Chapter 5

Virtual Colonoscopy CT

After completing this chapter, the learner should be able to:

- Explain when colon cancer screening should be performed
- Prepare the patient to undergo virtual colonoscopy CT exam
- Implement the scanning protocol for virtual colonoscopy
- Discuss the value of virtual colonoscopy CT as a screening tool
- Compare the advantages and disadvantages of virtual colonoscopy CT to conventional colonoscopy

INTRODUCTION

Colorectal cancer is third most common cancer diagnosed in both men and women in the United States. The lifetime risk of developing colorectal cancer is about 5%. Fortunately, the mortality rate from colorectal cancer has been dropping for more than 20 years as effective screening with colonoscopy has enabled detection and excision of **polyps** before they develop into cancers. Screening colonoscopy has also led to earlier treatment when a cancer is diagnosed.[1] Virtual colonoscopy (VC) CT — also called CT colonography —- has joined conventional colonoscopy as an effective screening tool for colorectal cancer.

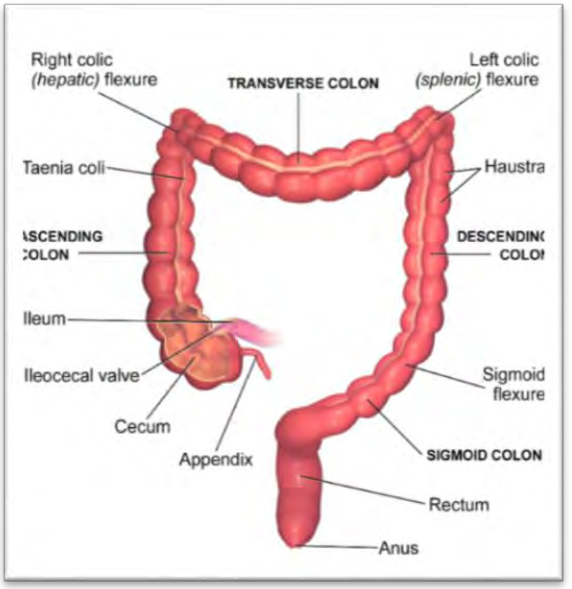


Figure 1. Anatomy of the colon.
Courtesy of Bruce Blausen.
Available at: Wikipedia

WHO SHOULD BE SCREENED FOR COLORECTAL CANCER?

All people age 50 or older should be screened for colorectal cancer, and patients at high risk for colorectal cancer may need to be screened at a younger age. Patients are considered higher risk if they have:[2]

- personal or family history of colorectal polyps or cancer
- history of inflammatory bowel disease
- history of a genetic syndrome like familial adenomatous syndrome polyposis (FAP) or hereditary nonpolyposis colorectal cancer.

Despite the importance of screening starting at age 50, the Centers for Disease Control and Prevention reports that only one in three patients ages 50-75 actually undergoes the screening exam. Several studies have indicated that the invasive nature of conventional screening is a barrier to consider having the procedure.

The increasing availability of virtual colonoscopy has shown to increase screening rates and likely will lead to a decrease in mortality from colorectal cancer.[3]

PATIENT PREPARATION

Patients undergoing virtual colonoscopy must undergo bowel cleansing just as they would for conventional colonoscopy. Preparation may begin 1 to 3 days before the study and includes a clear liquid diet. Orange juice should not be taken, and pulp must be removed from other types of juice.

Recommended choices for a clear liquid diet:

- strained apple or grape juice
- water
- coffee or tea without cream or milk; sugar is okay
- lemon, lime, or orange gelatin
- lemon, lime, or orange sports drinks
- fat-free bouillon or broth

On the night before the exam, a laxative and an enema must be taken to increase bowel movement and begin evacuation of the colon. This portion of the prep is often challenging as up to a gallon of liquid laxative must be consumed.[4] It is imperative that the bowel be completely cleansed to allow optimal visualization of the colon during imaging. Retained fluid or stool may create visual artifacts, resulting in rescheduling of the procedure.

Oral barium (barium sulfate 2%) and a water-soluble contrast like Gastrografin® must be taken the night before the VC procedure. During imaging, barium helps distinguish residual stool from tissue and Gastrografin depicts residual liquids.[5]

Colonic Insufflation

Along with adequate bowel cleansing, colonic distention is the most important prerequisite for the detection of polyps. Manual room air **insufflation** is commonly used to create colon distention due to ease of use and low cost. However, manually-infused room air may cause significant patient discomfort due to cramping.

Along with adequate bowel cleansing, colonic distention is the most important prerequisite for the detection of polyps.

An alternative to room air is machine-pumped CO2, which provides greater control of the distention process. CO2 is easily absorbed through the colon wall and released through the lungs and therefore does not tend to produce as much cramping as room air, especially after the exam.[6]

Exquisite care should be taken when inserting the rectal insufflation tube. A non-rigid tube is recommended and should only be inserted by a physician or trained assistant (radiologic technologist, physician assistant, or nurse). A rectal retention balloon may be used to keep the tube in place. Insufflation must be stopped immediately if the patient complains of severe pain. Significant pain could indicate a bowel tear or perforation and, while rare, could require emergency surgical intervention.[7]

The tube or balloon can obscure anorectal pathology. To avoid this risk, it is recommended that the balloon be deflated immediately before the last series of images is obtained, which is typically during the prone series. A digital rectal examination (DRE) performed by the referring physician should be performed prior to the colonoscopy.[8]

Virtual Colonoscopy Imaging Protocol

After the colon has been insufflated, CT localizer images are obtained and reviewed to ensure adequate colonic distention before proceeding with the acquisition of cross-sectional images.[7] Virtual colonoscopy requires imaging in at least two positions, usually supine and prone. The lateral decubitus position is an alternative should the patient be unable to tolerate the prone position.

In accordance with the American College of Radiology guidelines, the CTDI should not exceed 6.25 mGy per series or a total of 12.50 mGy for the entire exam. However, increases in CTDI are warranted when scanning obese patients or when an intravenous contrast agent is indicated. Although VC typically does not require the use of an iodinated contrast agent, IV contrast administration is indicated if intracolonic findings like diverticulosis or extracolonic structures like aneurysm are identified (**Figure 2**). When intravenous contrast is administered, a prone series without contrast should be acquired using the normal VC technique, followed by a contrast-enhanced supine series using a standard abdominal CT protocol.[7]

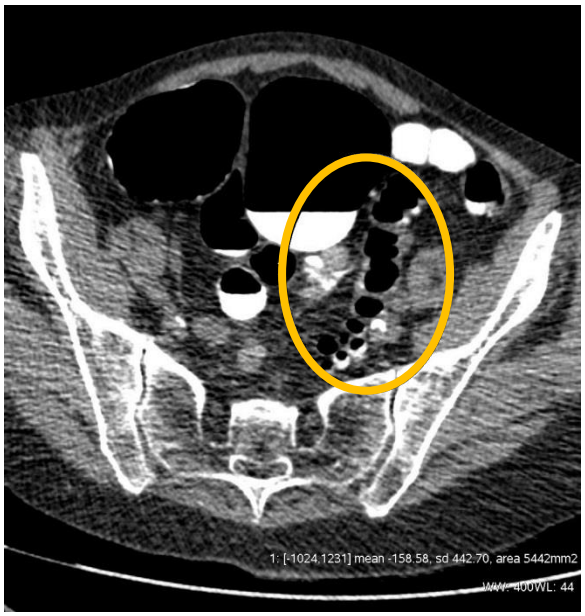


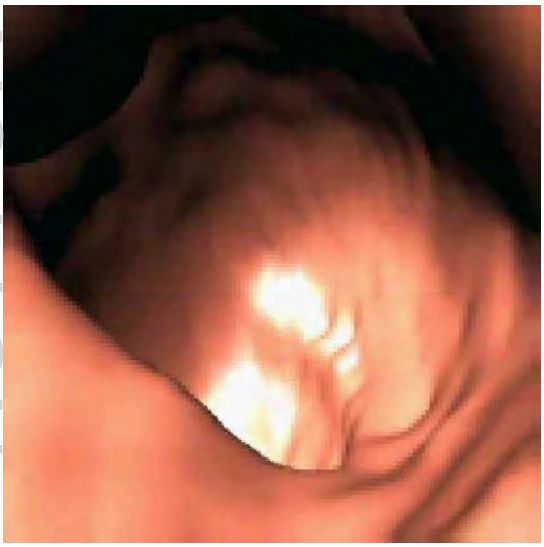
Figure 2. Diverticulosis identified on virtual colonoscopy.

The use of radiation dose reduction techniques like iterative reconstruction is preferred for VC. Image slice thickness should not exceed 1.25mm, with recommended intervals of ≤1mm. To ensure the highest quality image, VC studies should be performed on a MDCT scanner with ≥16 detectors.[7]

It is the responsibility of the technologist to confirm the colon has been adequately cleansed and distended before the exam begins and ensure the entire colon and rectum has been imaged before the patient leaves the CT suite.

If sections of the bowel are inadequately distended, additional insufflation is required for acquisition of the affected section only. Additional imaging in the right or left decubitus position may be necessary if the prone and supine images do not adequately display the colonic lumen. Again, repeat images should be limited to the area of interest to minimize radiation dose to the patient.[7]

It is the responsibility of the technologist to confirm the colon has been adequately cleansed and distended before the exam begins and ensure the entire colon and rectum has been imaged before the patient leaves the CT suite. Thorough preparation by both the patient and technologist should ensure detection of any abnormalities.



3D Reconstructions

After scan acquisition, thin section images are sent to a 3D workstation for interpretation. 3D software creates a navigational view similar to an endoscopic view produced during conventional colonoscopy, allowing the radiologist to "fly through" the colon in forward or reverse motion (**Figure 3**). The user can also rotate or zoom the image, allowing visualization of complex folds or narrow sections of colon.[9]

Figure 3. VIDEO "Fly through" of the rectosigmoid colon performed in a retrograde fashion. There is a 10mm colonoscopically-proven polyp in the sigmoid colon seen at the top of the frame at the midpoint of the movie. The movie concludes at the tip of the rectal tube which was used to insufflate the colon.

Courtesy of C. Daniel Johnson, MD Department of Radiology, Mayo Clinic, Rochester, MN.
Video available at: http://clinicalcenter.nih.gov/drd/colonoscopy.html

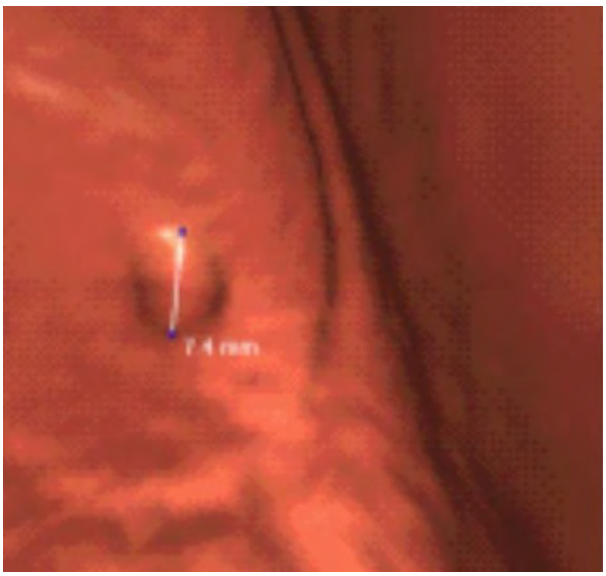


Figure 4. 3D color-coded 7mm sigmoid polyp seen on virtual colonoscopy.

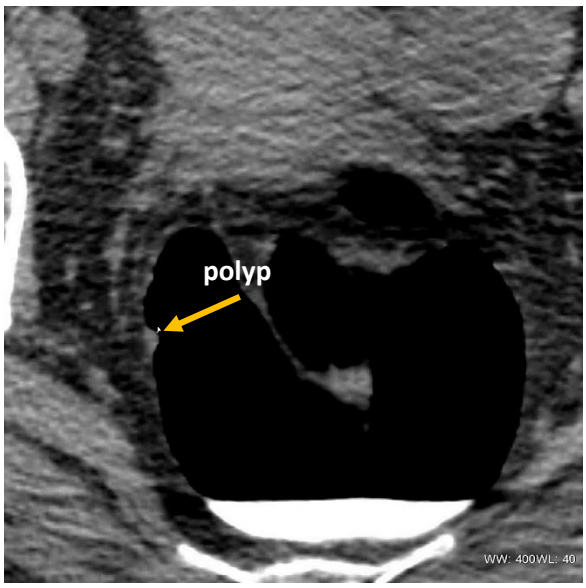


Figure 5. 7mm sigmoid polyp seen on virtual colonoscopy taken in the supine position.

VC software color codes muscle, fat, liquid, and soft tissue densities like polyps, further aiding diagnosis. Polyps ≥ 5mm are more likely to become cancerous; polyps greater than 5mm may require a follow-up VC scan to monitor any changes (**Figure 4**). Polyps ≥ 1cm or three or more polyps in the 6-9mm range may require follow-up with conventional colonoscopy in the event a polyp requires biopsy or excision.[9]

3D fly-through views are used in conjunction with 2D source images to render a diagnosis. Evaluation of source images is vital for confirming the findings seen on the 3D fly-through.

VIRTUAL COLONOSCOPY AS A SCREENING TOOL

Colon Polyps

Colon polyps are growths that occur on the inner lining of the large intestine (colon) and usually protrude into the colon (**Figure 5)**. Polyps are characterized as **hyperplastic** which are harmless, and **adenomatous**. Adenomatous polyps typically develop over a period of years and are a precursor to cancer.[10]

The potential for a polyp to become cancerous is directly related to its size: the larger the polyp, the greater the chance that it will become or is malignant.[11] The clinical significance of smaller polyps <5mm is unknown. The vast majority of these smaller, hyperplastic polyps are not precancerous; some practitioners routinely remove them and other practitioners choose to monitor them through regular follow-up exams.

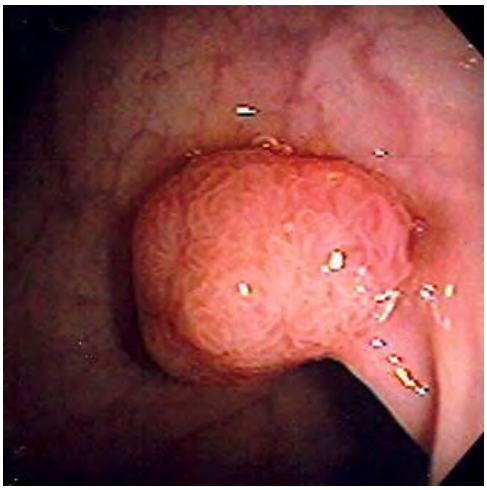


Figure 6. Colon polyp on a short stalk seen on conventional colonoscopy.
Available at: Wikimedia Commons

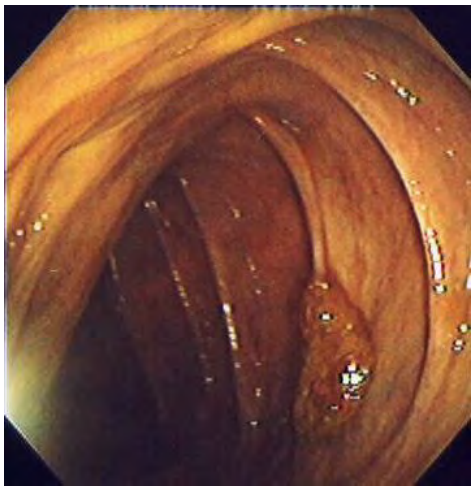


Figure 7. Sessile colon polyp seen on conventional colonoscopy.
Available at: Wikimedia

Images courtesy of Stephen Holland, MD. Naperville Gastroenterology, Naperville, IL

There are three types of polyps:

- **Polypoid** polyps look like a mushroom and are attached to the lining of the colon by a stalk (**Figure 6**).
- Sessile polyps are attached to the colon by a broad base (**Figure 7**).
- Flat polyps, or nonpolypoid polyps, are flat or even slightly depressed. They are the least common type of colon polyp and are more likely to be cancerous than are polypoid lesions. Flat polyps are more difficult to detect on VC than on conventional colonoscopy [12]

Conventional colonoscopy remains the gold standard in colon cancer screening. However, virtual colonoscopy as a screening tool has been well studied and is gaining credibility as an alternative to conventional colonoscopy.

Effectiveness of Virtual Colonoscopy CT as a Screening Tool

In 2008, a large multi-center trial sponsored by the National Cancer Institute published a study comparing VC to conventional colonoscopy for detection of colon cancer. The American College of Radiology Imaging Network (ACRIN) conducted the National CT Colonography Trial, which enrolled more than 2,600 participants from 15 imaging centers.

Study participants were 50 years or older, scheduled for a screening colonoscopy, and had not undergone a colonoscopy within the previous five years. Each participant underwent a virtual colonoscopy, followed by a conventional study, usually on the same day.

The results showed that 90% of polyps ≥1cm were detected on VC, and polyps as small as 5mm were detected with a high degree of accuracy. The study concluded that VC is effective at identifying intermediate to large lesions.[13]

The SAVE trial was a large European study of more than 16,000 participants that compared both reduced preparation and full cathartic preparation in screening with FOBT (fecal occult blood test), virtual colonoscopy, and conventional colonoscopy. Published in 2015, the study results demonstrated that for detection of advanced **neoplasms**, conventional colonoscopy slightly outperformed VC with a detection rate of 7.2% compared to 4.9%.[12]

However, VC significantly outperformed the fecal immunochemical test (FIT) for detection of advanced neoplasia with a detection rate of 5.5% to only 1.7% for FIT. In Europe, FIT is the most widely used screening test for colon cancer due to its low cost and ease of use (in the US, the guaiac-based FOBT test is most commonly used). In previous randomized trials, the fecal test has demonstrated a decrease in mortality from colorectal cancer, but the SAVE trial results showed that FIT was reliable only for identifying cancers only in the distal colon (sigmoid and descending sections).[12]

Perhaps the most important outcome of the SAVE trial was that for the detection of polyps *between 6-9mm*, VC performed with reduced-preparation (without laxative/enema) was as sensitive as a VC with full preparation.

VIRTUAL and CONVENTIONAL COLONOSCOPY: PROS and CONS

Conventional colonoscopy remains the gold standard screening exam in the fight against colon cancer. Its detection rate is generally greater than that of VC, and polyps can be biopsied and excised during the procedure. There are centers that offer same-day conventional colonoscopy should the VC reveal polyps that require biopsy or removal.

However, virtual colonoscopy is finding its way into clinical practice because of the benefits of the VC exam compared to conventional colonoscopy:

- VC is less invasive and does not require sedation
- The entire length of the colon can be visualized, which cannot always be achieved by conventional means
- Because VC requires no sedation, patients are able to return to work the same day; most conventional colonoscopy patients feel the effects of sedation for several hours and are not allowed to drive themselves home
- VC patients are less likely to experience cramping and bloating after the exam[14]

Bowel Perforation on Conventional Colonoscopy

Although rare, patients undergoing a conventional colonoscopy can suffer a serious complication like a tear or perforation of the bowel. In 2003, Gatto et al published results of a study of almost 40,000 colonoscopy patients. Results showed that 77 patients suffered bowel perforations within seven days after undergoing a conventional colonoscopy for a rate of 1.96/1,000. Patients 75 and older had a four times greater risk of bowel perforation. Mortality for subjects with perforations from colonoscopy was 51.9 deaths per 1,000 perforations, or 0.05%.[15]

Radiation Dose on Virtual Colonoscopy

While VC is less invasive than conventional colonoscopy, it exposes patients to ionizing radiation, which increases cancer risk in proportion to the amount of radiation received. As in any CT exam, care must be taken to limit the amount of radiation during virtual colonoscopy. The American College of Radiology recommends that the average patient receive an effective radiation dose of about 3 mSv, similar to the amount of natural background radiation that most people are exposed to in the United States per year.[7]

Exam Time

A benefit of VC is reduced exam time. While a conventional colonoscopy may take an hour to complete, the virtual colonoscopy exam usually requires about 10 minutes. However, recommendation for follow-up screening using VC is every five years because of its reduced sensitivity in identifying small polyps, while conventional colonoscopy is usually recommended every 10 years.[14]

Extracolonic Findings on Virtual Colonoscopy

As noted earlier, virtual colonoscopy is able to identify structures outside of the colon that may lead to identification of an important incidental finding, for example, aortic aneurysm/dissection or solid organ tumors.

While extracolonic findings are uncommon, they can be clinically significant. A large study of 7,952 patients published in 2016 quantified the incidence of unsuspected significant extracolonic findings on VC imaging. Researchers then followed patients whose scans had identified potentially clinical significant extracolonic findings.

Overall, 202 patients (2.5%) had a potentially significant extracolonic finding and were recommended for further imaging or for clinical follow-up. Of the 180 patients not lost to follow-up, 99 were found to have clinically significant disease; 42 patients with malignant or potentially malignant neoplasms and 57 patients with abdominal aortic or other visceral artery aneurysms required treatment or surveillance.[16]

Cost and Coverage

The cost for virtual colonoscopy is significantly lower than that of conventional colonoscopy. In 2015, Pyenson et al reviewed the cost of 56,578 colonoscopies performed on Medicare beneficiaries. Screening by conventional colonoscopy cost an average of $1,036, while the cost of VC was on average $436. The VC average cost also included the cost of the 12.9% patients undergoing virtual colonoscopy who required follow-up with conventional colonoscopy.[17]

Currently the Centers for Medicare and Medicaid Services does not cover virtual colonoscopy. In late 2015, a bipartisan bill, S.2262 CT Colonography Screening for Colorectal Cancer Act of 2015, was introduced. Should this bill be passed, CMS would be required to cover virtual colonoscopy as a colorectal cancer screening option. Fortunately, several large insurance companies currently provide coverage for VC.[3]

Table 1 summarizes the benefits and disadvantages of both virtual and conventional colonoscopy.

	Virtual Colonoscopy	Conventional Colonoscopy
Sedation	No sedation required	IV sedation required
Patient Comfort	Less invasive, no scope	Invasive procedure, requires insertion of several feet of tubing
	Requires colonic insufflation which may be uncomfortable	Does not require colonic insufflation
	Less post-procedure cramping and bloating	Cramping and bloating often occur post-procedure
	Patient can return to work	Patient is often unable to return to work
Recovery	No recovery time needed	Sedation requires +/- 1 hour recovery time and a ride home
Scan Time	10-15 minutes in the CT scanner	60-minute procedure on the table
Performance	Reduced ability to detect nonpolypoid lesions	Greater ability to detect non-polypoid lesions
	Detection rate not as sensitive for polyps <5mm	Greater detection rate of smaller polyps
	Can detect extracolonic abdominal abnormalities	Extracolonic abdominal abnormalities cannot be detected
	Cannot perform biopsy or excision of polyps at the time of the exam	Abnormalities can be biopsied or removed at the time of the exam
Cost/Coverage	Less expensive, but currently not covered by CMS for screening	More costly, but currently covered by CMS for screening
Interval Time	Typically 5 years	Typically 10 years
Adverse Events	Little to no risk of bowel tear or perforation	Small risk of bowel tear or perforation
	Small exposure to radiation	No exposure to radiation

Table 1. Comparison of virtual and conventional colonoscopy.

CAPSULE ENDOSCOPY

In addition to conventional colonoscopy and virtual colonoscopy, there is a third FDA-approved method for visualizing the colon — capsule endoscopy or camera colonoscopy. Capsule endoscopy is approved only for patients who have not been able to complete a colonoscopy and as the first method for colorectal cancer screening. As of this writing, the FDA has approved only one device for this exam.

Capsule endoscopy requires a pill-shaped device 1.25 inches long and 0.50 inch wide, housing a battery, a light, and two tiny color video cameras to be swallowed by the patient. While traveling through the digestive tract, the miniature cameras wirelessly transmit video to a recording device worn on the patient's belt. It takes approximately 10 hours for the camera to complete its journey, and during this time the patient must limit physical activity and avoid stooping or bending. After the camera is excreted, the video is uploaded to a computer for interpretation.

Although more comfortable than a conventional colonoscopy or even virtual colonoscopy, the patient must undergo the standard bowel cleansing preparation to ensure diagnostic-quality images. As with VC, a follow-up conventional colonoscopy may be indicated.[18]

A recent study of 320 adults conducted in Brussels compared the cancer detection rates of camera colonoscopy to conventional colonoscopy. Each patient underwent a camera study, followed by a conventional colonoscopy at some point later. Nineteen cancers were detected by conventional colonoscopy, while the camera detected 14 cancers. As with the other methods, the diagnostic capability of the camera colonoscopy increased with better bowel preparation. The study authors theorized that with adequate bowel cleansing and technological advances, camera colonoscopy could become a viable screening tool. [19]

C-RADS: CLASSIFICATION OF COLONIC LESIONS

In 2005, Zalis et al proposed adoption of a lesion reference guide to standardize interpretation and communication of colonoscopy results. The Working Group on Virtual Colonoscopy, comprised of clinical faculty from the Division of Abdominal Imaging and Intervention at Massachusetts General Hospital and members of the Colon Cancer Committee from the American College of Radiology, presented the CT Colonography Reporting and Data System, or C-RADS (see **Table 2** at the end of this chapter). This structured reporting system followed the style of the American College of Radiology's BI-RADS® for breast imaging reporting and data system. The proposal also included post-procedure follow up recommendations.[20]

SUMMARY

Virtual colonoscopy has been shown to be an effective screening tool in the fight against colorectal cancer. Although conventional colonoscopy remains the gold standard for colon cancer detection, virtual colonoscopy provides greater patient comfort while offering similar detection rates, providing greater access to those patients who may avoid scheduling a conventional procedure.

FEATURE DESCRIPTORS FOR POLYPS AND MASSES
Lesion Size (mm) For lesions ≥6 mm, the single largest dimension of the polyp head (excluding stalk if present) on either multiplanar reconstruction (MPR) or 3D views. The type of view employed for measurement should be stated. **Morphology** Sessile – broad-based lesion whose width is greater than its vertical height Pedunculated – polyp with separate stalk Flat – polyp with vertical height <3mm above surrounding normal colonic mucosa **Location** Refer to named standardized colonic segmental divisions: rectum, sigmoid colon, descending colon, transverse colon, ascending colon, and cecum. **Attenuation** Soft – tissue attenuation Fat
CATEGORIZATION SYSTEM FOR CTC FINDINGS AND FOLLOW-UP RECOMMENDATIONS
C0 – Inadequate study/awaiting prior comparisons • inadequate prep; cannot exclude lesions ≥10mm owing to presence of fluid/feces • inadequate insufflation: one or more colonic segments collapses on both views • awaiting prior colon studies for comparison C1 – Normal colon or benign lesion; continue routine screening • no visible abnormalities of the colon • no polyp ≥6mm • lipoma or inverted diverticulum • nonneoplastic findings, eg, colonic diverticula C2 – Intermediate polyp or indeterminate finding: surveillance or colonoscopy recommended • intermediate polyp 6-9mm, <3 in number • indeterminate findings, cannot exclude polyp ≥6mm in technically adequate exam C3 – Polyp, possibly advanced adenoma; follow-up colonoscopy recommended • lesion compromises bowel lumen, demonstrates extracolonic invasion C4 – Colonic mass, likely malignant; surgical consultation recommended
CATEGORIZATION SYSTEM FOR EXTRACOLONIC FINDINGS
E0 – Limited exam – compromised by artifact; evaluation of extracolonic soft tissues is severely limited E1 – Normal exam or anatomic variant. No extracolonic abnormalities visible. • anatomic variant, eg, retroaortic left renal vein E2 – Clinically unimportant finding. No work-up indicated. Examples: • liver/kidney: simple cysts • gallbladder: cholelithiasis without cholecystitis • vertebra: hemangioma E3 – Likely unimportant finding, incompletely characterized. Subject to local practice and patient preference; work-up may be indicated. Example: • kidney: minimally complex or homogeneously hyperattenuating cyst E4 – Potentially important finding. Communicate to referring physician as per accepted guidelines. • kidney: solid renal mass • lymphadenopathy • vasculature: aortic aneurysm • lung: non-uniformly calcified parenchymal nodule ≥1cm

Table 2. C-RADS 2005 classification for CT colonography.[21]

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