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Research paper

Influence of Adaptive Statistical Iterative Reconstruction on coronary plaque analysis in coronary computed tomography angiography

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A B S T R A C T

Purpose: The purpose of this study was to study the effect of iterative reconstruction (IR) software on quantitative plaque measurements in coronary computed tomography angiography (CCTA).
Methods: Thirty patients with a three clinical risk factors for coronary artery disease (CAD) had one CCTA performed. Images were reconstructed using FBP, 30% and 60% adaptive statistical IR (ASIR). Coronary plaque analysis was performed as per patient and per vessel (LM, LAD, CX and RCA) measurements. Lumen and vessel volumes and plaque burden measurements were based on automatic detected contours in each reconstruction. Lumen and plaque intensity measurements and HU based plaque characterization were based on corrected contours copied to each reconstruction.
Results: No significant changes between FBP and 30% ASIR were found except for lumen- (−2.53 HU) and plaque intensities (−1.28 HU). Between FBP and 60% ASIR the change in total volume showed an increase of 0.94%, 4.36% and 2.01% for lumen, plaque and vessel, respectively. The change in total plaque burden between FBP and 60% ASIR was 0.76%. Lumen and plaque intensities decreased between FBP and 60% ASIR with −9.90 HU and −1.97 HU, respectively. The total plaque component volume changes were all small with a maximum change of −1.13% of necrotic core between FBP and 60% ASIR.
Conclusions: Quantitative plaque measurements only showed modest differences between FBP and the 60% ASIR level. Differences were increased lumen-, vessel- and plaque volumes, decreased lumen- and plaque intensities and a small percentage change in the individual plaque component volumes.

1. Introduction

Coronary computed tomography angiography (coronary CTA) is valuable tool for the evaluation of coronary artery disease (CAD) as it allows the noninvasive assessment of stenoses and atherosclerotic plaque.[1] Continued developments in scanner technology and post-processing reconstruction software keep improving the diagnostic efficacy of coronary CTA. A recently developed technique is iterative reconstruction (IR), which is an alternative to filtered back projection (FBP) for image reconstruction.[2] The adaptive statistical IR (ASIR) is a mathematical trial and error procedure.[3] It synthesizes raw data and iteratively corrects the projection of the beam to the actual measurement with statistical modeling of noise information. IR is usually combined with filtered back projection (FBP). The amount of IR that is combined with the FBP data during the reconstruction can be selected as a parameter of the reconstruction process. IR has been developed with the aim to allow the use of acquisition protocols with lower radiation dose without adversely influencing diagnostic image quality. This has previously been shown in several studies, most of which were focused on subjective or objectively measured image quality.[4–8] In theory, noise suppression included in the IR algorithm will only remove

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high frequency structures in the image.[9,10]

Dedicated multi-detector row CT (MDCT) post-processing software is able to quantitatively measure atherosclerotic plaque and to differentiate between different plaque types in coronary arteries.[11] For accurate differentiation, it is important that very small structures with small differences in HU can be recognized.[12,13] Some studies have looked at the effect of applying IR to the CT data without dose reduction on quantitative plaque measurements. However, these studies either only evaluated individual plaques[14,15] or used manual tracing in ex-vivo data on selected slices.[16] The influence of IR on detailed plaque and artery units has not been investigated yet, but could be important. If ASIR is used in consecutive examinations, when changes in plaque size and composition are of relevance, it is necessary to know the impact of the different levels of ASIR on these measurements compared with FBP. If significant differences are found, it would be necessary to use the identical image reconstruction algorithms in baseline and follow-up examinations.

The aim of this study was to investigate the influence of IR on reconstructed images in MDCT without dose reduction regarding quantitative measurements in the total coronary artery tree. The influence of different IR levels was evaluated for plaque volume, intensity and plaque characterization between three types of reconstructions - FBP, 30% ASIR and 60% ASIR.

2. Materials and methods

2.1. Patient population

Thirty consecutive patients with chest pain referred to coronary CTA for assessment of suspected coronary artery disease (CAD) with a minimum of three clinical risk factors[17] were included. Patients were prospectively enrolled in this study more than a three-week period. Exclusion criteria were: age < 18 years, inability to hold breath for at least 15 s, body mass index (BMI) > 40, atrial fibrillation, etopic heart beats or other irregular heart rhythm, serum-creatinine ≥200 μmol/l, contrast medium allergy, previous coronary artery bypass grafting and inability to cooperate during the data acquisition process.

No IRB approval was required from the regional scientific ethics committee since routine clinical data was used for this analysis.

2.2. CT acquisition

All thirty patients had one MDCT examination performed for which the raw data was processed with both routine FBP software and iterative reconstruction using ASIR software (GE Healthcare, Wisconsin, Milwaukee, USA) at two levels: 30% ASIR and 60% ASIR. Hence three image sets were created of the same raw data for each patient. Additionally, a non-contrast acquisition was performed before the contrast scan to obtain the coronary calcium score.

All acquisitions were performed using a CT750 HD scanner (GE Healthcare, Wisconsin, Milwaukee, USA). Patients with a heart rate >60 beats per minute received i.v. β-blockers and all patients were given 0.4 mg of sublingual nitroglycerin immediately before the acquisition. A triple-phase iodine contrast protocol was used containing 55 mL of iodixanol (Visipaque 320 mg l/ml, GE Healthcare), followed by 40 mL of a 60:40 mixture of iodixanol and saline and followed by a 50 mL saline flush. Contrast was injected through a cannula in the brachial vein (18G) with a flow rate of 6.0 mL/s.

Data acquisition parameters included a rotation time of 350 ms, 64 × 0.625 mm collimation, 32 cm scanning FOV, four sequential steps in the Z-direction, 10–12 s scan time, tube voltage of 100 kV and tube current of 650–750 mA depending on the patient chest size. Prospectively gated sequential scanning was used with 25 ms padding. The reconstruction parameters were 15–18 cm display FOV depending on patient heart size, small cardiac kernel and standard recon type. For all patients, sex, height, weight, chest size, heart rate, length of scan and radiation dose was noted. The effective dose was calculated using a conversion factor of 0.014 mSv/(mGy × cm).

2.3. Quantitative coronary CTA analysis

All image sets were transferred to a workstation for furthermore processing using a quantitative coronary analysis package (QAngioCT Research Edition 2.1, Medis medical imaging systems bv, Leiden, the Netherlands). An overview of the quantitative analysis steps is shown in Fig. 1.

2.3.1. Initial analysis

For each patient the FBP reconstructed image set was used to perform the initial quantitative coronary analysis.[11,17,18] These analyses started with the automatic extraction of the centerlines for the full coronary artery tree for each patient.[19] If needed, the coronary trees were manually corrected. Next, an automatic labeling algorithm[20] was used to define the coronary segments of the arteries per patient based on the modified American Heart Association (AHA) model.[21]

The LM, LAD, CX and RCA vessels were selected from the extracted trees and the luminal and outer vessel contours were automatically detected in a straightened multi planar reformat (MPR) stack along the vessel centerlines. The MPR planes had a dimension of 64 × 64 pixels with a resolution of 0.25 mm in-plane and a separation (pitch) of 0.5 mm between consecutive planes. If needed, the lumen and outer vessel contours were manually corrected. Good intra- and inter- observer reproducibility using the QAngioCT software has been shown by Papadopoulou et al.[18] Finally, an automatic plaque characterization algorithm was used to characterize the regions between the lumen and the outer vessel into four plaque types: dense calcium (DC), fibrotic (FI), fibro fatty (FF) and necrotic core (NC). Plaque characterization was achieved with a “fixed threshold” mode that characterizes the different plaque types based on HU ranges (NC: −30HU to 75HU, FF: 76HU to 130HU, FI: 131HU to 350HU, DC: 351HU and above).

A number of quantitative parameters were extracted from the lumen contours, outer vessel contours and plaque characterization. The obtained parameters are described in Table 1.

2.3.2. Derived analysis

Analyses of the 30% and 60% ASIR images were based on the analyses performed on the FBP data. Coronary tree centerlines and segment labels were copied from the FBP analyses to the 30% and 60% ASIR images and used to create the MPR stacks for each target vessel. In this way, the slices in the MPR stacks have the same position and orientation in all reconstructions and only potentially differ with respect to their pixel intensities (as a result of the different reconstruction algorithms).

To study the effect of ASIR on automatic contour detection, a first group of derived analyses was created in which the same automatic contour detection algorithm was applied to the 30% ASIR and 60% ASIR analysis as was used for the initial FBP analyses. On this group of analyses, the measurements for lumen-, vessel- and plaque volumes as well as plaque burden were performed. To study average intensity differences, a second group of analyses was created by copying the corrected contours from the FBP analyses into the new MPR stacks for the 30% and 60% ASIR datasets. In this way, only the intensity information between these analyses changed but all geometric parameters (e.g. lumen and vessel volumes) remained constant.