CT Colonography: Single– versus Multi–Detector Row Imaging[1]

Amy K. Hara, MD
C. Daniel Johnson, MD
Robert L. MacCarty, MD
Timothy J. Welch, MD
Cynthia H. McCollough, PhD
W. Scott Harmsen, MS

Index terms:
Colon, CT, 75.12115
Colon neoplasms, CT, 75.12115
Colon neoplasms, diagnosis, 75.311, 75.32
Colonoscopy, 75.1289
Computed tomography (CT), comparative studies
Computed tomography (CT), helical, 75.12115

Radiology 2001; 219:461–465

[1] From the Department of Diagnostic Radiology, Mallinckrodt Institute of Radiology, 510 S Kingshighway Blvd, St Louis, MO 63110 (A.K.H.), and the Departments of Diagnostic Radiology (C.D.J., R.L.M., T.J.W., C.H.M.) and Biostatistics (W.S.H.), Mayo Clinic, Rochester, Minn. Received June 12, 2000; revision requested July 26; revision received September 22; accepted November 1. **Address correspondence to** A.K.H. (e-mail: *haraa2@yahoo.com*).

PURPOSE: To compare respiratory artifacts, colonic distention, and polyp detection at computed tomographic (CT) colonography by using single– and multi–detector row helical CT systems.

MATERIALS AND METHODS: A total of 237 consecutive patients received subcutaneously administered glucagon and underwent prone and supine CT colonography with single–detector row CT ($n = 77$) and multi–detector row CT ($n = 160$), followed by colonoscopy. Examination results were graded for colonic distention, respiratory artifacts, and polyp depiction by two radiologists working independently.

RESULTS: Suboptimal colonic distention was significantly more common with single–detector row CT and was present in at least one segment in 52% (40 of 77 patients) of examinations versus only 19% (30 of 160 patients) with multi–detector row CT ($P < .001$). Mild respiratory artifacts were present in 61% (47 of 77 patients) of single–detector row CT examinations versus only 16% (26 of 160 patients) of multi–detector row CT examinations ($P < .001$). Depiction of polyps larger than 10 mm was 89% (eight of nine polyps) for single–detector row CT and 80% (eight of 10 polyps) for multi–detector row CT ($P > .05$).

CONCLUSION: CT colonography performed with multi–detector row CT significantly improved the demonstration of colonic distention and depicted fewer respiratory artifacts compared with single–detector row CT. No significant differences in the depiction of polyps larger than 10 mm were demonstrated between single– and multi–detector row CT for a small number of polyps. Studies with a larger prevalence of clinically important polyps are needed for further evaluation of differences in polyp detection.

Multi–detector row helical computed tomography (CT) has multiple technical advantages over single–detector row CT, including faster imaging times with the acquisition of thinner sections (1–4). This improved technology has potential advantages in multiple areas of radiology, including CT angiography and lesion enhancement and detection (5,6). CT colonography is another area of potential improvement with multi–detector row scanners. The purpose of this study was to compare the degree of respiratory artifacts, colonic distention, and polyp detection at CT colonography by using single– and multi–detector row systems.

MATERIALS AND METHODS

A total of 283 consecutive patients underwent CT colonography followed by colonoscopy from January 1998 through March 1999. Patients were at high risk for colorectal cancer and had a history of colon polyps or cancer in a first-degree relative, a prior history of colon cancer or a polyp, or a recent onset of iron deficiency anemia. Patients selected for the study were between 40–80 years of age and able to provide written consent. Patients with colostomies, inflammatory bowel disease, or acute diverticulitis; those who were pregnant; those who had undergone colonic biopsy in the previous 72 hours or polypectomy in the previous 6 weeks; and those who had severe claustrophobia were excluded.

Author contributions:
Guarantor of integrity of entire study, A.K.H.; study concepts and design, A.K.H.; literature research, A.K.H.; clinical studies, T.J.W., R.L.M., C.D.J.; data acquisition, T.J.W., R.L.M., C.D.J.; data analysis/interpretation, W.S.H., C.H.M.; statistical analysis, W.S.H.; manuscript editing, A.K.H., C.D.J., C.H.M.; manuscript preparation, definition of intellectual content, revision/review, and final version approval, A.K.H.

This study was approved by our institutional review board, and informed consent was obtained for all participants.

Only patients (n = 237) who received subcutaneously administered glucagon were included in this study to eliminate bias related to colonic distention. Forty-six patients refused glucagon. Of the 237 patients who received glucagon, 77 patients underwent CT colonography with the use of a single–detector row CT scanner (HiSpeed Advantage; GE Medical Systems, Milwaukee, Wis), and 160 patients underwent CT colonography with use of a multi–detector row CT scanner (LightSpeed; GE Medical Systems). The single–detector row CT study group consisted of 50 men and 27 women (age range, 46–74 years; mean age, 63.3 years ± 6.4 [SD]). A similar age and sex distribution was present in the multi–detector row CT study group, which consisted of 102 men and 58 women (age range, 41–75 years; mean age, 63.5 years ± 6.5).

All patients underwent standard oral colonoscopic preparation (polyethylene glycol electrolyte solution and bisacodyl tablets) in the 24 hours preceding the CT colonographic examinations. Glucagon, 1.0 mL, was subcutaneously administered to all patients 10 minutes preceding the examination. Colonic insufflation to maximal patient tolerance without pain was performed by the same radiology nurse for 213 (90%) of 237 examinations, with the remaining 24 (10%) performed by a second experienced radiology nurse. Approximately 2 L of CO_2 was manually administered through a rectal tube.

The scanning protocols for single– and multi–detector row CT used in this study are summarized in Table 1. The scanning protocol for single–detector row CT examinations has been previously reported (7,8) and includes the acquisition of an anteroposterior localization image followed by the acquisition of transverse images with the following helical CT protocol: 5-mm collimation, 6.5 mm/sec table speed (pitch of 1.3), 3-mm reconstruction interval, 512 × 512 matrix, field of view to fit, 70 mA, 1-second exposure time, 120 kVp, and 22-second breath holds. Three to four 22-second breath holds were needed to scan 40 cm by using single–detector row CT with a 3-cm overlap between acquisitions.

The scanning protocol for multi–detector row CT examinations was determined by using in vitro and in vivo studies aimed at resolving 5-mm polyps while matching or reducing the patient dose and image noise at single–detector row CT examination (4,9). Multi–detector row CT examinations included the acquisition of an anteroposterior localization image followed by the acquisition of transverse images with the following helical CT protocol: 5-mm collimation, 18.8 mm/sec table speed, high-quality mode, 3-mm reconstruction interval, 512 × 512 matrix, field of view to fit, 50 mA, 0.8-second rotation speed, 120 kVp, and one 21-second breath hold for 40-cm coverage. The high-quality mode uses a pitch of 0.75 (4).

TABLE 1
CT Colonographic Scanning Protocols

Parameters	Single–Detector Row Helical CT	Multi–Detector Row Helical CT
Reconstructed section width (mm)	5	5
Reconstruction interval (mm)	3	3
Table speed (mm/sec)	6.5	18.8
Pitch	1.3	0.75
Scanning time for one breath hold (sec)	22	21
No. of breath holds required for 40-cm coverage	3–4	1
Kilovolt peak level	120	120
Milliampere level	70	50
Exposure time (sec)	1.0	0.8
Effective dose (mrem)*		
Men	440	470
Women	670	670

* Total effective dose for one localization image with the patient in supine and prone positions. To convert to sieverts (SI unit), 1 Sv = 100 rem.

TABLE 2
Colonic Distention

Grade	Single–Detector Row Helical CT (%)*	Multi–Detector Row Helical CT (%)†	*P* Value
1, excellent throughout	44	80	<.001
2, suboptimal in 1–2 segments	52	19	<.001
3, suboptimal in >2 segments	4	1	>.05

* n = 77.
† n = 160.

All images were obtained with the patient first in the supine position and then in the prone position, with reinsufflation as needed based on the scout image. The effective radiation dose was approximately 450 mrem (4.5 mSv) in men or 670 mrem (6.7 mSv) in women for both the single– and multi–detector row CT examinations.

Image processing was performed with a computer workstation (Ultra2; Sun Microsystems, San Jose, Calif) by using customized software developed at our institution. Each prone and supine image was graded for overall colonic distention as follows: 1, excellent throughout; 2, suboptimal in one to two segments; 3, suboptimal in more than two segments. Each image was graded for respiratory artifacts as follows: 0, none; 1, mild; 2, moderate; 3, severe and nondiagnostic. For grading purposes, the colon was divided into eight segments: cecum, ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, sigmoid colon, and rectum.

The Wilcoxon rank sum test for ordered categories was used for evaluation of colonic distention and respiratory artifacts (10). For all tests, a *P* value of .05 or less indicated a statistically significant difference.

All colonoscopic examinations were performed immediately after CT colonography and were videotaped. Three radiologists (C.D.J., R.L.M., T.J.W.) evaluated the CT colonographic findings. Findings of each examination were independently evaluated by two of the three radiologists by using magnified axial CT images with lung window settings (width of 1,500 HU, level of −500 HU) to first screen the colon for abnormalities. Any suspicious areas were indicated with a cursor on the axial image, and fully interactive two- and three-dimensional endoluminal CT colonographic images were then immediately available at the specified location for problem solving. Polyp size

TABLE 3
Respiratory Artifacts

Grade	Single–Detector Row Helical CT (%)*	Multi–Detector Row Helical CT (%)†	*P* Value
0, none	39	84	<.001
1, mild	61	16	<.001
2, moderate	0	<1	>.05
3, severe, nondiagnostic	0	0	>.05

* $n = 77$.
† $n = 160$.

TABLE 4
Detection of Polyps Larger than 10 mm

Detection	Single–Detector Row Helical CT		Multi–Detector Row Helical CT	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Per patient	100 (5/5)	90 (65/72)	78 (7/9)	93 (140/151)
Per polyp	89 (8/9)	Not applicable	80 (8/10)	Not applicable

Note.—CT results were positive if either of the two radiologists called the examination findings positive. Differences were not statistically significant. Data in parentheses are the numbers of findings.

TABLE 5
Detection of Polyps Larger than 10 mm by Observer

Observer	Single–Detector Row Helical CT		Multi–Detector Row Helical CT	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
A	80 (4/5)	88 (44/50)	50 (4/8)	95 (111/117)
B	100 (2/2)	96 (43/45)	33 (1/3)	98 (92/94)
C	100 (3/3)	100 (49/49)	71 (5/7)	96 (86/90)
Weighted mean (%)*	91	94	56	96

Note.—Polyp detection rates are per patient. Data in parentheses are the numbers of findings.
* Weighted mean of CT colonographic results among observers.

and location were independently identified. Both observers were instructed to ignore polyps smaller than 5 mm, since these require more time to evaluate and are of little clinical importance (11).

CT colonographic results were compared with colonoscopic findings, which served as the standard. The Fisher exact test was used to compare the sensitivity and specificity of CT colonographic polyp detection with the use of each type of scanner. Single– and multi–detector row CT results were compared in two ways: by requiring only one observer to correctly identify the positive examination findings and then by requiring both observers to call the examination findings positive. CT colonographic results were also analyzed by randomly choosing one of the two observers and using his or her CT colonographic result, as well as by using a weighted mean among all of the radiologists. Interobserver results were also compared to determine statistically significant differences. The results were compared by a research nurse familiar with CT colonographic examinations. Any questions concerning the findings were discussed with a radiologist (C.D.J.), and the CT colonographic findings were reviewed. If the location of the polyp at colonoscopy was within one segment of the location at CT colonography and if the sizes were similar, the videotape was not reviewed for confirmation. If both CT colonographic reviewers reported a false-positive finding of 10 mm or larger, the videotape was sent to a gastroenterologist for review.

All CT colonographic examinations with findings of polyps 10 mm or larger that were identified at colonoscopy and missed at CT colonography were retrospectively reviewed to determine the cause of the false-negative finding. In addition, all false-positive CT colonographic findings of polyps 10 mm or larger were also reviewed to determine the cause of the error.

RESULTS

The results with regard to colonic distention are summarized in Table 2. Suboptimal colonic distention was significantly more common at single–detector row CT and was present in at least one segment in 52% of these examinations versus in only 19% of multi–detector row CT examinations ($P < .001$). Suboptimal distention in more than two segments was found in three single–detector row CT examinations versus in only one multi–detector row CT examination.

The results with respect to respiratory artifacts are summarized in Table 3. The majority (84%) of multi–detector row CT examinations revealed no respiratory artifacts. This was true in less than half (39%) of the single–detector row CT examinations ($P < .001$). Images in only one patient in each group showed moderate respiratory artifacts, which were due to advanced emphysema. No images were nondiagnostic because of severe respiratory artifacts.

Colonoscopy depicted nine polyps (mean size, 10 mm; range, 10–30 mm) larger than 10 mm in five patients undergoing single–detector row CT and depicted 10 polyps (mean size, 11 mm; range, 10–35 mm) in nine patients undergoing multi–detector row CT. CT colonographic results for polyps larger than 10 mm are summarized in Table 4. Detection of polyps larger than 10 mm was slightly lower at multi–detector row CT (eight [80%] of 10 polyps) compared with single–detector row CT (eight [89%] of nine polyps); the difference was not statistically significant. In addition, no statistically significant differences in detection sensitivity or specificity were revealed when patients with polyps larger than 10 mm were evaluated or when patients with polyps larger than 5 mm were included. Few polyps smaller than 5 mm were reported, since observers were instructed not to identify these small lesions.

Results of individual observers and a weighted mean among observers for polyp detection are shown in Table 5. Comparison of single– and multi–detector row CT results indicates no statistically significant differences when only one observer was required to correctly identify the positive findings or when both observers were required to call the findings positive. CT colonographic results were also analyzed by randomly choosing one of the two observers and using his or her CT colonographic results, as well as by using a weighted mean among all of the radiologists. No statistically significant differences were found between single– and multi–detector row CT by using any of the methods. In addition, no statistically significant interobserver differences were found.

Review of the false-negative single–detector row CT examination findings of polyps larger than 10 mm revealed that all errors were due to perceptive errors (ie, the polyp was identified retrospectively). At single–detector row CT, only one polyp larger than 10 mm was missed by both observers, while four other polyps were missed by only one observer. At multi–detector row CT, two polyps larger than 10 mm were missed by both observers. One polyp was missed because of colonic collapse, and the cause of the other false-negative finding could not be determined in retrospect. At multi–detector row CT, five other polyps larger than 10 mm were missed by at least one observer.

The majority of false-positive results of polyps larger than 10 mm were caused by retained stool. Stool was responsible for five of seven false-positive findings at single–detector row CT and six of 11 false-positive findings at multi–detector row CT. One false-positive finding at single–detector row CT was attributed to a haustral fold that was mistaken for a polyp, and another cause remained indeterminate (ie, not definitely a fold or stool at CT colonography or videotaped colonoscopy). There were two cases at single–detector row CT that had both true- and false-positive findings of polyps larger than 10 mm, and these findings were ultimately classified as true-positive. The false-positive findings in these cases were attributed to stool and a haustral fold. The other false-positive findings at multi–detector row CT were attributed to haustral folds (n = 2), an appendiceal stump (n = 1), and incomplete distention (n = 1). The remaining false-positive finding at multi–detector row CT remained indeterminate.

DISCUSSION

Most errors encountered at CT colonography can be attributed to retained fluid, suboptimal distention, respiratory artifacts, and perceptive errors (12). Errors secondary to retained fluid and collapsed segments have been markedly reduced with prone images (13). Further optimization of CT colonography could be achieved by using multi–detector row helical CT scanners, which can reduce respiratory artifacts by reducing the scanning time. In addition, multi–detector row scanning can reduce problems with suboptimal colonic distention, since patients are not required to retain the air for as long as with single–detector row CT.

Although in the optimal comparison of multi– and single–detector row CT colonography the same patients would undergo both techniques, this was not performed because of radiation dose and patient compliance. Instead, this study involved two separate groups of patients who underwent either multi– or single–detector row CT colonographic examination.

A comparison of these two groups demonstrated that respiratory artifacts were significantly reduced with multi–detector row CT. Most (84%) multi–detector row CT images in this study had no identifiable respiratory artifacts, while less than half (39%) of the single–detector row CT images had the same results. The decrease in respiratory artifacts at multi–detector row CT may be due to the patient's ability to perform a single breath hold well (21 seconds with multi–detector row CT) rather than to perform the multiple long breath holds required with single–detector row CT. In addition, faster scanning with multi–detector row CT eliminates image misregistration between overlapping acquisitions, since all the images are acquired in a single breath hold. Although respiratory artifacts were recognized by the experienced observers in this study and did not affect diagnostic results for polyps larger than 10 mm, they can prolong image evaluation time and cause diagnostic errors (8,12,14). For example, image misregistration artifacts with partially imaged folds can mimic polyps. Minimizing these types of artifacts and associated diagnostic errors would be most beneficial in reducing evaluation time and diagnostic errors for less-experienced observers.

Another potential advantage of multi–detector row CT is improved colonic distention, as the patients are not required to retain the air for as long as with single–detector row CT. Faster scanning minimizes the risk of gas being expelled via the rectum or refluxing into the small bowel through an incompetent ileocecal valve. Results of a previous study (15) in 23 patients indicate that only eight (35%) of 23 examinations were graded as having optimal distention by using a single–detector row CT overlapping breath-hold acquisition in the supine and prone positions. In another study (16), patients were instructed to suspend respiration for as long as possible and then to resume shallow respirations while the last pelvic images were acquired. With this faster combined single breath hold and shallow respiratory technique lasting less than 60 seconds, optimal colonic distention was reported in all 60 examinations.

Similar results were found in our study, in which only 44% of single–detector row CT examinations performed with multiple overlapping breath-hold acquisitions were graded as having optimal distention. Colonic distention was improved by using a multi–detector row CT breath-hold acquisition, with 80% of examinations having optimal distention. Other factors such as the experience of the person inflating the colon, variable patient tolerance levels, and anatomic differences (redundant colonic segments) may also have contributed to improved colonic distention. It is unlikely that variable insufflation of the colon contributed to the differences between results at single– and multi–detector row CT in this study, since 90% of the examinations were performed by the same nurse. It is possible, however, that with more experience the use of the colonic insufflation technique improved during the later multi–detector row CT examinations, contributing to the improved results.

Multiple technical factors are also improved with multi–detector row CT. For example, at multi–detector row CT, faster imaging of narrow sections is allowed, compared with imaging at single–detector row CT. Also, at multi–detector row CT, a wider x-ray beam is used so that the x-ray tube is used more efficiently, and cooling restrictions are reduced (1–3,9). Image acquisition time is also reduced to a single 21-second breath hold, allowing faster patient throughput.

Potential disadvantages of multi–detector row CT include possible increased radiation doses for some protocols in which thinner sections are used, as well as the introduction of additional artifacts. The pitch used in this study was less than 1; that is, the table moved 15 mm per acquisition with a 20-mm x-ray beam. Therefore, each tube rotation overlapped by 25%, increasing the radiation dose if all other parameters were unchanged (4).

Prior to this study, multiple in vitro and in vivo multi–detector row CT studies (9) were performed at our institution to maintain detection of 5-mm polyps while matching patient dose and minimizing image artifacts and breath holds. The use of 40 mAs for multi–detector row CT (50 mA with a 0.8-second rotation speed) compared with 70 mAs for single–detector row CT (70 mA with a 1.0-second rotation speed) increased the center CT dose index by 10% (multi–detector row CT, 0.37 rad [3.7 mGy], vs single–detector row CT, 0.35 rad [3.5 mGy]) (4,9). The effective dose, however, was equal between the two techniques (450–670 mrem [4.5–6.7 mSv]) since the 3-cm overlap between breath-hold acquisitions with single–detector row CT was not required with single–breath-hold multi–detector row CT (9). No previously undescribed artifacts were identified in the in vitro or in vivo multi–detector row CT studies. Therefore, by reducing the milliampere seconds and eliminating overlapping breath-hold acquisitions, the effective dose of multi–detector row CT equals that of single–detector row CT, without a reduction in polyp depiction.

Theoretically, improved polyp detection is expected with the use of multi–detector row CT, since collapsed colonic segments and respiratory artifacts have been identified as important causes of false-negative findings. An adequate assessment of polyp detection with the use of multi–detector row CT compared with single–detector row CT, however, was difficult in this study, which included a high-risk screening population with a low prevalence of polyps. Only five and nine single– and multi–detector row CT examinations, respectively, revealed polyps larger than 10 mm. Although detection of polyps larger than 10 mm was slightly better at single–detector row CT (eight [89%] of nine polyps) compared with that at multi–detector row CT (eight [80%] of 10 polyps), the numbers are too small to indicate a statistically significant difference. Improved polyp depiction with the use of multi–detector row CT may be indicated in future studies, since in multi–detector row CT, sections as thin as 1.25 mm may be obtained in the same time required for a current single–detector row CT examination. Although these thin sections would likely improve detection of smaller polyps, the larger number of images would increase image storage requirements and image processing times. In addition, the thinner section mode has an increased (by approximately 100%) radiation dose, compared with the mode used in this study (4). The detection of polyps smaller than 10 mm is of debatable clinical benefit (11) and will likely be addressed in future studies.

In conclusion, optimization of the CT colonographic examination continues with the implementation of multi–detector row CT. CT colonography with the use of multi–detector row scanners compared with single–detector row scanners demonstrates decreased respiratory artifacts, improved colonic distention, and faster scanning times. Detection of polyps larger than 10 mm was not significantly different between single– and multi–detector row scanners. Future studies may demonstrate improved polyp depiction not only by decreasing respiratory artifacts and improving colonic distention with faster scanning but by allowing rapid acquisition of sections that are even thinner than those currently used.

References

1. Berland LL, Smith JK. Multidetector-array CT: once again, technology creates new opportunities. Radiology 1998; 209:327–329.
2. Taguchi K, Aradate H. Algorithm for image reconstruction in multi-slice CT. Med Phys 1998; 25:550–561.
3. Hu H. Multi-slice CT: scan and reconstruction. Med Phys 1999; 26:5–18.
4. McCollough CH, Zink FE. Performance evaluation of a multi-slice CT system. Med Phys 1999; 26:2223–2230.
5. Weg N, Scheer MR, Gabor MP. Liver lesions: improved detection with dual-detector-array CT and routine 2.5-mm thin collimation. Radiology 1998; 209:417–426.
6. Rubin GD, Schiau MC, Leung AN, Kee S, Logan LJ, Sofilos MC. Aorta and iliac arteries: single versus multiple detector-row helical CT angiography. Radiology 2000; 215:670–676.
7. Hara AK, Johnson CD, Reed JE, et al. Reducing data size and radiation dose for CT colonography. AJR Am J Roentgenol 1997; 168:1181–1184.
8. Hara AK, Johnson CD, Reed JE, et al. Detection of colorectal polyps with CT colography: initial assessment of sensitivity and specificity. Radiology 1997; 205:59–65.
9. McCollough CH, Bruesewitz MR, Zink FE, Johnson CD. CT colonography (CTC) using a multislice scanner: optimization of scan acquisition parameters (abstr). Radiology 1999; 213(P):197.
10. Moses LE, Emerson JD, Hossein H. Analyzing data from ordered categories. N Engl J Med 1994; 311:442–448.
11. Waye JD, Lewis BS, Frankel A, Geller SA. Small colon polyps. Am J Gastroenterol 1988; 83:120–122.
12. Fletcher JG, Johnson CD, MacCarty RL, Welch TJ, Reed JE, Hara AK. CT colonography: potential pitfalls and problem-solving techniques. AJR Am J Roentgenol 1999; 172:1271–1278.
13. Fletcher JG, Johnson CD, MacCarty RL, Welch TJ, Reed JE. Optimization of CT colonography technique: a prospective trial in 180 patients. Radiology 2000; 216:704–711.
14. Hara AK, Johnson CD, Reed JE. Colorectal neoplasms: evaluation using CTC (computed tomographic colography). RadioGraphics 1997; 17:1157–1167.
15. Chen SC, Lu DS, Hecht JR, Kadell BM. CT colonography: value of scanning in both the supine and prone positions. AJR Am J Roentgenol 1999; 172:595–599.
16. Yee J, Hung RK, Akerkar GA, Wall SD. The usefulness of glucagon hydrochloride for colonic distention in CT colonography. AJR Am J Roentgenol 1999; 173:169–172.