Non-invasive characterisation of coronary lesion morphology and composition by multislice CT: first results in comparison with intracoronary ultrasound

Abstract The reliable non-invasive detection of coronary artery disease (CAD) is a prime goal for future developments in clinical cardiology. In addition to the documentation of high-grade stenoses, the detection of vulnerable plaques is of major importance for risk stratification and early treatment to prevent plaque rupture. Recently, a new generation of fast spiral CT has been introduced using a multi-slice technique (MSCT), which is the first real quantum leap in CT since the introduction of spiral CT in the early 1990s. We report on non-invasive differentiation of coronary plaque morphology by MSCT in patients with lesions in the proximal left anterior descending artery (LAD). The results were compared with the findings of intracoronary ultrasound (ICUS). The ICUS and MSCT scans were analysed in 6 patients scheduled for ICUS-guided PTCA. One target lesion was selected in each patient. On ICUS, two lesions were classified as soft, two as intermediate and two as calcified according to established criteria based on echogenicity. By multislice CT, density measurements (expressed in Hounsfield Units, HU) were performed at 16 randomly selected areas within the plaques. The two soft plaques showed a mean density of $6 \pm 28$ and $-5 \pm 25$ HU, the two intermediate plaques of $83 \pm 17$ and $51 \pm 19$ HU, and the two calcified plaques of $489 \pm 372$ and $423 \pm 111$ HU. To our knowledge, this is the first report on non-invasive characterisation of coronary lesions by MSCT. Plaque composition could be clearly differentiated and classified according to the ICUS results by determining tissue density within the lesions. Thus, this new technology holds promise for non-invasive risk assessment in patients with known or suspected CAD since also rupture-prone soft coronary lesions can be detected by use of this new technique.

Keywords Coronary artery disease · Multislice CT · Intracoronary ultrasound · Plaque morphology

Introduction

The non-invasive detection of coronary artery disease (CAD) is a prime goal for future developments in clinical cardiology. In addition to the documentation of significant stenoses, the detection of vulnerable plaques is
Coronary plaques [1]. However, because of the restriction to axial, non-spiral scanning in ECG-synchronized cardiac investigations, EBCT can only provide limited z-resolution within a single breath-hold scan resulting in difficulties to detect non-calcified atherosclerotic plaques [7, 15]. Although coronary soft plaques might be detected by MRI, this approach is still in the early stage of clinical research and further technological improvements are required [3, 4, 5].

Recently, a new generation of fast spiral CT has been introduced using a multi-slice technique (MSCT), which is the first real quantum leap in CT since the introduction of spiral CT in the early 1990s [9, 11]. The significantly increased scan speed together with newly developed algorithms results in thinner collimated slice widths and an improved spatial and temporal resolution which is indispensable for high-resolution examinations such as CT angiography of the coronary arteries [10]. We report on non-invasive differentiation of coronary plaque morphology by MSCT in patients with lesions in the proximal left anterior descending artery (LAD). The results were compared with the findings of intra-coronary ultrasound (ICUS).

Materials and methods

Patients and study protocol

The study protocol was approved by the local ethics committee. All patients gave informed consent before inclusion in the study. The study population consisted of patients with chronic stable angina due to a high-grade stenosis in the left anterior descending coronary artery (LAD) who had been assigned for percutaneous transluminal angioplasty (PTCA). The major inclusion criterion was the presence of a clearly identifiable plaque in the proximal LAD. One plaque was selected for analysis in each patient. Multi-slice technique of the heart was performed within 24 h prior to the intervention. Immediately before PTCA, ICUS was performed to analyse vessel morphology proximal to or at the target lesion. To ensure that the identical plaque was assessed by the different techniques and to allow correlation, landmarks were used, i.e. origin of side branches and distance to target lesion.

MSCT

For MSCT, a multislice spiral CT (Volume Zoom, Siemens, Forchheim, Germany) was used. This technology allows the application of dedicated spiral algorithms, which provide 125-ms temporal resolution and ECG-gated heart phase selective image reconstruction. After a low-dose precontrast spiral scan (collimation 2.5 mm, pitch 1.5, 120 kV, 60 mAs, rotation time 500 ms), a test bolus of 20 ml of contrast medium and a chaser bolus of 20 ml of saline were injected in order to determine the circulation time. For the contrast-enhanced scan (collimation 1.0 mm, pitch 1.5–1.8, 120 kV, 300 mAs, rotation time 500 ms), 150 ml of contrast agent (400 mg/ml) were injected through an 18-gauge catheter into an antecubital vein at 4 ml/s followed by 30 ml of saline. These scans were performed after the sublingual application of 400 μg nitroglycerin. The start of the contrast-enhanced scan was adapted to the calculated circulation time. All scans were performed during one breathhold. Image reconstruction was performed in the diastolic phase using dedicated algorithms for multislice retrospective gating [13, 14]. Data from CT angiography were transferred to a computer workstation for postprocessing (3D Virtuoso, Siemens, Forchheim, Germany). For plaque detection, contrast-media-enhanced axial slices were analysed. Image reconstruction as well as plaque detection and classification were performed and repeated several times by two independent observers to account for reproducibility.

ICUS and PTCA

The transfemoral Judkins technique was used for all interventions. After passage of the guidewire across the target lesion, ICUS was performed under fluoroscopic guidance (UltraCross 3.2F, 30 MHz coronary imaging catheter, SCIMED, Boston Scientific Corporation, San Jose, Calif.). All measurements were done after the intracoronary administration of 0.2 mg nitroglycerin. Continuous ultrasound images were received by motorised pullback of the transducer (0.5 mm/s) from preferably 10 mm distal to the target lesion into the guiding catheter. The images were immediately digitised by using ecoPlaque software (Indec Systems, Mountain View, Calif.). All ICUS measurements were performed by one observer who was blinded to the angiographic and MSCT results and repeated by a second independent observer to account for reproducibility.

Definitions

ICUS criteria

The determination of plaque morphology was based on echogenicity. All plaques were classified according to established ICUS criteria [2].

Soft plaque. More than 80 % of the plaque area composed of tissue with an echogenicity lower than the echogenicity of the adventitia (arc of lesion calcium < 90 %).

Intermediate plaque. More than 80 % of the plaque area composed of tissue producing echoes as bright or brighter than the adventitia but without acoustic shadows (arc of lesion calcium < 90 %).

Calcified plaque. Plaque involving bright echoes with acoustic shadowing accompanying more than 90° of the vessel wall circumference.

Lesion severity was defined as mild < 50 %, moderate 50–75 % and severe > 75 % area stenosis.

MSCT criteria

Since the use of MSCT to determine plaque morphology and composition still has to be established for clinical routine practice, we had to find reproducible MSCT criteria to describe plaque morphology. We performed a total of 16 density measurements (as expressed by Hounsfield units, HU) with a region of interest of 1 mm² at randomly selected points at axial slices within the plaque area. Tissue characterisation of the plaque was based on the mean value of these 16 measurements. Lesion severity was defined as mild < 50 %, moderate 50–75 % and severe > 75 % area stenosis.