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Research paper

Relationship of the duke jeopardy score combined with minimal lumen diameter as assessed by computed tomography angiography to the hemodynamic relevance of coronary artery stenosis

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ABSTRACT

Objectives: To study the diagnostic performance of the ratio of Duke jeopardy score (DJS) to minimal lumen diameter (MLD) assessed by coronary computed tomographic angiography (CCTA) for differentiating functionally significant from nonsignificant lesions, with reference to fractional flow reserve (FFR).
Methods: Patients who underwent both CCTA and FFR measurement during invasive coronary angiography (ICA) within 2 weeks were retrospectively included. DJS/MLDCT ratio was recorded, alongside other anatomical parameters. Lesions with FFR ≤ 0.8 were considered to be functionally significant.
Results: One hundred and sixty-one patients with 175 lesions were finally included for analysis. The diameter stenosis, area stenosis, plaque burden, lesion length, ICA-based stenotic extent, DJS, LL/MLD4 ratio, DJS/MLACT ratio as well as DJS/MLDCT ratio were all significantly longer or larger in the group of FFR ≤ 0.8 ($p < 0.05$ for all), while smaller minimal lumen area and MLD were also noted ($p < 0.001$ for both). ROC curve analysis determined the best cut-off value of DJS/MLDCT ratio as 1.96 (area under curve = 0.863, 95% confidence interval = 0.803–0.910), which yielded high diagnostic accuracy (86.9%, 152/175).
Conclusions: The DJS/MLDCT ratio, as characterized by CCTA, is able to predict the hemodynamical status of coronary stenosis.

1. Introduction

Coronary computed tomography angiography (CTA) is establishing itself as a reliable non-invasive modality for the detection of obstructive coronary artery disease.[1–3] However, has limited ability to determine the functional significance of coronary artery stenoses. On the other hand, fractional flow reserve (FFR) has emerged as the invasive reference standard for assessment of coronary obstructions.[4,5]

Di Serafino et al.[6] have recently put forward the “DJS/MLD ratio”, defined by the ratio of the Duke Jeopardy Score (DJS) to the minimal lumen diameter (MLD), both determined during quantitatively evaluated invasive coronary angiography (QCA as a parameter to estimate the hemodynamic relevance of coronary stenoses. The DJS/MLD ratio provides high accuracy to predict FFR values ≤ 0.80. We hypothesized that the DJS/MLD ratio derived from coronary CTA should carry similar predictive value. Hence, the aim of our study was to evaluate the diagnostic performance of the DJS/MLD_{CT} ratio to differentiate between functionally relevant and non-relevant stenoses, using invasive FFR as the reference standard.

2. Methods

2.1. Patient population

Institutional review board approval was obtained to conduct this

Abbreviations: CTA, computed tomography angiography; DJS, Duke Jeopardy Score; FFR, fractional flow reserve; MLD, minimal lumen diameter; PCI, percutaneous coronary intervention

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retrospective study, and informed consent was waived.

We retrospectively identified patients with clinically suspected coronary artery disease (CAD) who underwent both coronary CTA and FFR measurement during ICA between January 2011 and December 2016. FFR measurements were clinically indicated to determine the hemodynamic significance of coronary stenosis in order to determine treatment strategy (revascularization or medical treatment). For inclusion. an interval between coronary CTA examination and FFR measurement of less than 2 weeks was required.

Exclusion criteria were as follows: I) patients who had a history of bypass surgery or coronary intervention of any vessel; II) patients who had serial lesions within the target vessel; III) patients who had a history of previous myocardial infarction; IV) patients in whom the coronary CTA examination was uninterpretable due to poor image quality; V) duffuse calcification of the target lesion (defined as calcium covering ≥50% of any vessel cross-section within lesion); VI) coronary total occlusion or retrograde collateral flow as revealed by ICA; VII) concomitant heart valve disease, cardiomyopathy or class IV heart failure according to New York Heart Association functional classification; VIII) intra-cardiac metallic devices; IX) congenital coronary anomalies.

2.2. Coronary CT angiography protocol

A 128-slice multi detector-row CT system (Definition AS, Siemens Medical Solutions, Forchheim, Germany) was used for data acquisiion. Oral β-blockers (25–75 mg) were administrered orally 1 h prior to the examination in patients with heart rates > 65 bpm. Nitroglycerin was administered sublingually in all patients. A bolus of contrast media (Iopamidol, Isovist, 370 mg iodine/ml, Schering AG, Berlin, German) was injected into an antecubital vein at a rate of 4.5–5 ml/s, followed by a 20–40 ml saline flush, using a dual-barrel power injector (Tyco, Cincinnati, US). The amount of contrast medium was determined according to the patient's body weight and scan time. A test bolus was initially injected and a region of interest was placed within the ascending aorta to determine a proper delay time, which was defined as 4s plus the time to peak enhancement in the ascending aorta. Spiral acquisition with retrospectively ECG-gated image reconstruction was performed in patients with final heart rates ≥70bpm, with collimation = 64 × 0.6 mm, reconstructed slice thickness = 0.6 mm, reconstructed slice interval = 0.5 mm, and rotation time = 300 ms. Pitch varied between 0.2 and 0.5 depending on heart rate and patient size. Tube current was automatically adjusted according to the patients' body habitus by automatic exposure control (CareDose 4D, Siemens Medical Solutions, Forchheim, Germany) and ECG-based tube current modulation was used (full dose during the a time window between 40% and 70% of the R-R interval). Prospectively ECG-triggered axial acquisition was performed in patients with heart rates < 70bpm, with the center of the imaging window set at 70% of the R-R interval, with collimation = 64 × 0.6 mm, reconstructed slice thickness = 0.6 mm, reconstructed slice interval = 0.5 mm, rotation time = 300 ms.

2.3. Image reconstruction and analysis of coronary artery

Data were transferred to an offline workstation (Syngo, Siemens) and the phases with best image quality were identified and used for further analyses. Axial images, cross-sectional views, curved planar reformations (CPR), multi-planar reformations, three-dimensional volume rendering and maximum intensity projection (MIP) images were available for evaluation.

Lesions were quantified using a visually adjusted window setting to subjectively optimize the display of the lumen and outer vessel area. Parameters were measured as follows: Total lesion length (LL) was measured on CPR images and was defined as the length from the proximal to the distal shoulder of the lesion, where no plaque could be detected. Minimal lumen area (MLA) and Minimal lumen diameter (MLD) were measured manually using a digital caliper at the narrowest level of the lesion on the cross-sectional images. The proximal and distal vessel diameter/area, measured immediately proximal/distal to the lesion where no plaque could be detected, was determined with a digital caliper on cross-sectional images. Reference diameter and reference area were determined as an average of proximal and distal vessel diameter/area, respectively. The MLD and proximal/distal vessel diameters were determined as the shortest diameters in eccentric lesions. The stenosis diameter was defined as the (reference diameter – MLD)/reference diameter; the stenosis area was defined as the (reference area – MLA)/reference area; plaque burden was defined as (vessel cross-sectional area–MLA)/cross-sectional area; the remodeling index was defined as the ratio of cross-sectional vessel area of the lesion to the proximal reference area.

Two experienced radiologists (observer 1, with 8 years of experience in cardiac imaging, and observer 2, with 6 years of experience in cardiac imaging) who were blinded to all clinical information independently analyzed the lesions. The mean values of various parameters measured by the two observers were used for analysis.

2.4. DJS/MLD_{CT} ratio

The amount of perfused myocardium subtended by the target stenosis was assessed using the Duke jeopardy score.[7,8] The coronary tree was divided into 6 segments: left anterior descending (LAD), the major diagonal branch of LAD, the major septal perforating branch, the left circumflex artery, the major obtuse marginal branch, and posterior descending artery. Two points were assigned to each of these segments (Fig. 1). In particular, for the LAD, the lesion was considered proximal if localized before a well-developed (≥2 mm) first diagonal branch, or within the proximal third of the vessel, whereas the remaining lesions were considered distal. In patients with a left dominant system, the right coronary artery was assigned no points and left circumflex was assigned two additional points. All segments distal to the index stenosis were considered to be at risk. The maximum possible score was 12 for the entire myocardium and, for example, 6 for a lesion of the LAD proximal to the takeoff of the first major septal branch and the first major diagonal branch.

The DJS/MLD_{CT} ratio was calculated as the ratio of DJS to MLD, respectively assessed during coronary CTA, analogous to the definition of the DJS/MLD index in invasive angiography.[6] Other parameters, such as LL/MLD^4 ratio and DJS/MLA_{CT} ratio were also calculated as previously reported.[9]

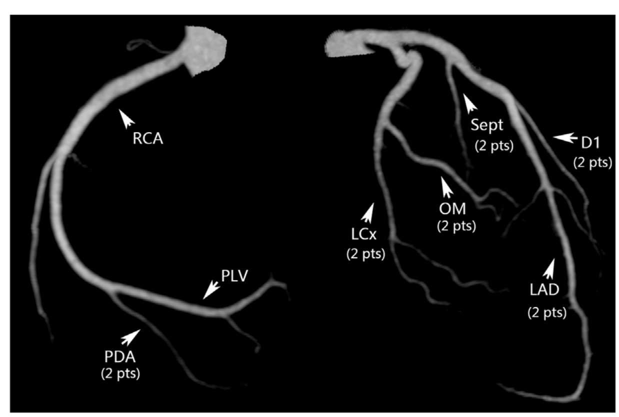

Fig. 1. Illustration of the Duke Jeopardy Score. The coronary tree was divided into 6 segments: LAD, the major diagonal branch of the LAD, the major septal perforating branch, the LCx, the major OM branch, and PDA. Two points are assigned to each of these segments.
Abbreviations: D1 = first diagonal, LAD = left anterior descending, LCx = left circumflex, OM = obtuse marginal, PDA = posterior descending artery, PLV = posterior lateral vessel, RCA = right coronary artery, Sept = septal branch.