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Advanced modelled iterative reconstruction for abdominal CT: Qualitative and quantitative evaluation

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AIM: To determine qualitative and quantitative image-quality parameters in abdominal imaging using advanced modelled iterative reconstruction (ADMIRE) with third-generation dual-source 192 section CT.

MATERIALS AND METHODS: Forty patients undergoing abdominal portal-venous CT at different tube voltage levels (90, 100, 110, and 120 kVp, $n = 10$ each) and 10 consecutive patients undergoing abdominal non-enhanced low-dose CT (100 kVp, 60 mAs) using a third-generation dual-source 192 section CT machine in the single-source mode were included. Images were reconstructed with filtered back projection (FBP) and ADMIRE (strength levels 1–5). Two blinded, independent readers subjectively determined image noise, artefacts, visibility of small structures, and image contrast, and measured attenuation in the liver, spleen, kidney, muscle, fat, and urinary bladder, and objective image noise.

RESULTS: Subjective noise was significantly lower and image contrast significantly higher for each increasing ADMIRE strength level and also for ADMIRE 1 compared to FBP (all, $p < 0.001$). No significant differences were found for artefact and visibility ratings among image sets (all, $p > 0.05$). Attenuation was similar across tube voltage-image datasets in all anatomical regions (all, $p > 0.05$). Objective noise was significantly lower for each increasing ADMIRE strength level, and for ADMIRE 1 compared to FBP (all, $p < 0.001$, maximal reduction 53%). Independent predictors of noise were tube voltage ($p < 0.05$) and current ($p < 0.001$), diameter ($p < 0.05$), and reconstruction algorithm ($p<0.001$); the amount of noise reduction was related only to the reconstruction algorithm ($p < 0.001$).

CONCLUSION: Abdominal CT using ADMIRE results in an improved image quality with lower image noise as compared with FBP, while the attenuation of various anatomical regions remains constant among reconstruction algorithms.

Introduction

Iterative reconstruction (IR) of CT image data was recently introduced with the aim of improving image quality through a non-uniform reduction of noise as

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compared to filtered back projection (FBP). This has repetitively been shown in several studies employing different types of IR techniques in various body regions.[1–11] For example Deak et al.[12] recently showed that the use of IR in abdominal CT decreased image noise by as much as 58% compared with FBP for standard dose protocols; thereby, the subjective image quality improved significantly.

Manufacturers have developed several types of IR algorithms for CT, including earlier techniques (IRIS, Siemens),[4,13] adaptive iterative dose reduction (AIDR 3D, Toshiba),[14] adaptive statistical IR (ASIR, GE Healthcare),[6,7] or more advanced types such as sinogram-affirmed IR (SAFIRE, Siemens)[5,8] and model-based IR (MBIR, GE Healthcare).[3,11] Most recently, advanced modelled IR (ADMIRE) was introduced with third-generation dual-source 192 section CT. ADMIRE combines statistical data modelling in the raw data domain and model-based noise detection in the image domain.

In order to replace conventional FBP by any of the IR algorithms mentioned above in clinical routine, it is mandatory that both qualitative and quantitative information is retained in the image. However, this does not hold true for all IR techniques. For example, some previous studies reported a changed image appearance with IR, being blotchy, pixilated,[7] or plastic-like.[11]

Furthermore, some previous studies reported alterations in quantitative parameters with attenuation values on IR images differing to images with FBP, depending on the radiation dose levels.[15–17] For example, Chang et al.[15] showed lower attenuation in the liver, paraspinal muscles, subcutaneous fat, main portal vein, and inferior vena cava in IR images, whereas others reported no such differences.[11,12,16,18] Notwithstanding these divergent results, stability of attenuation measurements in CT irrespective of the reconstruction algorithm is mandatory for both the reporting and characterization of disease entities, for example, renal cysts and adrenal lesions.

The purpose of the present study was to determine subjective and objective parameters of image quality in abdominal imaging using ADMIRE with third-generation dual-source 192 section CT.

Materials and methods

Patients

The present study was conducted after institutional review board approval was obtained. Written informed consent was waived by the local ethics committee because of the retrospective nature of the study. All CT examinations were clinically indicated, and CT examinations were not performed for the mere purpose of the study.

Between November 2013 and January 2014, 50 patients (27 male; mean age 60 ± 15 years; range 26–84 years) who underwent clinically indicated abdominal CT were enrolled in the study. Forty patients undergoing contrast-enhanced portal-venous CT with different tube voltage settings at standard radiation dose were also included: group 1 (120 kVp, $n = 10$), group 2 (110 kVp, $n = 10$), group 3 (100 kVp, $n = 10$), and group 4 (90 kVp, $n = 10$). In addition, 10 consecutive patients undergoing non-enhanced abdominal low-radiation-dose CT (group 5) were also included. Exclusion criteria for contrast-enhanced CT were nephropathy (serum creatinine level >150 μmol/l) and known hypersensitivity to iodine-containing contrast medium. Clinical indications for contrast-enhanced abdominal CT was suspicion of tumour ($n = 23$) and infection ($n = 17$); clinical indications for non-enhanced low-dose CT was suspicion ($n = 7$) or known ($n = 3$) urinary stone disease.

CT imaging

All data were acquired on a third-generation dual-source 192 section CT machine (SOMATOM Force, Siemens Healthcare, Forchheim Germany) which allows for tube voltage levels ranging from 70–150 kVp at 10 kVp steps. The CT scan range covered the abdomen from level of the dome of the diaphragm to the lesser trochanter in all patients.

Studies were performed in the single-source mode. Contrast-enhanced CT was performed with automated tube current modulation (CareDose4D, Siemens) using a reference tube current–time product of 100 mAs and using automated attenuation-based tube voltage selection (CAREkV setting 7, Siemens) with a reference tube potential of 120 kVp, while non-enhanced CT was performed with automated tube current modulation at 60 mAs and a fix tube potential of 100 kVp. Contrast-enhanced CT was acquired after the administration of 80 ml iso-osmolar, non-ionic iodinated contrast material, (300 mg iodine/ml, iopromide; Ultravist 300; Bayer Schering Pharma, Berlin, Germany) followed by a saline flush of 40 ml, which was injected into an antecubital vein at a flow rate of 2.4 ml/s. Seventy seconds after contrast material injection scanning was initiated in the portal-venous phase of enhancement. The following imaging parameters were kept identical for all acquisitions: pitch 0.6, 96 × 0.6 mm section collimation, 192 × 0.6 mm section acquisition by means of a z-flying focal spot, 0.5 s gantry rotation time.

CT data reconstruction

CT images were reconstructed with FBP and ADMIRE at all strength levels from 1–5 at a section thickness of 2 mm with an increment of 1.6 mm using a smooth tissue convolution kernel (Br36). The reconstructed field-of-view (FoV) was 350 ± 14 mm, and the image matrix was 512 × 512 pixels. The time for reconstruction of each image dataset was measured.

Iterative reconstruction

The technical features of ADMIRE have been described in detail elsewhere.[19] In brief, IR incorporates statistical modelling in raw data domain, followed by back projection, regularization in image domain, and forward projection utilizing an adequate system model. The resulting pseudo raw data are subtracted from the measurement data, and reinserted into the loop afterwards. ADMIRE uses a