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Fundamental Elements for Successful Performance of CT Colonography (Virtual Colonoscopy)

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There are many factors affecting the successful performance of CT colonography (CTC). Adequate colonic cleansing and distention, the optimal CT technique and interpretation with using the newest CTC software by a trained reader will help ensure high accuracy for lesion detection. Fecal and fluid tagging may improve the diagnostic accuracy and allow for reduced bowel preparation. Automated carbon dioxide insufflation is more efficient and may be safer for colonic distention as compared to manual room air insufflation. CT scanning should use thin collimation of $\leq$3 mm with a reconstruction interval of $\leq$1.5 mm and a low radiation dose. There is not any one correct method for the interpretation of CTC; therefore, readers should be well-versed with both the primary 3D and 2D reviews. Polyps detected at CTC should be measured accurately and reported following the "polyp size-based" patient management system. The time-intensive nature of CTC and the limited resources for training radiologists appear to be the major barriers for implementing CTC in Korea.

Index terms:
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CT colonography (CTC), also known as virtual colonoscopy, is rapidly gaining acceptance as a viable option to screen for colorectal cancer and its role for diagnosing colonic disease is being extended. The largest clinical study to date with using CTC for screening of colorectal neoplasia (1), which included 1,233 adults who were at average-risk for colorectal cancer, showed impressive per-patient and per-lesion sensitivities of 93.8% and 92.2%, respectively, for adenomatous polyps $\geq$ 10 mm and 88.7% and 85.7%, respectively, for adenomatous polyps $\geq$ 6 mm (1). However, the follow-up studies have shown contradicting results (2, 3). The discrepancy of the reported results (4) is a reflection of the myriad of required factors for the successful performance of CTC, including bowel preparation and distention, fecal and fluid tagging, the CT scanning parameters, the interpretation methods and the readers' experience and training (5, 6). The purpose of this article is to review the essential elements for successful CTC and to discuss implementation of CTC in routine clinical practice from a Korean perspective.

Bowel Preparation

Polyethylene glycol (PEG), sodium phosphate, magnesium citrate and bisacodyl are widely used laxatives for bowel preparation before performing colonic examinations. Sodium phosphate and magnesium citrate are saline cathartics and they are known as "dry preparation" since they typically leave little fluid in the colon after the preparation. They are preferred for CTC over PEG, which is known as a "wet preparation" that often leaves a large amount of luminal fluid that can compromise the diagnostic

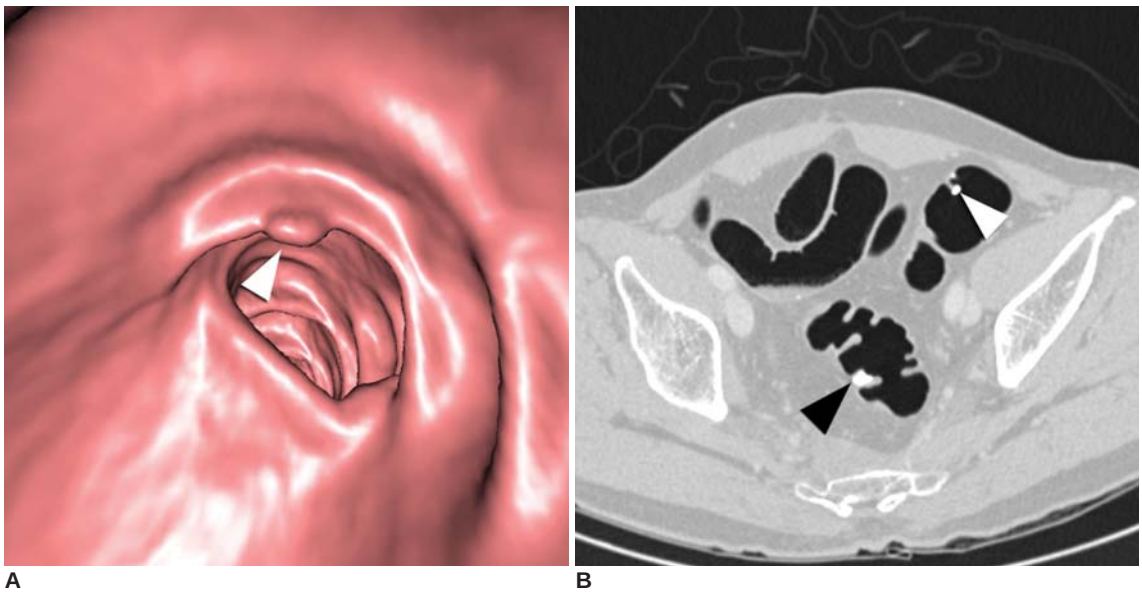
performance of CTC (7). In contrast to the relatively small volumes of sodium phosphate (i.e. typically 90 mL or 45 mL) and magnesium citrate (i.e. typically 250 mL) that are administered to the patient, a large quantity of PEG (i.e. typically 236 g of PEG mixed with 4 L of water) should be given. One study performed in a Korean population with a high residue diet showed better colonic cleansing and shorter CTC interpretation times with using PEG as compared to sodium phosphate (8). However, in general, PEG is known to provide inferior bowel cleansing as compared to sodium phosphate (7, 9, 10). Sodium phosphate is a high-sodium preparation and on rare occasion it can cause significant electrolyte disturbances (11, 12). Thus, it is contraindicated for patients with known renal failure, pre-existing electrolyte abnormalities, congestive heart failure, ascites and ileus (7). Some practitioners use double the normal dose (i.e. 45 ml) of sodium phosphate for a total of 90 ml (1), and this double dose should be used with caution. Magnesium citrate is known to be safer and it also has a more tolerable taste than sodium phosphate (7). Bisacodyl is often used in conjunction with sodium phosphate or magnesium citrate. It stimulates parasympathetic reflexes to induce evacuation of stool (7).

Although complete bowel cleansing is helpful for a colonic evaluation on CTC, it is not mandatory for successful performance of CTC. CTC can be successfully performed using reduced bowel preparation with the aid of fecal and fluid tagging. In one study, bowel preparation was rated as the most unpleasant aspect of both CTC and optical colonoscopy (13). This suggests that reducing the discomfort of purgative bowel preparation would be a major factor in increasing patient compliance with colonic tests. Therefore, efforts to minimize bowel purgation for CTC with the effective use of fecal and fluid tagging should be made.

Fecal and Fluid Tagging

Fecal and fluid tagging is labeling the fecal residue in the colon with using radiopaque contrast media (Figs. 1, 2). The contrast agent is orally administered at each meal, typically the day before the CTC. It then mixes with the ingested food material starting from the stomach. As the mixture passes through the bowel, the nutrients are digested and absorbed, and the tagging agent becomes more thoroughly mixed with the undigested residue. The contrast material also mixes with the residual fluid in the colon. Some of the tagged feces and fluid are evacuated after bowel preparation and the rest remains in the colon. On CT, the fecal matter that is mixed with the orally administered contrast material appears hyperdense or white, making it easily distinguishable from the homogeneous soft tissue density of colonic polyps.

There are two main advantages of performing fecal and fluid tagging. First, the diagnostic performance may be improved due to the easier and more accurate differentiation of polyps from fecal residue (14, 15). Second, there



A B

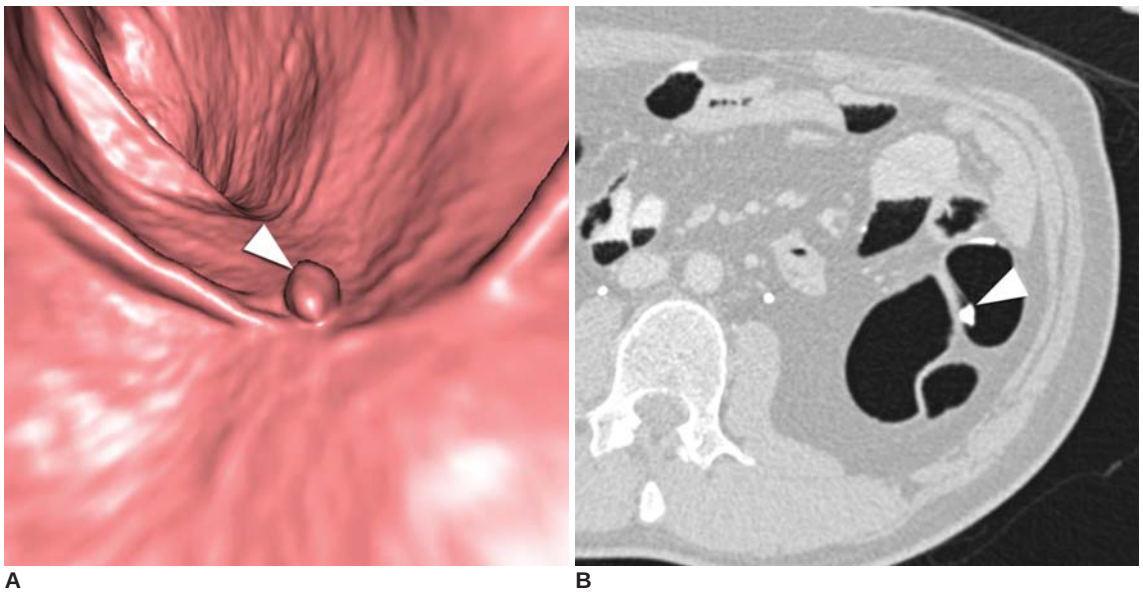
Fig. 1. A 68-year-old male with fecal residue that is tagged with orally-administered barium.
A. 3D endoluminal view shows an 8-mm polypoid structure (arrowhead) on a haustral fold of the sigmoid colon.
B. 2D transverse image using a wide-window setting (width: 1500 HU, level: −400 HU) shows very high attenuation of the polypoid structure (white arrowhead), which clearly demonstrates it is tagged stool. Another piece of tagged stool is noted in the sigmoid colon (black arrowhead).

may be increased patient compliance by decreasing examination-related patient discomfort. A relatively large amount of tagged fecal residue in the colon is tolerable from a reader's standpoint without compromising scan interpretation because the tagged fecal residue can be easily distinguished from a true lesion. Thus, rigorous dietary restriction the day prior to CTC is not mandatory and purgative bowel cleansing can also be reduced (16). Laxative-free CTC with the use of fecal tagging has been attempted (17–19). A relatively large study that evaluated laxative-free CTC yielded very good results with 100% per-patient and per-lesion sensitivities for colonic polyps ≥ 10 mm (19). Although laxative-free CTC is still being evaluated by researchers, it has great potential for dramatically decreasing patient discomfort and thereby increasing patient acceptance.

Various tagging agents, including various densities of barium (Fig. 1), iodinated contrast (Fig. 2) and their combinations, have been used (1, 14, 19). At present, there is no consensus with regard to the most effective method (i.e. which agent, dose, administration protocol, etc.) of fecal and fluid tagging. The optimal tagging method may vary according to the dietary habits of different ethnic groups. At present, there is no available data regarding the optimal method of fecal and fluid tagging for a Korean population and whether there might be any difference from the tagging protocols that are used elsewhere. Given the importance of fecal and fluid tagging for the performance of CTC, studies to determine the optimal tagging method for a Korean population are probably necessary. Sodium amidotrizoate and meglumine amidotrizoate (gastrografin) is an iodinated contrast agent that is often used for tagging. It may induce diarrhea. It is generally safe; however, rare anaphylactoid reactions after oral administration of gastrografin have been reported in a blunt trauma patient without bowel disease (20) and in a patient with pseudomembranous colitis (21). A small amount (3%) of gastrografin is absorbed from the gastrointestinal tract after oral administration and this is eliminated mainly via the kidneys (22). Therefore, it should not be used in those patients with hypersensitivity to iodine, hyperthyroidism and decreased renal function (22).

Colonic Distention

The importance of proper colonic distention during the performance of CTC cannot be overstated. A suboptimally distended colon can obscure (Fig. 3) or mimic a lesion (Fig. 4). Even a fairly large lesion can be missed if the colon is collapsed. Automated carbon dioxide (CO_2) insufflation is increasingly being used for colonic distention during CTC. Automated CO_2 insufflation is reported to improve colonic distention (23) and be safer compared to manually administered room air insufflation (24). Colonic perforation associated with CTC is a rare event. Almost all the reported cases of colonic perforation during CTC have been associated with the use of manual insufflation, whereas only two cases of asymptomatic perforations and



A B

Fig. 2. A 42-year-old male with fecal residue that is tagged with orally-administered gastrografin.
A. 3D endoluminal view shows a 10-mm polypoid structure (arrowhead) in the descending colon.
B. 2D transverse image with using a wide-window setting (width: 1500 HU, level: −400 HU) shows very high attenuation of the polypoid structure (arrowhead), and this consistent with tagged stool.

one case of symptomatic perforation, which occurred in a patient with active stenosing ileocolic Crohn's disease, have been associated with the use of automated CO_2 insufflation (25–30). Although CO_2 has not been clearly shown to decrease patient discomfort during the examination, the post-procedural discomfort is less with CO_2 compared to room air due to the rapid absorption of CO_2 through the colonic mucosa (23).

Colonic distension is achieved by using automated CO_2 insufflation at a pressure of 15–20 mmHg starting with the patient in a left lateral decubitus position. The patient is turned supine after 1 to 1.5 L has been introduced and the pressure is maximized to 25 mm Hg. A scout view is taken after noting the suggestive signs of fully-distended colon (i.e. patient's intolerance, insufflation of approximately 2 L or a consistent rectal pressure over 25 mmHg). Yet in some cases, a desirable level of colonic distension is not achieved despite the rectal pressure consistently exceeding 25 mmHg. The following should then be performed: 1) check the extension tube for the presence of any blockage, compression or kink, 2) reposition the rectal tube tip to avoid possible occlusion of the tip against the rectal wall, 3) have the patient's knee and hip joints in a slightly flexed position in order to relax the abdomen, 4) gentle manual palpation of the abdomen to distribute the CO_2, 5) additional positional changes, 6) disconnect the tube for 3 seconds to allow for decompression of the rectum while not deflating the entire colon, then reinitiate insufflation (31) and 7) place a cushion under the patient's lower chest to decrease compression of the abdomen in the prone

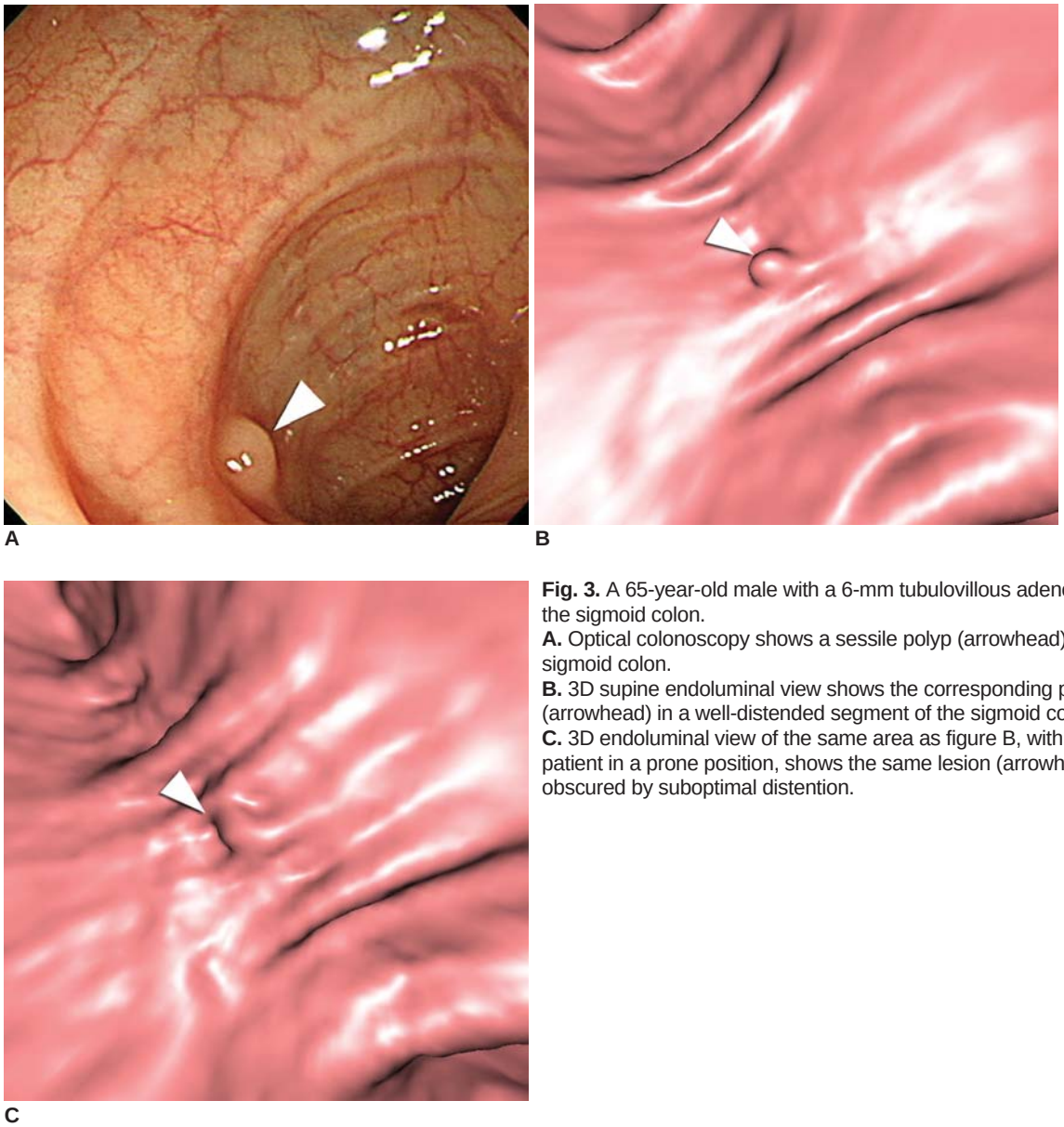
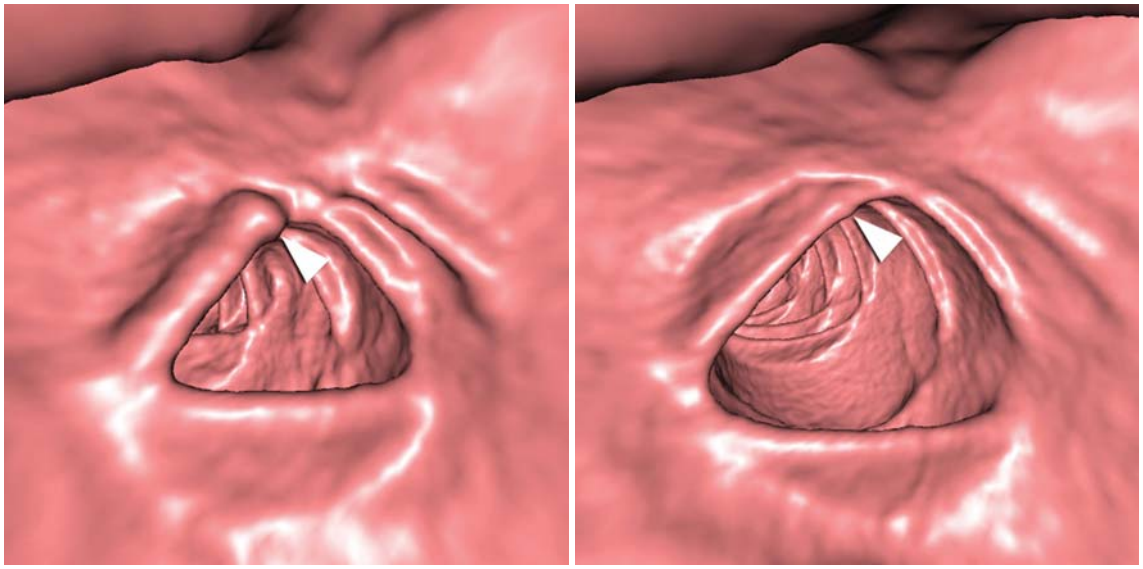


Fig. 3. A 65-year-old male with a 6-mm tubulovillous adenoma in the sigmoid colon.
A. Optical colonoscopy shows a sessile polyp (arrowhead) in the sigmoid colon.
B. 3D supine endoluminal view shows the corresponding polyp (arrowhead) in a well-distended segment of the sigmoid colon.
C. 3D endoluminal view of the same area as figure B, with the patient in a prone position, shows the same lesion (arrowhead) obscured by suboptimal distention.



A B

Fig. 4. A 68-year-old female with a pseudopolyp in the transverse colon.
A. 3D prone endoluminal view shows focal bulbous thickening (arrowhead) of a haustral fold in the suboptimally-distended transverse colon, which resembles a sessile polyp.
B. 3D endoluminal view of the same area as figure A, with the patient in a supine position, shows the disappearance of the pseudopolyp (arrowhead) when the colon is well-distended.

position.

An antispasmodic agent such as hyoscine butylbromide (buscopan) or glucagon may be administered prior to colonic insufflation to relieve colonic spasm and patient discomfort (32, 33). Intravenous (IV) administration of 20 mg of buscopan immediately prior to gas insufflation has been shown to be associated with significantly improved colonic distention (33), whereas glucagon has not shown a definitive benefit in patients undergoing colonic distention (34). Buscopan should be used with some caution because glaucoma, cardiac ischemia and urinary retention may all be precipitated and self-limiting dry mouth and blurred vision may also occur.

CT Scanning

Both supine and prone scans are routinely obtained and the field of view should be adjusted to obtain complete anatomic imaging of the colon and the rectum in both positions (32). A combination of supine and prone positioning allows superior colonic distention and a higher sensitivity for polyp detection compared to those with using either position alone (35, 36). Slice collimation affects polyp visualization in important ways. A recent meta-analysis suggests that multidetector CT (MDCT) with the use of thin sections is a substantial improvement over single-detector CT (4). According to the practice guidelines for the performance of CTC in adults by the American College of Radiology (ACR), a slice collimation of $\leq$3 mm with a reconstruction interval of $\leq$1.5 mm gives optimal imaging (32). With using modern scanners (i.e. 16 or 64-MDCT) that are already in widespread use, scanning with a thinner collimation is easily achieved. One should use the thinnest slice that allows covering the entire abdomen in a single breath-hold. Because of the intrinsic high contrast between the colonic mucosa and luminal air, detailed images of the colonic luminal surface can be obtained even with the use of a very low radiation dose. 120 kVp is generally used. It has been shown that the radiation dose could be decreased, without sacrificing diagnostic accuracy, to as low as 10 mAs with a total effective dose of 1.8 mSv in men and 2.4 mSv in women (37), which is less than half the radiation dose of a barium enema (38). In practice, scanning with 50 mAs allows evaluation of colonic and extracolonic findings on CTC.

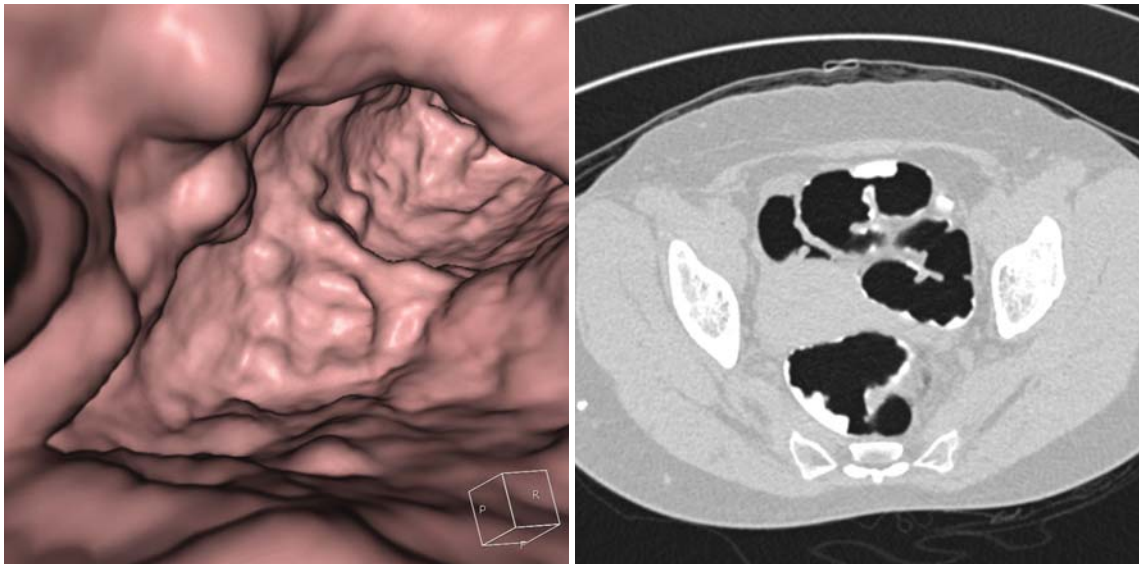
IV contrast enhancement is helpful for differentiating polyps from fecal residues (39, 40) and for improving the detection of polyps in suboptimally prepared colons (41). Yet it is not routinely used with screening CTC due to its risk and uncertain cost-effectiveness (32). On the other hand, IV contrast enhancement is important for the detection and characterization of clinically significant extracolonic abnormalities. Therefore, it is necessary to use contrast enhancement for patients with known colorectal cancer or if they have the suspicion of it, for patients who are followed up after curative surgery for colorectal cancer and for those patients with symptoms that suggest an increased prevalence of extracolonic abnormalities (32, 42,

43). The arterial (or mucosal) phase may be appropriate for the purpose of polyp detection since bowel wall enhancement is maximized (44) and polyps are better visualized (45) at this phase. The portal phase is presumably more appropriate for extracolonic evaluation, and particularly for the detection of hepatic metastasis. When IV contrast enhancement is used for extracolonic evaluation, a standard radiation dose for body CT should be used (32).

Interpretation and Reporting

Primary Two-Dimensional (2D) versus Three-Dimensional (3D) Reviews

Primary 2D interpretation refers to review of the colon from the rectum to cecum by scrolling through serial transverse images in a stack mode. Wide display window width and level settings such as 2000 HU/0 HU, 1500 HU/-400 HU or 1500 HU/-200 HU are used to maximize visualization of polyp. Primary 3D review typically refers to an optical colonoscopy-like endoluminal fly-through of a 3D reconstructed colon. This type of review consists of four different fly-throughs: antegrade and retrograde in both the supine and prone positions. The primary 2D review, which requires rapid tracing of the colonic outline on each image to find small contour abnormalities, is generally more reader-intensive (i.e. a higher level of reader concentration and experience is required) than is the primary 3D review. Although it was not proven, a higher sensitivity of the primary 3D review compared to the primary 2D review for polyp detection was also suggested (1). A primary 3D review, on the other hand, has some disadvantages. The primary 3D review is less time-efficient than the 2D review (46–49), and it may not work well with a protocol of reduced preparation and fecal tagging that leaves a large amount of fecal residue in the colon (Fig. 5). Although a 3D fly-through may be capable of detecting all polyp-like structures in a colon, in cases of excess luminal protrusions, differentiation of a true polyp from polyp-like stool by repeated reference to the 2D images or to a translucency map based on lesion density would render the interpretation exhausting. Moreover, those lesions buried under fecal material would not be detectable at all during the 3D fly-through. Unless robust electronic cleansing is available (i.e. digital subtraction of the tagged feces and fluid) (50, 51) with the capability of removing the majority of pseudopolyps (i.e. feces) before the 3D review, primary 3D review of CTC that's performed with reduced preparation, and especially laxative-free CTC, is not likely to be feasible. In contrast, the 2D interpretation of tagged cases is still effective without digital subtraction (Fig. 5B). There is not any one correct method for performing interpretation of CTC. Almost all cases will require a combination of both the 3D and 2D review methods. Therefore, readers should be well-versed with both methods.



A B

Fig. 5. A 54-year-old female with a large amount of tagged fecal residue in the sigmoid colon.
A. The 3D endoluminal view shows many polypoid and mass-like structures in the sigmoid colon. Examining each polypoid or mass-like structure to distinguish a true polyp/mass from fecal residue is tiresome. Additionally, lesions buried under fecal material are not detected at all during the 3D fly-through.
B. Using a wide-window setting (width: 1500 HU, level: −400 HU) for the 2D transverse image, all the pseudolesions (i.e. tagged fecal residue) are easily recognized.

Alternative 3D Display Methods

Various alternative 3D display methods have been developed that allow visualization of the complete colonic surface in a time-efficient way. The virtual dissection method divides the colon along its longitudinal axis; it straightens and flattens the colon mathematically so that it resembles an open pathologic specimen (Fig. 6) (52–54). The main advantage of this method is that it allows a large area of colonic surface to be examined quickly and it does not require both anterograde and retrograde fly-throughs, which potentially allows shorter interpretation times (55). The primary disadvantage of this technique is image distortion (Fig. 6), particularly in areas with sharp curves and at the anus and cecum (55). The diagnostic value of this technique is currently under investigation. Despite the image distortion, the virtual dissection method has been shown to yield a similar diagnostic performance compared to that of primary 2D interpretation for the detection of colorectal lesions (55).

Computer-Aided Diagnosis (CAD)

CAD of polyps with using CTC is currently an area of active research and it will undoubtedly have an impact in the future on CTC interpretation. CAD has the potential to improve the sensitivity for polyp detection especially for inexperienced readers, and so it may decrease the variability of diagnostic accuracy among readers having different levels of experience. Despite its relatively short history, the fundamental CAD scheme has been established for the detection of colonic polyps (56, 57) and this has already been incorporated in several commercial CTC systems. The CAD scheme generally consists of the four typical tasks: 1) segmentation of the colonic wall, 2) detection of polyp candidates, 3) extraction of texture features and 4) differentiation of true polyps from false-positives. The performance of CAD has been validated in several studies (46, 56–61). Of those, the largest study to date by Summers et al. has reported both a per-polyp and per-patient sensitivity of 89.3% for retrospectively identifiable adenomatous polyps $\geq$ 1 cm with 2.1 false-positive polyps per patient in an asymptomatic screening population (61). Although CAD will likely improve the sensitivity for polyp detection and decrease the inter-observer variability, it is unclear how CAD will influence the interpretation time. This will likely depend on whether CAD is used as a primary versus secondary reader for CTC. Regulatory requirements stipulating that an exam be initially reviewed by a human reader prior to referring to CAD may increase the interpretation time. On the other hand, a recent study showed that 2D interpretation with CAD was quicker than a 3D fly-through and just as sensitive (46), and this supports the potential of CAD for reducing interpretation time.

Polyp Measurement and Reporting

Polyp size is clinically the single most important feature of a colorectal polyp because it serves as a rough gauge for the risk of carcinoma and so it dictates patient care. Therefore, polyps should be measured accurately and reliably at CTC and patient management should be done according to the reported polyp size. Polyps measuring $\geq$ 10 mm should be reported with a recommendation for therapeutic colonoscopy (32, 62). Reporting of polyps measuring $\leq$5 mm is not recommended because they often represent false-positives and they are frequently non-neoplastic or are associated with an extremely low risk of malignancy (32, 62). The potential harm of colonoscopy may outweigh the benefits for patients with diminutive polyps. Reporting of polyps measuring between 6–9 mm varies, depending on the specific lesion size, the certainty of the findings, the patient's age and the existing comorbid conditions (32). One guideline that used the CT Colonography Reporting and Data System (C-RADS) classification scheme suggested immediate colonoscopy for those patients with three or more 6–9 mm polyps and follow-up colonoscopy should be done in three years for patients with less than three 6–9 mm polyps (62).

Polyp measurements obtained on the 3D endoluminal view were found to be more accurate than the measurements obtained with using the standard orthogonal 2D images (i.e. the transverse, coronal and sagittal images) (63). The long axis of an asymmetric polyp is often not aligned with the orthogonal 2D planes so that 2D measurements often underestimate the true polyp size unless an oblique multiplanar reformation (MPR) plane that shows the maximum polyp diameter is used. Polyp sizing on 3D views, on the other hand, has limitations. The accuracy of lesion measurements applies only to the 3D endoluminal view or the cube view, and 3D measurements should not be obtained with using 3D techniques that have image distortion, such as the "virtual dissection" view. 3D measurements should be performed with particular care so as not to place the measurement cursor outside of the lesion boundary. Even slight misplacement off the lesion boundary can lead to significant overestimation of lesion size (Fig. 7). In contrast, this is not a significant problem with 2D measurement.

Implementation of CTC in Routine Clinical Practice: A Korean Perspective

Colorectal cancer is a significant health concern in Korea;

it was the fourth leading cause of cancer death in Korea in 2004, constituting 9.1% of all cancer deaths, and its incidence continues to increase (64). However, public awareness of colorectal cancer screening is relatively low, and widespread adoption of CTC in routine clinical practice still seems far off. One Swedish national survey

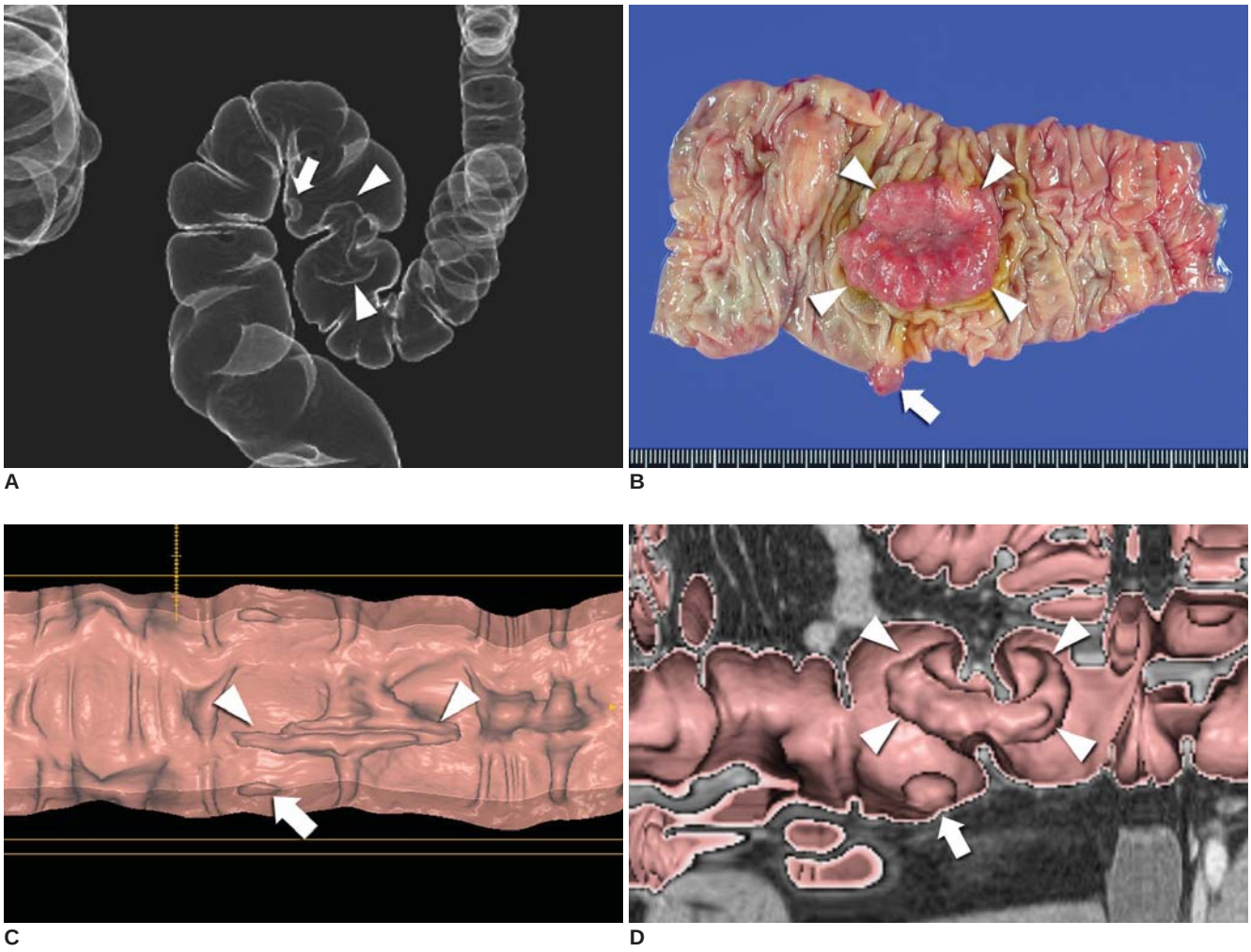
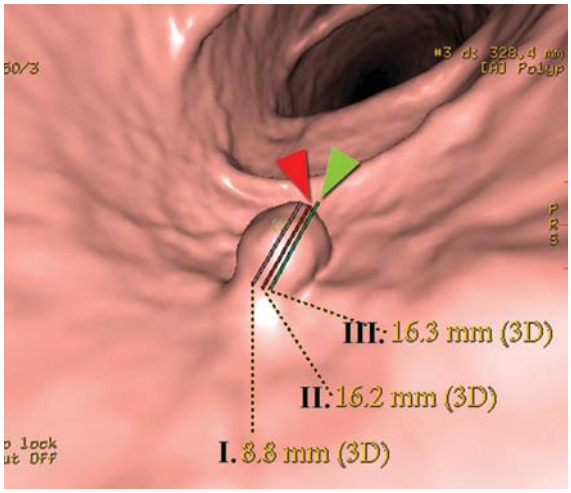


Fig. 6. A 53-year-old male with an adenocarcinoma and a tubular adenoma in the sigmoid colon.
A. The locations of the adenocarcinoma (arrowheads) and the tubular adenoma (arrow) in the sigmoid colon are clearly demonstrated on the raysum image.
B. The surgical specimen shows a 3.5-cm ulcerofungating adenocarcinoma (arrowheads) and an 8-mm pedunculated tubular adenoma (arrow) in the sigmoid colon.
C. The 3D "virtual dissection" image shows the morphologic distortion of the cancer mass (arrowheads) and the polyp (arrow).
D, E. In contrast to the virtual dissection image, image distortion is not noted on the volume-rendered image along the centerline of the colon without flattening (**D**) and on the 3D endoluminal view (**E**). Both lesions (arrowheads and arrow) show similar morphologies to those of the surgical specimen.



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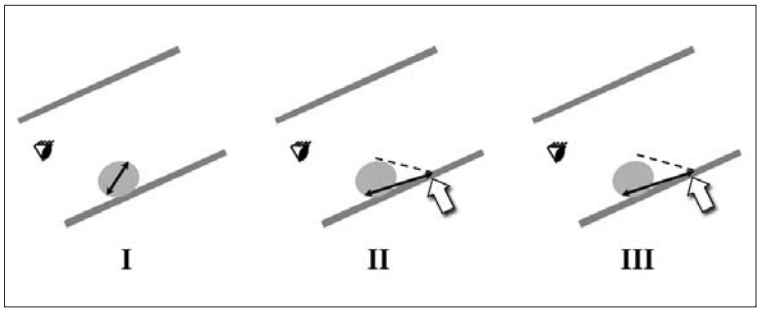

B

Fig. 7. A 53-year-old male with a tubular adenoma in the sigmoid colon.
A. 3D endoluminal view shows three different measurements ("I, II and III") of a sessile polyp with a narrow neck. Which of the three measurements is correct? "I (8.8 mm)" is correct. In "II (16.2 mm)", the measurement cursor (red arrowhead) is placed slightly off the lesion margin and leads to an erroneous measurement. In "III (16.3 mm)", the placement of the measurement cursor (green arrowhead) is clearly incorrect, resulting in an erroneous measurement.
B. Correlative measurement diagrams for "I, II and III" of figure **A**. If the measurement cursor is placed off the lesion boundary (II and III), then the first pixel on the colonic wall beyond the polyp in the viewing direction (arrows) is chosen for measurement (i.e. the measurement cursor cannot be placed in an "empty" luminal space, rather, it is placed on the colonic wall after progressing some distance in the viewing direction until it hits the colonic wall), causing overestimation of lesion size. Even slight misplacement of the cursor (e.g. a single pixel), which may be imperceptible by the naked eye, causes this phenomenon and this can lead to significant overestimation of lesion size as demonstrated in measurement "II".

showed that the lack of CTC training and expertise and the unavailability of MDCT scanners and CTC software were the major factors preventing the widespread adoption of CTC (65). This is in contrast with the United States where the lack of reimbursement is cited as a key barrier. Although concrete data regarding the reasons for the delayed implementation of CTC in Korea is not available, a few points are worthy of discussion.

First, the Korean medical environment requires a rapid turnover of CT exams and thus the time-intensive nature of CTC may be a deterrent. Interpretation of CTC involves meticulous evaluation of the complete luminal surface of the colon by viewing hundreds of images with searching for small lesions on the order of 6 mm and larger. In many patients who have no lesions, the search can be tedious, time-consuming and unsatisfying. A recent multi-center study that included nine European centers showed that the mean time for primary 2D interpretation of the colon, with ignoring the extracolonic findings, was 10.9 minutes and 15.7 minutes, depending on the reader's experience (66). In another study the mean time required for both the primary 3D fly-through of the colon and the evaluation of the extracolonic findings was reported to be 19.6 minutes (1). Although the interpretation time is shortened with the reader's increasing experience (1, 66), a plateau likely exists for continued significant improvement. As mentioned previously, the influence of CAD on the interpretation time is as yet unclear, and this will likely depend on whether CAD is used as a primary versus secondary reader for CTC.

Second, the resources for CTC training are limited. CTC is not simply an extension of abdominal CT to the colon, but it includes technical and interpretive aspects that may not be familiar to most radiologists. Thus, radiologists who are currently in practice should perform and interpret CTC only after adequate training (67). An intensive hands-on course with the supervision of experienced radiologists is suggested as the most advisable training method (67). The ACR practice guidelines for CTC recommend that interpreting physicians review at least 50 cases that have optical colonoscopic proof, together with hands-on interactive training under the supervision of CTC-trained physicians (32). In contrast to the United States and Europe, there are no organized CTC training courses in Korea, except for a few occasional lectures. We advocate the development of training programs, and especially hands-on courses, that are easily accessible for Korean radiologists. Promotion of education through collaborations among institutions, as exemplified by the "Working Group for Virtual Colonoscopy" in the United States, should also be pursued. The availability of teaching cases is also important for training. Walter Reed Army Medical Center has recently released 52 CTC datasets for non-commercial, scientific and educational use (available at http://nova.nlm.nih.gov/WRAMC) (1). These cases will be useful for reader training, and especially for those institutions whose own teaching files are not available.

Third, most of the clinical CTC studies have been

performed in western populations, and CTC has not been adequately studied in a Korean population. Although several published studies (8, 68–70) that included a Korean population have yielded good results, all of them were small, single-center studies. Nevertheless, this should not be a hindrance to actively implementing CTC in routine practice in Korea. Given the performance of a myriad of clinical studies, including a meticulously-designed, large, multi-center trial (i.e. ACRIN 6664: National CTC Trial) that is currently in progress (71), additional scientific validation for an exclusively Korean population may not be necessary. Regardless, careful monitoring should be done for any characteristics that are unique to CTC practice in a Korean population.

CONCLUSION

CT colonography is a novel and rapidly evolving technique for colonic examination, and it is especially useful for colorectal cancer screening. Many factors influence successful performance of CTC. An understanding of these factors and continued efforts to improve them will help ensure widespread implementation of CTC into routine clinical practice.

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