Model-Based Iterative Reconstruction in Low-Dose CT Colonography—Feasibility Study in 65 Patients for Symptomatic Investigation

Varut Vardhanabhuti, FRCR, Julia James, FRCR, Rehaan Nensey, FRCR, Christopher Hyde, MRCP, Carl Roobottom, FRCR

Rationale and Objectives: To compare image quality on computed tomographic colonography (CTC) acquired at standard dose (STD) and low dose (LD) using filtered-back projection, adaptive statistical iterative reconstruction, and model-based iterative reconstruction (MBIR) techniques.

Materials and Methods: A total of 65 symptomatic patients were prospectively enrolled for the study and underwent STD and LD CTC with filtered-back projection, adaptive statistical iterative reconstruction, and MBIR to allow direct per-patient comparison. Objective image noise, subjective image analyses, and polyp detection were assessed.

Results: Objective image noise analysis demonstrates significant noise reduction using MBIR technique ($P < .05$) despite being acquired at lower doses. Subjective image analyses were superior for LD MBIR in all parameters except visibility of extracolonic lesions (two-dimensional) and visibility of colonic wall (three-dimensional) where there were no significant differences. There was no significant difference in polyp detection rates ($P > .05$). Doses: LD (dose-length product, 257.7), STD (dose-length product, 483.6).

Conclusions: LD MBIR CTC objectively shows improved image noise using parameters in our study. Subjectively, image quality is maintained. Polyp detection shows no significant difference but because of small numbers needs further validation. Average dose reduction of 47% can be achieved. This study confirms feasibility of using MBIR in this context of CTC in symptomatic population.

Key Words: Low dose; CT colonography; MBIR; model-based iterative reconstruction.

Computed tomographic colonography (CTC) is a widely accepted procedure for the investigation of colorectal cancer, both in the context of symptomatic and screening population (1,2). Diagnostic performance has been well validated previously (3–5), but the procedure is still associated with high radiation dose especially for symptomatic population with dose estimates of around 7–10 mSv (6,7) with some studies showing that this trend is not decreasing despite increasing tools available for dose reduction (8). Using new iterative reconstruction techniques, investigators have performed work on phantom models to assess the accuracy of polyp detection (9) and also there are ongoing clinical trials (10). Some work has also been performed using other versions of hybrid iterative reconstruction (11). The aim of our study was to perform low-dose (LD) feasibility study in clinical setting in the symptomatic population. This cohort allows iterative reconstruction to be evaluated on many different levels and for assessment of colonic and extracolonic findings with the methodology allowing direct per-patient comparison of standard-dose (STD) and LD scans based on the findings from previous phantom studies (9,12). Our primary objectives were (1) to compare objective image noise between traditional reconstruction method of filtered-back projection (FBP), adaptive statistical iterative reconstruction (ASIR), and model-based iterative reconstruction (MBIR) using STD and LD CT scans; and (2) to compare

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From the Plymouth University Peninsula Schools of Medicine and Dentistry, Plymouth, United Kingdom (V.V., C.R.); Department of Diagnostic Radiology, Li Ka Shing Faculty of Medicine, Queen Mary Hospital, University of Hong Kong, Room 406, Block K, Pok Fu Lam Road, Hong Kong (V.V.); Department of Radiology, Torbay Hospital, Torquay, United Kingdom (J.J.); Department of Radiology, Derriford Hospital, Plymouth, United Kingdom (R.N.); and University of Exeter Medical School, Exeter, United Kingdom (C.H.). Received October 15, 2014; accepted December 18, 2014. No external funding was used for this project. **Address correspondence to:** V.V. e-mail: varv@hku.hk

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subjective image noise and quality analysis of STD ASIR scans versus LD MBIR scans to assess feasibility of LD scanning in clinical practice. Our secondary objective was to compare diagnostic accuracy of detected polyps between STD and LD scans across all three reconstruction algorithms.

MATERIALS AND METHODS

Patient Selection

Institutional and regional ethical review board approved this prospectively enrolled study. Informed consent was obtained from all patients. Inclusion criteria were age >50 years, scheduled for a standard-of-care CTC for symptomatic investigation, and fit to undergo the procedure. All patients had standard departmental protocol bowel preparation. Two days before the examination, patient was advised to have low-fiber diet only. The day before the examination, laxatives (sodium picosulfate; Ferring Pharmaceuticals, Saint-Prex, Switzerland) were given as two sachets of 15.08 g dissolved each in one glass of water for morning and afternoon. On the day of examination at 3 hours before examination, Gastrografin (diatrizoate dimeglumine; Bayer Pharma, Leverkusen, Germany) was given to drink for fecal residue tagging (50 mL in 500 mL of water). Our departmental protocol is in line with the recent European Society of Gastrointestinal and Abdominal Radiology consensus statement (13). Exclusion criteria included age <50 years, inability to give informed consent, hemodynamic instability, and prior contrast agent reaction. Sixty-five patients were prospectively recruited (26 men and 39 women). Sample size was based on calculation of number that would be needed to reduce mean image noise by a value of 1 (standard deviation (SD) of 1.75) using significance criterion of 0.05 (95% confidence interval) and statistical power of 90%. Referring indications were as follows (and some patients had more than one): weight loss, $n = 43$; changing bowel habits, $n = 34$; unexplained anemia, $n = 17$; abdominal pain, $n = 22$; palpable mass, $n = 13$; per rectal bleeding, $n = 10$; staging scan, $n = 8$; failed colonoscopy, $n = 8$; and suspected recurrent disease, $n = 5$. In terms of prior investigation, other than the eight patients who had failed colonoscopy before this examination, no patients had prior optical colonoscopy or CTC in the preceding 12 months. Mean weight was 75.4 ± 12.1 kg (range, 53–109 kg). Mean age was 75 ± 9.5 years (range, 55–92 years). Scans were performed between October 28, 2012 and March 31, 2013.

Scanning Techniques

Scans were performed using a 64 multidetector CT scanner (Discovery CT750HD; GE Healthcare, Milwaukee) in the supine and prone/decubitus positions. Intravenous antispasmodic agent was given (hyoscine butylbromide; Boehringer Ingelheim, Ingelheim am Rhein, Germany) before colonic distension unless there were contraindications. Automated insufflator (Protocol Insufflation System; Bracco Diagnostics, High Wycombe, UK) was used with CO_2 gas pressure up to maximum of 25 mm Hg. Technologist obtained initial scout after signs of adequate distension was achieved. Weight-adjusted intravenous administration of contrast agent (ioversol 300, Optiray; Covidien) was also given (75–125 mL) followed by scan initiation between 62 and 72 seconds after injection. Automatic tube current modulation is used and in our scanner this is based on noise index (NI), which is based on maintaining a constant SD in the central region in a uniform water phantom. Higher NI means higher SD, and therefore higher resultant image noise. In the supine position, a standard supine scan was performed first at an NI of 33 (used as standard in our clinical practice). This was immediately followed by an LD scan performed at NI of 50. The patient was then turned prone/decubitus, and a standard prone scan was performed first at NI of 55 (used as standard in our clinical practice). This was immediately followed by an LD scan performed at NI of 70. For an overview of scanning sequence and parameter, refer to Figure 1. All scans were acquired at 1.25-mm slice thickness. To avoid misregistration and artifacts, STD and LD scans at either position were performed within a single breath-hold. All scanning parameters, with the exception of NI (and therefore tube current), were held constant (tube voltage, 120 kVp; pitch, 0.984:1; table speed, 39.37 mm/gantry rotation; helical acquisition mode; detector configuration, 64 × 0.625 mm; gantry rotation time, 0.5 seconds; and standard reconstruction kernel). The tube current range was set to the maximum allowable range of 10–770 mA.

Image Reconstruction

Computing time for MBIR is approximately 50 minutes per series during which time the scanner can be used to scan other patients. After processing, all scans were reconstructed with FBP, ASIR (with 30% blending with FBP), and MBIR into 1.25-mm slice thickness for further analysis. For each patient, four scans are generated. In 65 patients, this resulted in 260 prone/supine datasets per reconstruction algorithms. A total of 780 datasets were created in all reconstruction algorithms and these were used to perform objective image noise analysis. For subjective assessment, the purpose of this study was to compare the diagnostic confidence of LD MBIR images to that of STD ASIR images (and not FBP). Therefore, 520 prone/supine image datasets were created comprising standard-of-care ASIR supine/prone images (NIs of 33 and 55, respectively), and LD MBIR supine/prone images (NIs of 50 and 70, respectively). These were coded, anonymized, and reconstructed into 1.25- and 5-mm transverse sections. This was done solely by a study author who did not take part in subjective image analysis. When the images were viewed by assessors the datasets were fully anonymized by both patients and reconstruction methods.

Objective Image Noise Analysis

Mean objective image noise and CT numbers (both measured in Hounsfield units) were measured for all 780 CT image series (1.25-mm slice thickness). Circular regions of interest (ROIs)