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Original article

Computed tomography angiography for prediction of atrial fibrillation after coronary artery bypass grafting: Proof of concept

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ABSTRACT

Background: Postoperative atrial fibrillation (AF) is a serious complication of coronary artery bypass grafting (CABG). There are scant data on the application of coronary computed tomography angiography (CCTA) for prediction of postoperative AF.

Methods: A total of 102 patients (77 male, mean age: 64 $\pm$ 10 years) with pre-procedural CCTA undergoing isolated CABG were enrolled. Clinical risk factors were collected. Qualitative and quantitative CCTA analysis of the atria, pulmonary veins (PV), and epicardial adipose tissue (EAT) along the left atrium (LA) was performed to determine the predictors for postoperative AF. The primary endpoint was defined as any in-hospital AF requiring treatment.

Results: Postoperative AF occurred in 24% of patients. Patients with AF had higher body mass index (29.7 $\pm$ 4.8 kg/m^2 vs 27.3 $\pm$ 3.9 kg/m^2, p = 0.013), larger right atrial area (25.4 $\pm$ 5.3 cm^2 vs 22.3 $\pm$ 6.4 cm^2, p = 0.035), LA systolic volume (114.7 $\pm$ 32.8 ml vs 96.8 $\pm$ 30.4 ml, p = 0.015), LA EAT volume (5.6 $\pm$ 3 ml vs 4 $\pm$ 2.5 ml, p = 0.009), and right superior PV ostium area (3.8 $\pm$ 1.3 cm^2 vs 3 $\pm$ 1 cm^2, p = 0.021) compared to non-AF patients. By multivariable analysis, only LA EAT volume [odds ratio (OR): 1.21, 95% confidence interval (CI): 1.01–1.44, p = 0.036] and right superior PV ostium area (OR: 1.63, 95% CI: 1.06–2.50, p = 0.026) were independent predictors of AF. The optimal cut-offs for LA EAT volume and right superior PV ostium were >3.4 ml and >4.1 cm^2, respectively (max. sensitivity: 83%, max. specificity: 86%).

Conclusions: Increased LA EAT and right superior PV ostial size are independently associated with AF after CABG. CCTA might be used as a noninvasive prediction tool for AF in patients undergoing CABG.

Introduction

Atrial fibrillation (AF) is the most common arrhythmia after cardiac surgery affecting approximately 30% of patients undergoing coronary artery bypass grafting (CABG) [1,2]. Its sequelae such as stroke, heart failure, or worsening of ischemia are not uncommon and might contribute to the increased mortality, specifically in the view of the growing risk profile of contemporary CABG populations [3]. Moreover, a significant increase in healthcare costs associated with a potentially prolonged hospital stay due to postoperative AF has been reported [4]. Thus, identifying patients at high risk for developing postoperative AF would be beneficial both for facilitating preventive measures and tailored medical interventions.

To date several clinical, laboratory, echocardiographic, and surgical predictors of postoperative AF have been identified [5]. Recently, coronary computed tomography angiography (CCTA) has become an accurate and routinely used noninvasive tool for

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diagnosis of coronary artery disease and assessing the anatomical features of the atria and pulmonary veins (PVs) [6]. While CCTA has been successfully employed for the prediction of recurrent AF in patients undergoing PV ablation [7], data describing its potential application for the detection of AF after CABG are limited. The purpose of this investigation was to determine the ability of preoperative CCTA to predict the onset of AF after CABG in a large cohort of patients referred for a routine coronary diagnostic work-up at a single high-volume institution.

Materials and methods

Study design and population

A consecutive series of patients who underwent CCTA before isolated CABG between June 2008 and July 2013 were included. All CCTA scans were performed during the 4 weeks prior to CABG. All patients underwent 12-lead electrocardiogram (ECG), transthoracic echocardiography, and coronary angiography as a routine diagnostic work-up before CABG. The exclusion criteria included the presence of permanent atrial fibrillation, prior implantation of a permanent pacemaker or cardioverter defibrillator, significant valvular heart disease requiring concomitant valve surgery, use of class I or class III anti-arrhythmic agents, and renal dysfunction (serum creatinine >2.0 mg/dl). All clinical data (including surgical and anesthesia protocols) and postoperative outcomes were documented in a prospective database according to local site protocol, and patient risk stratification was determined using the logistic European System for Cardiac Operative Risk Evaluation score [8]. Potential predictors of AF were chosen based on a comprehensive review of the literature [1,2,5]. The study was approved by the local ethics committee and conducted in accordance with the declaration of Helsinki.

Study endpoints

The primary endpoint was defined as any new or recurrent AF during the postoperative hospital stay requiring treatment. Short and self-limited runs were excluded. After surgery, all patients were subjected to continuous ECG monitoring for at least 72 h by using a bedside monitor in the intensive care unit and telemetry on the cardiothoracic wards. In addition, nursing observations were repeated every 12 h by measuring blood pressure, pulses, and assessing the heart rhythm until hospital discharge.

CCTA protocol and image reconstruction

During the study period 2 generations of dual-source computed tomographic scanners were used (Somatom Definition CT and Somatom Definition Flash CT, Siemens, Erlangen, Germany). Unless contraindicated, an intravenous or oral dose of metoprolol was given to target a heart rate of <65 beats/min, and sublingual nitroglycerin was administered before CCTA scan. The contrast transit time was estimated by injection of a test bolus. For acquisition of the volume data set, 80–120 ml iodinated contrast material (Iomeron 400, Bracco Altana Pharma, Konstanz, Germany) was injected followed by a mixture of 20% contrast agent and 80% saline. The scan parameters were as follows and varied according to the scanner type: beam collimation 64 × 0.6 mm, tube voltage 100 or 120 mV, gantry rotation time 330 or 280 ms, tube current 330–438 mAs/rotation or 320 mAs/rotation. Dose reduction strategies including ECG-gated tube current modulation and prospective axial triggering were used to reduce radiation dose whenever possible. Routine reconstructions of scan data were in mid-to-end systole and diastole (35–45% and 65–75% of the R–R interval) with a slice thickness of 0.6 mm and an increment of 0.4 mm.

CCTA analysis

CCTA data were evaluated offline by a highly experienced reader on a dedicated workstation (Leonardo, Siemens). The CCTA analysis was performed blinded to all clinical data. The CCTA data sets were analyzed using multiplanar reconstructed images. For each patient the 3-chamber view parallel to the left-ventricular outflow tract and the 4-chamber view parallel to the interventicular septum were generated as previously described [9]. In the 3-chamber view, anterior–posterior left atrial (LA) diameter was measured, whereas in the 4-chamber view, the following measurements were obtained: superior–inferior and medial–lateral LA diameters, superior–inferior and medial–lateral right atrial (RA) diameters, and LA and RA areas. All atrial quantitative measurements were performed in end-systolic phase of the cardiac cycle representing the largest atrial cavity [9,10]. LA volume was determined using a semi-automated software tool (Volume Viewer, Leonardo, Siemens, Forchheim, Germany) in both systolic and diastolic cardiac phases. Initially, regions of interests (ROI) were manually traced every 5 mm in axial multiplanar reconstructions from the roof of the LA to the level of the mitral valve with exclusion of the PV and LA appendage. The contour delineation was checked and manually corrected if necessary in coronal and sagittal views. A window of 100–1000 Hounsfield units was applied to exclude parts of the muscular wall and trabecula within the ROI as previously described [11]. The LA volume was calculated automatically by summation of pixels within the ROI and Hounsfield units window using the Simpson's rule. The volume and radiodensity of the LA epicardial adipose tissue (EAT) were calculated with the same software tool by using a window of −200 to −30 Hounsfield units within the limits of the pericardial sac in the diastolic phase of the cardiac cycle (Fig. 1) [12]. To assess the regional characteristics of the LA EAT, the thickness of the periatrial fat was measured in the short-axis view at the level of the mid LA as the shortest distance between the LA wall and three anatomic landmarks: esophagus, main pulmonary artery, and descending thoracic aorta as previously described [13]. The LA stroke volume was defined as the difference between the end-systolic LA volume and the end-diastolic LA volume. The LA ejection fraction was calculated according to the standard formula (end-systolic LA volume − end-diastolic LA volume/end-systolic LA volume) × 100%, and then indexed to the body surface area [10]. Additionally, the number of PV was determined, and the cross-sectional area of each PV ostium was calculated at the level of the inflection between PV and LA wall (Fig. 2) [14]. All PV measurements were conducted in the diastolic phase reconstruction [15]. Finally, the radiodensity ratio of the LA appendage to the ascending aorta was calculated by measuring a Hounsfield unit density of 1 cm^2 circular ROI placed in the LA appendage and ascending aorta in order to assess LA filling disturbances [16]. Interobserver variability was assessed by a second experienced reader in 25% of all CCTA studies.

Operative protocol

Standard anesthesia was used for all patients. All patients underwent standard median sternotomy with the intention of complete coronary revascularization. The type of CABG technique (off-pump or on-pump CABG) was left to the discretion of the operator. An initial dose of 1.5 mg/kg heparin sulfate was administered to maintain an activated clotting time of ≥250 s during surgery. Conduits for bypass included the left internal mammary artery, radial arteries, and/or saphenous vein grafts. The left internal mammary artery was harvested using the pedicled technique and was exclusively used to bypass the left anterior descending coronary artery, whereas radial arteries and/or major