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Technical Notes

Feasibility of coronary calcium and stent image subtraction using 320-detector row CT angiography

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ABSTRACT

Background: The reader confidence and diagnostic accuracy of coronary CT angiography (CCTA) can be compromised by the presence of calcified plaques and stents causing blooming artifacts. Compared to conventional invasive coronary angiography (ICA), this may cause an overestimation of stenosis severity leading to false-positive results. In a pilot study, we tested the feasibility of a new coronary calcium image subtraction algorithm in relation to reader confidence and diagnostic accuracy.

Methods: Forty-three patients underwent clinically indicated ICA and CCTA using a 320-detector row CT. Median Agatston score was 510. Two data sets were reconstructed: a conventional CCTA ($CCTA_{conv}$) and a subtracted CCTA ($CCTA_{sub}$), where calcifications detected on noncontrast images were subtracted from the CCTA. Reader confidence and concordance with ICA for identification of >50% stenosis were recorded. We defined target segments on $CCTA_{conv}$ as motion-free coronary segments with calcification or stent and low reader confidence. The effect of $CCTA_{sub}$ was assessed. No approval from the ethics committee was required according to Danish law.

Results: A total of 76 target segments were identified. The use of coronary calcium image subtraction improved the reader confidence in 66% of these segments. In target segments, specificity (86% vs 65%; $P < .01$) and positive predictive value (71% vs 51%, $P = .03$) were improved using $CCTA_{sub}$ compared to $CCTA_{conv}$ without loss in negative predictive value.

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Conclusions: Our initial experience with coronary calcium image subtraction suggests that it is feasible and could lead to an improvement in reader confidence and diagnostic accuracy for identification of significant coronary artery disease.

1. Introduction

Coronary CT angiography (CCTA) is an established method for the evaluation of patients with suspected coronary artery disease (CAD).[1,2] The method is suitable to exclude coronary atherosclerosis but has shown less diagnostic accuracy in the presence of severe coronary calcification or implanted stents. These appear larger on CT than they are because of blooming artifacts, which may cause low reader confidence and overestimation of coronary stenosis severity with false-positive results.[3–5] This again may lead to more futile downstream diagnostic tests. As a result of the reduced performance, patients with high coronary calcium score are frequently excluded from examination with CCTA. As coronary calcifications are relatively common in patients with chest pain syndromes in need of diagnostic evaluation, this limitation may affect a large proportion of patients referred for CCTA.[6]

Volumetric CT digital subtraction angiography (CTDSA) allows for the subtraction of coronary calcium and stents ($CCTA_{sub}$). A contrast scan and a corresponding noncontrast scan are registered and subtracted. The result is a 3-dimensional (3D) volume in which coronary calcifications and stents have been removed leaving the contrast-enhanced blood in the lumen as the only high-intensity material. First experiences with CTDSA were made by Yoshioka et al and Tanaka et al, who found that CTDSA may improve the evaluation of calcified segments on CCTA.[7–9]

In a pilot study setting, we aimed to investigate the feasibility of CTDSA and the possible improvement in reader confidence and diagnostic accuracy of coronary segments with severe calcifications and stents using invasive coronary angiography (ICA) as reference.

2. Materials and methods

Between September 2012 and March 2013, patients suspected of CAD, undergoing sequential CCTA and ICA as part of clinical diagnostic evaluation at Rigshospitalet, Copenhagen, or at the National Institute of Health, MD, were retrospectively screened and included if they had an Agatston score >50. Exclusion criteria were kidney dysfunction, atrial fibrillation, implanted cardiac device, and heart rate >75 beats/min during the scan. The Danish Committee System on Health Research Ethics deemed that this retrospective, anonymized analysis of clinically acquired coronary calcium scans, and CCTA was exempt from additional institutional review. Institutional review board from the National Institutes of Health approved the study (www.clinicaltrials.gov [NCT01621594]).

The CCTA image reader confidence and diagnostic accuracy of CCTA to identify a >50% coronary artery stenosis using conventional image data ($CCTA_{conv}$) and $CCTA_{sub}$ were assessed in coronary artery target segments using ICA as a reference. A coronary artery target segment was defined as a motion-free coronary segment with poor CCTA reader confidence due to stent or calcium blooming artifacts.

2.1. Invasive coronary angiography

Clinically indicated ICA was obtained according to clinical routine and international guidelines. All patients had ICA performed within 30 days of the CT scan. Evaluation of the presence of obstructive CAD (defined as >50% luminal diameter stenosis) was performed visually according to clinical practice in target segments in a standard 17-segment model,[10] by an expert reader unaware of the CT findings.

2.2. CT image acquisition

CCTA was performed using a 320-detector row CT scanner (Aquilion ONE, Toshiba Medical Systems, Japan) with 0.5-mm detector elements and a rotation time of 350 ms. The software included a dose-reduction technology (adaptive iterative dose reduction 3D). The protocol consisted of a noncontrast scan followed by a contrast-enhanced scan, according to a standard acquisition protocol. This represents a 2-breathhold subtraction approach.[9]

For each patient, tube voltage and tube current were determined using the automated exposure control function (^{SURE}Exposure, Toshiba Medical Systems, Japan) with a target image noise level of 33 or 55 for noncontrast scan and 33 or 40 for contrast scan. Depending on body mass index, either 100 kV or 120 kV was used for both scans. The scans were obtained in diastolic phase using the prospective scan mode and were reconstructed at 0.5-mm slice thickness and 0.25-mm interval with an FC03 algorithm and adaptive iterative dose reduction 3D for subtraction. The noncontrast scan was additionally reconstructed with 3-mm slice thickness and 3-mm interval with an FC12 algorithm for evaluation of Agatston score. The effective radiation dose was estimated based on the dose-length product (mGy·cm).[11]

2.3. CT image postprocessing: Alignment and subtraction

Accurate registration and subtraction of coronary images were performed using a dedicated algorithm, CTDSA, on the scanner console.[12] For CTDSA, 2 sets of volumetric data were required: with and without contrast enhancement of the coronary artery lumen. After sequential image acquisition, the 2 data sets were aligned using a combined rigid and nonrigid registration algorithm, and the registered noncontrast volume was subtracted from the contrast volume (Fig. 1). The result was a 3D image volume in which coronary