Original Investigation

Model-based Iterative Reconstruction in Low-radiation-dose Computed Tomography Colonography: Preoperative Assessment in Patients with Colorectal Cancer

Narumi Taguchi, MD, Seitaro Oda, MD, PhD, Masanori Imuta, MD, PhD, Sadahiro Yamamura, MD, PhD, Takeshi Nakaura, MD, PhD, Daisuke Utsunomiya, MD, PhD, Masafumi Kidoh, MD, PhD, Yasunori Nagayama, MD, PhD, Hideaki Yuki, MD, PhD, Kenichiro Hirata, MD, PhD, Yuji Iyama, MD, PhD, Yoshinori Funama, PhD, Hideo Baba, MD, PhD, Yasuyuki Yamashita, MD, PhD

Rationale and Objectives: To assess the effect of model-based iterative reconstruction (MBIR) on image quality and diagnostic performance of low-radiation-dose computed tomography colonography (CTC) in the preoperative assessment of colorectal cancer.

Materials and Methods: This study included 30 patients with colorectal cancer referred for surgical treatment. All patients underwent CTC with a standard dose (SD) protocol in the supine position and a low-dose (LD; radiation dose reduction of approximately 85%) protocol in the prone position. The SD protocol images were post-processed using filtered back projection (FBP), whereas the LD protocol images were post-processed using FBP and MBIR. Objective and subjective image quality parameters were compared among the three different methods. Preoperative evaluations, including site, length, and tumor and node staging were performed, and the findings were compared to the postsurgical findings.

Results: The mean image noise of SD-FBP, LD-FBP, and LD-MBIR images was 17.3 ± 3.2, 40.5 ± 10.9, and 11.2 ± 2.0 Hounsfield units, respectively. There were significant differences for all comparison combinations among the three methods ($P < .01$). For image noise, the mean visual scores were significantly higher for SD-FBP and LD-MBIR than for LD-FBP, and the scores for SD-FBP and LD-MBIR were equivalent (3.9 ± 0.3 [SD-FBP], 2.0 ± 0.5 [LD-FBP], and 3.7 ± 0.3 [LD-MBIR]). Preoperative information was more accurate under SD-FBP and LD-MBIR than under LD-FBP, and the information was comparable between SD-FBP and LD-MBIR.

Conclusion: MBIR can yield significantly improved image quality on low-radiation-dose CTC and provide preoperative information equivalent to that of standard-radiation-dose protocol.

Key Words: CT colonography; preoperative assessment; colorectal cancer; iterative reconstruction; radiation dose.

INTRODUCTION

Colorectal cancer (CRC) is a significant cause of cancer-related death globally, and early detection and appropriate treatment are critical (1). In patients with CRC, accurate preoperative staging is indispensable and can be generally performed using conventional colonoscopy, double-contrast barium enema, computed tomography (CT), magnetic resonance imaging, and positron emission tomography (2). More recently, it has been suggested that computed tomography colonography (CTC) is of value in the preoperative evaluation of patients known to have CRC (3).

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From the Department of Diagnostic Radiology, Faculty of Life Sciences, Kumamoto University, 1-1-1 Honjyo, Chuo-ku, Kumamoto 860-8556 (N.T., S.O., M.I., T.N., D.U., M.K., Y.N., H.Y., K.H., Y.I., Y.Y.); Department of Radiology, Japanese Red Cross Kumamoto Hospital, Kumamoto (S.Y.); Department of Medical Physics, Faculty of Life Sciences, Kumamoto University, Kumamoto (Y.F.); Department of Gastroenterological Surgery, Faculty of Life Sciences, Kumamoto University, Kumamoto, Japan (H.B.). Received August 22, 2017; revised September 29, 2017; accepted October 2, 2017. **Address correspondence to:** S.O. e-mail: seisei0430@nifty.com

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However, there has been some concern about ionizing radiation exposure associated with increased use of CT in medical practice (4). As patients with CRC frequently undergo repeated diagnostic and follow-up CT examinations, radiologists must consider radiation dose reduction techniques during CT examinations while maintaining image quality in accordance with the as low as reasonably achievable principle (5).

Iterative reconstruction (IR) for CT is currently widely used and helps to reduce the quantum noise associated with filtered back projection (FBP) reconstruction. Thus, with the introduction of IR, significant radiation dose reduction during CTC has become possible (6). Recently, the next generation of IR algorithms have been developed to focus on data restoration and noise reduction using a model-based process (model-based iterative reconstruction [MBIR]) (7). Previous investigations reported that the radiation dose in screening CTC using MBIR can be reduced by 47%–60% while maintaining diagnostic image quality (8,9). However, to the best of our knowledge, there have been no attempts to assess the feasibility of MBIR for radiation dose reduction at preoperative CTC in patients with CRC.

We hypothesized that MBIR in low-radiation-dose preoperative CTC would yield diagnostically acceptable image quality. The present study aimed to investigate the effect of MBIR (Forward Projected Model-based Iterative Reconstruction Solution [FIRST]) on the preoperative assessment and planning of CRC in low-radiation-dose CTC.

MATERIALS AND METHODS

We received institutional review board approval for this study and obtained prior written informed consent from all patients.

Study Population and Bowel Preparation

Our study included 30 consecutive patients (12 women and 18 men; mean age, 67.7 ± 12 years; age range 44–88 years) with CRC staged as T1–T4 on the basis of the tumor-nodes-metastases (TNM) staging system (T1, n = 3; T2, n = 6; T3, n = 11; T4, n = 10) between January and August 2016. All patients underwent CTC within a week of complete or incomplete colonoscopy and underwent colectomy after these examinations. Standard bowel preparation was performed. For fecal tagging, 10 mL of diatrizoate meglumine and diatrizoate sodium (concentration 370 mgI/mL, Gastrografin, Bayer, Osaka, Japan) diluted in 200 mL of water was orally administered 3 hours before CTC. The patient characteristics are summarized in Table 1.

TABLE 1. Patient Demographics

Sex (male/female)		18/12
Age (years)		67.7 ± 12
Body weight (kg)		60.3 ± 12.9
Body mass index (kg/m²)		23.1 ± 4.1
Tumor size (mm)		40 ± 18
T stage and tumor size (n/mm)	T1	3/34.3 ± 23.5
	T2	6/15.7 ± 5.5
	T3	11/43.2 ± 16.1
	T4	10/49.8 ± 12.4
N stage (N0/N1/N2)		16/5/9
Tumor location (ascending colon/transverse colon/descending colon/sigmoid colon/rectum)		5/3/2/10/10

Data are presented as mean ± standard deviation or number.

CTC Protocol and Image Reconstruction

All patients were examined using a 320-row CT scanner (Aquilion ONE GENESIS edition, Toshiba Medical Systems, Otawara, Japan). CTC was performed in the supine position with the standard dose (SD) protocol and in the prone position with the low dose (LD) protocol. No intravenous contrast agents were used. A balloon-tipped silicone catheter was inserted via the rectum and carbon dioxide was insufflated with an automated device (PROTOCO2L, Bracco Diagnostics Inc., Monroe Township, NJ) to maximum patient tolerance or an equilibrium pressure of 20–22 mmHg. The scan parameters for both protocols were as follows: tube voltage, 120 kVp; detector configuration, 80 × 0.5 mm (detector collimation); gantry rotation time, 0.5 seconds; and helical pitch (beam pitch), 0.813. The tube current was determined by automatic exposure control. The noise index for automatic exposure control was set at 15 Hounsfield units (HU) for the SD protocol. For the LD protocol, the tube current setting was reduced by approximately 85% compared to that in the SD protocol. The image reconstruction section thickness and the section interval were 5.0 and 5.0 mm for routine axial image reconstruction, and 0.5 and 0.5 mm for 3D image reconstruction, respectively. The SD supine CTC series was reconstructed using FBP (SD-FBP), and the LD prone CTC series was reconstructed using FBP (LD-FBP) and FIRST "body sharp" setting (LD-FIRST, Toshiba Medical Systems). The original 0.5-mm axial images were processed using a commercially available image-processing workstation (Ziostation2; Ziosoft, Tokyo, Japan) for 3D image reconstruction. The 3D volume-rendered images and 3D endoluminal image renderings were generated on the workstation by applying the same rendering and surface threshold parameters for both the supine and prone data sets. The workstation was operated by a board-certified radiologist. The acquisition parameters for the SD and LD protocols are summarized in Table 2.

Radiation Dose Evaluation

We recorded the machine-generated volume CT dose index ($CTDI_{vol}$ [mGy]) and the dose length product (DLP [mGy · cm]) for all image data sets following completion of CTC. A Monte Carlo simulation-based analysis platform (Radimetrics, Bayer Healthcare, Leverkusen, Germany), which is a software tool for monitoring and tracking patient radiation exposure from CT data, was used to calculate the organ-specific radiation doses. The software automatically