements minimizes but does not eliminate 2D undersizing of polyps on 2D.

There are several additional 3D tools and features that can further benefit the radiologist's interpretation. Translucency rendering is a tool that allows for rapid distinction between soft tissue polyps and adherent tagged stool on the 3D view, reducing the need for time-consuming 2D correlation.¹⁹ A missed patch tool allows for tracking and visualization of mucosal surfaces that are not seen during standard bi-directional navigation

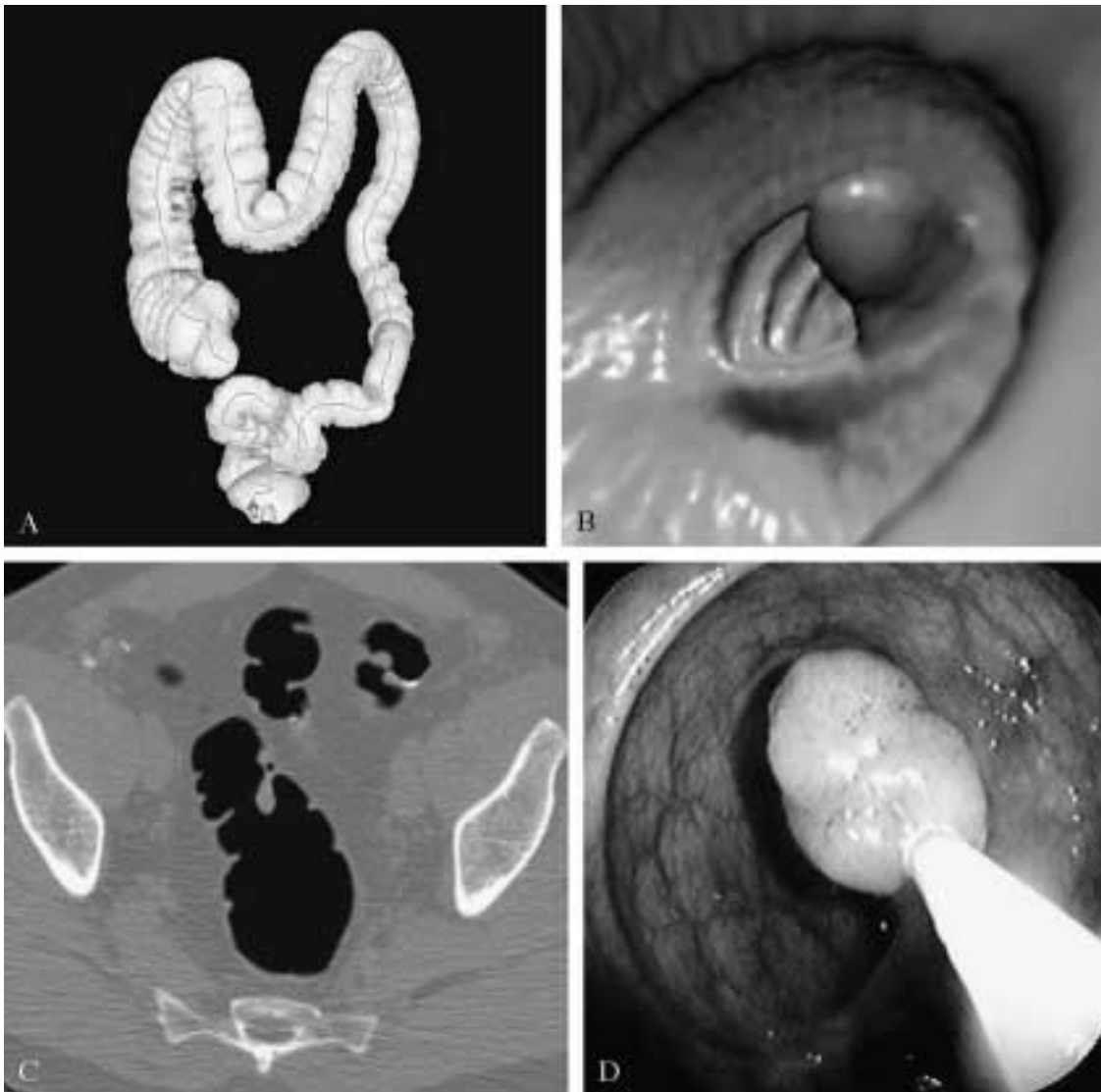


Figure 2.—Ten-mm tubulovillous adenoma in an asymptomatic 61-year-old man undergoing VC screening. A) Colonic map with centerline for 3D navigation (black line) generated from VC software (V3D Colon, Viatronix). The automated nature of this step increases reading efficiency for the radiologist. The map also provides an effective means for communicating the location of detected polyps. B-D) Three-dimensional endoluminal view from VC (A), axial 2D CT image from VC (B), and digital photograph from OC (C) all show the same polyp, which was located near the rectosigmoid junction. The conventional study was performed within 2 h of the virtual study; all pertinent images from VC were shared with the endoscopist prior to polypectomy.

along the automated centerline. Electronic fluid cleansing subtracts opacified luminal fluid and increases mucosal surface visualization, but also introduces artifacts that can be distracting (which is why we currently do not employ it).¹⁰ The colon map provides an overview of colonic anatomy and is useful for

communicating findings to endoscopists (Figure 2). Bookmarking features provide precise localization of polyps for either subsequent VC surveillance or OC polypectomy. The automated centerline for luminal navigation confers a significant time savings compared with systems where the flight path

must be manually determined by the radiologist (Figure 2).

Comparison of the multi-center VC trials

There have been 3 large multi-center VC trials that have been published to date: Pickhardt *et al.*,⁷ Cotton *et al.*,⁵ and Rockey *et al.*⁶ The results were strikingly different, with a by-patient sensitivity of 94% for adenomas at the 10-mm threshold in the Pickhardt trial, compared with sensitivities of 55% and 59% in the Cotton and Rockey trials, respectively (the figures for the Cotton and Rockey trials are in terms of all polyps – adenomas were not considered separately). There was less of a disparity between by-patient specificities, but this is of course of secondary importance compared with sensitivity. Of particular importance to note is that these studies actually transpired in reverse order of their publication, with Rockey *et al.* and Cotton *et al.* preceding the more recent and larger study by Pickhardt *et al.* by more than 2 years. With this in mind, one can begin to appreciate that the corresponding results could largely reflect the ongoing technical advances in this rapidly-evolving field. Furthermore, it stands to reason that a radiologist-led study (Pickhardt trial) would be more familiar and facile with advances in CT imaging than gastroenterologist-led studies such as the Rockey and Cotton trials.

Although there are many potential causes for the variable performance seen in these trials, 2 factors rise above all others. Most importantly, these studies collectively demonstrate that primary 3D polyp detection, used only in the Pickhardt trial, is vastly superior to 2D detection in low-prevalence populations. The second major factor is that tagging of residual colonic stool and fluid with oral contrast, which was also used only in the Pickhardt trial, is now recognized as a critical component of VC success.²⁰ Regrettably, the individual contributions to the decrease in accuracy resulting from the lack of 3D polyp detection and contrast tagging in the Cotton and Rockey trials cannot be ascertained. Regardless, both played a critical role in the success of the Pickhardt trial.

To properly assess a new colorectal screening tool, it would seem logical to evaluate a true screening population. However, neither the Rockey trial nor Cotton trial studied an asymptomatic screening population, whereas all adults in the Pickhardt trial were asymptomatic. Significant differences in VC performance might well be expected between symptomatic and asymptomatic cohorts. Another methodological drawback in the Cotton and Rockey trials was the small patient population relative to the number of study sites, resulting in an average of less than 50 patients per site, only a few of whom would be expected to harbor an adenoma 10 mm or greater. This sampling bias is further compounded by the fact that study radiologists did not receive feedback to allow for performance improvement during the trial. In comparison, the Pickhardt trial was twice the size of the Rockey and Cotton trials, involved an average of more than 400 studies per site, and allowed for ongoing performance feedback, all of which enable a better indication of how this new screening tool might perform in actual practice.

The results of the studies by Cotton and Rockey would have been much more valuable had they been published in their proper chronological and evolutionary order. The confusion created by their delayed publication has led to the misconception that VC performance is somehow going backwards. Nonetheless, it serves as another reminder that specific techniques, particularly 3D polyp detection and contrast tagging, truly matter and that further advances in this important area of radiologic imaging are best handled by radiologists. Of concern for the future is that ongoing or upcoming VC trials may simply try to co-opt the banner of 3D emphasis but actually employ the typical VC software system that does not allow for effective and efficient primary 3D evaluation.

Issues related to primary VC screening

Developing a diagnostic algorithm

For patients undergoing colorectal screening with VC, the largest detected lesion largely determines the next appropriate step. A

diagnostic algorithm based on polyp size stratifies patients into categories such as immediate OC for polypectomy, short-term VC surveillance, and routine follow-up.²¹ Adoption of reasonable polyp size thresholds and follow-up intervals will be critical to the ultimate success of VC screening.^{14, 22, 23} For patients with medium-sized (6-9 mm) colorectal polyps detected at VC, we offer the option of immediate polypectomy at OC *versus* noninvasive VC surveillance. We believe this represents a logical and clinically sound strategy. The rationale behind this paradigm shift lies in both the indolent nature of sub-centimeter polyps and the noninvasive method of detection. Once a patient has committed to primary OC for evaluation and has accepted the risks of this more invasive procedure, removal of all nondiminutive polyps is expected. The situation is quite different for VC screening because the exclusion of large polyps (≥ 10 mm) places the patient in a very low risk category and the risk/benefit ratio for subsequent OC is now less favorable.^{24, 25}

There is general agreement that immediate polypectomy is indicated for large polyps detected at VC screening. In our experience, this situation occurs approximately once every 20 cases; although most of these large lesions represent advanced adenomas, very few will harbor frank malignancy. One could argue whether a 10-mm threshold is too low, since it is estimated that fewer than 10% of polyps ≥ 10 mm will actually develop into cancer at 10 years.²⁶ Nonetheless, the risks of undergoing polypectomy by OC are likely outweighed by the malignant potential of these larger polyps. With regard to subcentimeter colorectal polyps, there also appears to be general consensus that diminutive lesions (≤ 5 mm) are of no practical clinical significance.^{7, 27} Only a fraction of these diminutive polyps are neoplastic, and of these, less than 1% are histologically advanced and essentially none are malignant.^{27, 28} As such, patients without any polyps measuring greater than 5 mm at VC are considered to have an essentially normal study in our screening program.

In my opinion, much of the controversy surrounding VC screening will center around the

clinical management of medium-sized polyps (6-9 mm) detected at VC. However, it is important to keep in mind that this issue is clearly secondary to increased screen detection of large polyps in a greater percentage of adults. Fueling this potential controversy over the management of medium-sized lesions is the relative dearth of information about the natural history of colorectal polyps. There is, however, some encouraging news that is often overlooked; the existing data on polyp growth rates, although somewhat limited, clearly support the validity of noninvasive surveillance of small sub-cm polyps. Several longitudinal OC studies have been published that followed unresected sub-cm polyps over time, all of which have demonstrated the indolent nature of these small colorectal polyps. Hofstad *et al.* reported on the largest and most meaningful of these studies, which followed unresected polyps up to 9 mm with serial OC examinations over a three-year period.^{29, 30} After the first year of surveillance, only one (0.5%) of 189 sub-cm polyps crossed the 10-mm size threshold.²⁹ At 3 years, the majority of polyps either remained stable or regressed in size, but more importantly, 5-9 mm polyps actually showed an overall tendency for regression.³⁰ The researchers concluded that follow-up of unresected colorectal polyps up to 9 mm is a safe practice, which closely parallels our current approach for noninvasive VC surveillance. In an earlier study, this same group showed that diminutive tubular adenomas rarely develop in to advanced lesions in the short term.³¹ In a smaller series, Bersentes *et al.* showed no significant change in the size of sub-cm polyps at two-year follow-up, with only a minority of lesions growing more than 1 mm in diameter.³² Finally, review of data from the National Polyp Study concluded that the high observed adenoma detection rates at surveillance colonoscopy and the low observed colorectal cancer incidence seen in this large study could only be explained by assuming a high incidence rate of adenoma regression.³³

Establishing appropriate follow-up intervals for patients with sub-centimeter polyps or no polyps detected at VC represents the other major challenge for developing an agreeable diagnostic screening algorithm. The routine

follow-up interval following a negative VC study (i.e., no polyps detected > 5 mm) could safely be set at 5 years to coincide with the accepted intervals for sigmoidoscopy and the barium enema. As more experience and data are gathered, this interval would likely expand towards the ten-year level that is currently accepted following negative OC examination. Although three-year follow-up of unresected medium-sized polyps (6-9 mm) was shown to be a reasonable approach in the Hofstad trial, more conservative parameters may be employed during the early implementation phase of VC screening. The Working Group on Virtual Colonoscopy has recently issued preliminary guidelines for VC screening that call for a 5-10 year interval for a negative VC examination and 3-year follow up for unresected medium-sized polyps.³⁴ It remains to be seen how swiftly these guidelines will be adopted by real-world practitioners.

Another potential inclusion with the diagnostic algorithm would be to stratify VC findings according to diagnostic confidence of the interpreting radiologist. We have found that increased reader confidence for an individual lesion detected at VC correlates with a significantly increased likelihood that: 1) a matched polyp will be found at OC and, 2) that this matched polyp will be neoplastic.³⁵

In summary, the initial debate over how to manage medium-sized polyps detected at VC screening will no doubt be spirited at times. However, regardless of how we decide to handle sub-centimeter polyps detected at VC screening, the emphasis should be placed on the detection of larger polyps, particularly in patients who otherwise may not have been screened at all. In my opinion, concentrating efforts more on the detection and removal of less common but more dangerous lesions in the majority of the screening population would represent a far more efficient, cost-effective, and efficacious strategy than the current practice of harvesting many small polyps in the minority.

Defining the appropriate patient population

The early VC studies essentially provided necessary proof of concept, demonstrating

that finding polyps with VC was feasible when carried out in polyp-rich cohorts. However, the ideal population for primary VC screening consists of asymptomatic adults.²¹ For one, these patients are least likely to require subsequent OC for polypectomy, whereas consideration for primary OC evaluation would seem more prudent in symptomatic patients or those with a high *a priori* risk for neoplasia, given its therapeutic capability. This risk stratification approach would minimize the number of patients requiring both examinations. Given the short supply of gastroenterologists, I believe that OC needs to be viewed as a limited resource that is better utilized as a therapeutic procedure for removing significant polyps, rather than being used for negative diagnostic exams. The argument could be made that the known risks of perforation and clinically significant bleeding associated with OC polypectomy, occurring in about 0.2% and 1-2% of cases, respectively,^{24, 25} outweigh the minuscule cancer risk posed by sub-cm polyps. Seemingly rare risks of a test are amplified when applied to a large number of people in an otherwise healthy screening population. In particular, perforation at OC may be particularly devastating (both physically and emotionally) when it occurs in a healthy 50-year-old adult - *primum non nocere*. Therefore, reserving OC for removal of the more important, large colorectal polyps found by VC in asymptomatic adults not only helps to preserve a valuable resource, it is also a sensible strategy from a risk/benefit standpoint.

Extracolonic CT findings identified at VC screening

Extracolonic evaluation from the 2D CT images at VC represents a double-edged sword. On one hand, potential benefits include personal reassurance for the vast majority in whom nothing ominous is found and, in a small minority, discovery of an unsuspected but clinically significant process at an early, pre-symptomatic stage. On the other hand, potential drawbacks include unnecessary anxiety and added costs related to additional work-up for findings that ulti-

mately prove to be of no consequence. Unfortunately, most studies to date on this topic have involved symptomatic or high-risk individuals, for which extracolonic findings are more frequent.³⁶⁻³⁹ In contrast, potentially significant extracolonic findings are encountered in asymptomatic adults at a much lower frequency.⁴⁰ It must be emphasized that the lack of IV contrast and the low dose technique employed for VC limit the evaluation of CT findings outside of the colon. For radiologists performing VC screening, a careful log of potentially important extracolonic findings should be kept and periodically checked to confirm resolution.

The vast majority of extracolonic findings at VC are of essentially no clinical significance and include things such as uncomplicated renal or hepatic cysts, mild arterial vascular calcification, hernias (particularly hiatal and inguinal), and benign skeletal findings (e.g. degenerative changes). Uncomplicated cholelithiasis and nephrolithiasis may be encountered in 5-10% of cases, but rarely requires further work up. Published studies have tended to report on the frequency of extracolonic findings at VC in terms of moderate importance and high importance, but this practice greatly overstates the frequency of truly significant findings, since even most in the highly important category ultimately prove to be of no consequence.³⁶⁻⁴⁰ To address this issue, we report such findings to be of potential importance to underscore both the need for further evaluation and the reasonable likelihood for a good outcome.^{7, 40} Extracolonic findings that may require further evaluation include complex-appearing adnexal lesions in post-menopausal women, indeterminate renal lesions, indeterminate hepatic lesions, and lymphadenopathy. Other occasional findings include abdominal aortic aneurysms, adrenal adenomas, pulmonary nodules, and a variety of incidental congenital variants. In our experience, unsuspected extracolonic malignancy is seen in approximately 1 case per 200 patients screened.⁴⁰ Interestingly, VC will typically uncover more extracolonic malignancies than colon cancers in a typical asymptomatic screening population, which underscores the fact that col-

orectal screening is more about cancer prevention than cancer detection.⁷ Regardless of whether one views extracolonic evaluation resulting from VC screening as a net benefit or liability, it is an unavoidable responsibility that must be handled with care by the interpreting radiologist.

Collaboration with endoscopists (gastroenterology and colorectal surgery)

It will be very important for radiologists, gastroenterologists, and colorectal surgeons to work together closely as colorectal screening evolves. VC screening, if properly implemented, will result in a win for all, including society as a whole. The potential added benefit of VC screening is obvious, since any reasonable increase in effective colorectal screening should lead to a net reduction in cancer incidence and mortality. For radiologists, there is now a viable and exciting opportunity to make a substantive contribution to colorectal cancer screening. For gastroenterologists and colorectal surgeons, VC screening should be viewed not as a threat but rather as a means to enhance their clinical practices, since it serves as a complement and not a replacement for the existing screening options.⁴¹ VC could be initially targeted to those who are either reluctant to undergo OC or are at significantly increased risk for a complication.¹⁴ In our experience, the net effect of this approach has been an increased frequency of therapeutic OC, relatively less time spent on negative (nontherapeutic) exams, and an overall increase in the total number of OC exams performed. One would assume that the level of gratification resulting from endoscopic removal of an advanced neoplasm would exceed that of a negative invasive examination.

By providing a comprehensive colorectal screening service, it is possible to provide a one-stop shop experience for patients. When the radiologist reads the VC examination online, a fasting patient can then undergo polypectomy at OC without the need for a second colonic preparation. This option is highly valued by many patients but it requires dedication from the radiologist to rapidly inter-

pret the VC study. A commitment from the endoscopist is also required to provide this same-day service. This cooperative arrangement functions as a two-way street, since same-day VC add-ons for incomplete OC also occur. As described below, this is the approach we have employed for the VC screening program at the University of Wisconsin.

The specific impact of VC screening on colorectal surgery practice promises to be very positive. In addition to detecting more advanced adenomas, an increase in effective colorectal screening should also result in the detection of more cancers at a surgically curable stage. It has been shown that detection of asymptomatic colorectal cancer offers a better prognosis and is more cost effective than waiting for symptomatic detection.⁴² VC can provide exquisite preoperative planning, with precise tumor localization and also evaluation of extracolonic structures. Beyond mucosal-based lesions, VC can provide much more complete characterization on submucosal lesions, because CT evaluates the entire bowel wall.¹⁶ VC has also proven useful for localization and characterization of appendiceal and small bowel tumors that are incidentally found.

Referrals from primary care physicians

Although visible support from gastroenterology and colorectal surgery colleagues can provide useful credibility for a new VC program, most referrals for VC screening will actually come from primary care providers. Therefore, it is this group of general practitioners that must ultimately appreciate the value of VC screening. Because of the possibility of finding not only colorectal polyps, but also potentially significant findings outside the colon, we do not accept self-referred patients for VC evaluation. We need to ensure that we have the ability to directly communicate with a referring physician if a potentially significant or unusual finding is identified that may need further work up. Although many primary care providers already see the benefit of an additional screening option for their patients, others can be educated and updated through the use of grand rounds lectures and the medical literature.

Current status of the VC screening program at UW

In April 2004, the VC program at the University of Wisconsin became the first in the US to receive standard third-party reimbursement for VC screening.^{8, 43} One year later, it unfortunately remains the only program in the US to enjoy this status. The reasons for delay in VC coverage at other centers are multifactorial, but the use of unproven or poorly performing VC techniques is a major issue. For the past 6 months, we have been routinely performing about 10 screening studies per day between 7 and 10 am. All studies are read on-line to allow for same day polypectomy, if needed. Approximately 5-10% of patients go on to same-day colonoscopy, the vast majority of which are performed on the same day. Put another way, over 90% of our patients that undergo VC screening avoid the need for OC. Without any organized marketing or advertising campaign, patient demand for VC has remained high, with hundreds of patients now scheduled out months in advance. Because we require physician referral, this also means that some primary care providers are already seeking out this test for their patients. Because of coverage by third-party payers, less than 1% of our patients pay out-of-pocket expenses for the procedure. We are currently seeking out additional ways to further expand our capacity, such as identifying a CT scanner that will be dedicated to VC screening.

Conclusions

Widespread implementation of VC screening faces multiple challenges, but these are all greatly overshadowed by the immediate need for increased participation in effective colorectal screening. Given its relatively noninvasive nature and the wide availability of CT, VC holds significant potential for addressing a very important yet preventable public health concern. For maximum impact, we need to shift our focus away from the ubiquitous diminutive polyp and concentrate more on the larger polyps that are a more realistic

cause for concern. Although further validation of this rapidly evolving technique may be useful, clinical implementation of state-of-the-art VC screening should proceed without delay by those who are willing and able to provide it.

Riassunto

Colonscopia virtuale per lo screening iniziale: il futuro è adesso

La colonscopia virtuale è una manovra minimamente invasiva che utilizza le moderne tecnologie tomografiche computerizzate per la valutazione colonrettale. Dalla sua introduzione, nel 1994, la colonscopia virtuale ha continuato a evolversi rapidamente e a migliorarsi quale strumento di screening diagnostico. Il successo iniziale ottenuto utilizzando una rilevazione bi-dimensionale (2D) in coorti di pazienti con molti polipi è stato disatteso nelle popolazioni a bassa prevalenza. La successiva introduzione della metodica tri-dimensionale (3D) endoluminale per il rilevamento del polipo primitivo e l'utilizzo di un mezzo di contrasto per via orale ha trasformato la colonscopia virtuale in uno strumento efficace di screening iniziale. Lo stato attuale della tecnologia relativa alla colonscopia virtuale ha già dimostrato di essere una via percorribile quando viene associata alle attuali tecniche di colonscopia che utilizzano fibre ottiche. Gli ulteriori perfezionamenti dello screening con colonscopia virtuale potranno rispondere a ulteriori sfide, ma al momento vi è necessità immediata di uno screening colonrettale efficace. Data la sua natura relativamente non invasiva e l'ampia disponibilità della tomografia computerizzata, la colonscopia virtuale rappresenta un potenziale significativo per rispondere a un aspetto molto importante della prevenzione della salute pubblica. Questa revisione si occuperà delle attuali tecniche di colonscopia virtuale, confronterà gli studi clinici multicentrici condotti su questa tecnica, discuterà gli aspetti relativi allo screening iniziale eseguito con essa e si occuperà brevemente degli aggiornamenti sui nostri programmi relativi alla colonscopia virtuale.

Parole chiave: Colonscopia virtuale - Colon patologie - Retto patologia - Tomografia computerizzata.

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