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Research paper

Absence of coronary sinus tributaries in ischemic cardiomyopathy: An insight from multidetector computed tomography cardiac venographic study

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ABSTRACT

Objective: Cardiac resynchronization therapy (CRT) is an important therapeutic strategy in heart failure. However, there is a high incidence of lead implantation failure and suboptimal response, particularly in ischemic cardiomyopathy. This failure rate may partly be secondary to lack of suitable coronary sinus branches for lead implantation. We sought to assess the presence of coronary sinus (CS) tributaries in patients with ischemic and non-ischemic cardiomyopathy.

Materials and methods: Multidetector computed tomography (MDCT) was performed in 100 patients: 25 coronary artery bypass graft (CABG) patients with impaired left ventricular ejection fraction (LVEF), 25 CABG patients with preserved LVEF, 25 patients with non-ischemic cardiomyopathy, and 25 controls. The presence of the CS and its tributaries, including the posterior interventricular vein (PIV), posterolateral vein (PLV), left marginal vein (LMV), and the anterior interventricular vein (AIV) was assessed.

Results: The CS, PIV, and AIV were demonstrated in all patients, whereas presence of a PLV and LMV was identified in 68% and 48% of CABG patients with impaired LVEF, 96% and 68% of CABG patients with preserved LVEF, 92% and 80% of patients with non-ischemic cardiomyopathy, and 100% and 80% of controls ($p = 0.001$ and 0.046 for PLV and LMV, respectively).

Conclusions: This is the first report to demonstrate that the posterolateral vein and left middle vein, branches of the coronary sinus, are detectable in a significantly smaller number of CABG patients with impaired LVEF compared to controls, CABG with preserved LVEF, and non-ischemic cardiomyopathy. The absence of CS tributary veins in ischemic cardiomyopathy potentially hinders proper lead implantation and results in suboptimal CRT response.

1. Introduction

Cardiac resynchronization therapy (CRT) has emerged as an important and effective therapeutic strategy in patients with advanced and refractory heart failure.[1–3] The beneficial symptomatic and prognostic effects of CRT have been well established in a number of large randomized controlled trials.[4–7] Unfortunately, response failure and suboptimal lead implantation remain as high as 30% and 10% respectively, despite strict selection criteria.[8,9] Failure rates are higher in patients with ischemic cardiomyopathy than non-ischemic cardiomyopathy, though the precise etiology has not been established. Thrombosis of the coronary veins draining the territory of infarcted myocardium is a potential contributor, but has not been documented in a systematic manner.[10]

Anatomical mapping of the cardiac venous anatomy prior to CRT may facilitate optimal left ventricular (LV) lead positioning. This might ensure that the area of latest mechanical activation can be accessed through a suitable coronary vein, typically via a percutaneous approach. Surgical placement of epicardial leads is considered in the absence of transvenous access.[11,12] Multidetector

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computed tomography (MDCT) is an effective non-invasive modality for the depiction of cardiac structures, including cardiac venous anatomy.[13–16] While previous studies have evaluated the anatomy of the coronary sinus (CS) tributaries in certain populations, including coronary artery disease (CAD) patients with preserved LV function and heart failure patients, the presence or absence of CS tributaries in patients with ischemic versus non-ischemic cardiomyopathies has not been compared.[13,14,17–23] Therefore, the aim of this study was to evaluate the presence versus absence of CS tributaries in patients with ischemic and non-ischemic cardiomyopathies.

2. Materials and methods

Cardiac venous anatomy was retrospectively studied in 100 patients who had undergone contrast-enhanced MDCT for evaluation of coronary arteries or coronary artery bypass grafts (CABG). Patients were recruited consecutively for the following categories: 25 CABG patients with impaired left ventricular (LV) function, 25 CABG patients with preserved LV function, 25 patients with non-ischemic cardiomyopathy, and 25 controls. Impaired LV systolic function was defined as LV ejection fraction (LVEF) <40% by transthoracic echocardiography. Non-ischemic cardiomyopathy was defined as LVEF <40% with normal coronary angiogram or negative single photon emission computed tomographic (SPECT) examination. Controls were patients with normal coronary arteries by MDCT and normal LV function by echocardiography. Approval was obtained for this study from the local institutional review board with waiver of individual informed consent.

Cardiac MDCT was performed using dual-source or 64-slice scanners (Definition, Siemens Medical Solutions, Erlangen, Germany; or Brilliance 64, Philips Medical Systems, Best, Netherlands). Each scan was performed in supine position during an inspiratory breath-hold, with retrospective electrocardiographic (ECG) gating. Contrast material (Ultravist 370, Berlex, Wayne, NJ) was injected into the antecubital vein (90 to 120 ml) with a power injector (Stellant D, Medrad, Inc, Pittsburgh, PA or E-Z-EM, Inc., EmpowerCT, Lake Success, NY) at a flow rate of 4 ml/sec. A bolus monitoring technique was applied for timing the onset of image acquisition primarily for coronary arteries. Scanning parameters were as follows: dual-source scanner: gantry rotation time 330 milliseconds; slice collimation 32 × 0.6 mm; pitch 0.2; tube voltage 120 kVp; maximum effective tube current-time product per rotation 650–850 mAs; temporal resolution 83 milliseconds; reconstructed slice thickness 0.75 mm. 64-slice scanner: gantry rotation time 420 milliseconds; collimation 64 × 0.6 mm; beam pitch 0.2; tube voltage 120 kVp; maximum effective tube current-time product per slice 700–850 mAs; temporal resolution 110–210 milliseconds; reconstructed slice thickness 1 mm. ECG-based tube current modulation was applied in all scans and on both scanners to reduce radiation dose.

Image processing was performed on a commercially available workstation (Leonardo, Siemens Medical Solutions, Erlagen, Germany). Image reconstruction was generated during the optimal phase for coronary veins. The course and tributaries of the cardiac venous system (Fig. 1) were evaluated using axial source data, multiplanar reconstructions, and 3-dimensional volume rendered reconstructions. The ostium of the CS was identified at its junction into right atrium, while its course and all tributaries were tracked. Standard nomenclature for tributaries was used to identify the posterior interventricular branch (PIV) (or middle cardiac vein), posterolateral branch (PLV), left marginal vein (LMV) (or lateral cardiac vein), and anterior interventricular vein (AIV). The PIV travels along the inferior interventricular groove, parallel to the posterior descending artery, then empties into the CS approximately 1 cm from the ostium. The AIV is the last CS branch that courses superiorly within the anterior interventricular groove parallel to the left anterior descending artery and then continues into the CS. The PLV and LMV reach the CS between the PIV and AIV. The PLV drains the posterolateral wall of the LV, whereas the LMV drains, most segments of the LV and usually follows a course cranial to the obtuse marginal artery.[15,16] The presence of the CS and its tributaries were systematically assessed in all 4 groups (Fig. 1). Images with well-contrasted vessels without significant artifact that would negatively impact accurate interpretation were considered to be of diagnostic quality. A vein was considered "present" if it was depicted with a diameter ≥1.5 mm and length ≥2 cm.

Intraobserver and intraobserver variability regarding the presence or absence of the CS, PIV, PLV, LMV and AIV were analyzed in all 100 patients by a re-assessment of the primary observer after a four week interval, and by interpretation by a second independent observer, respectively.

3. Statistics

Continuous data were expressed as mean values and corresponding standard deviations. Dichotomous data were presented as numbers and percentages. Chi-square testing was applied to assess differences among the groups with dichotomous data, whereas analysis of variance was used to compare differences among groups with continuous data. Intra-observer and inter-observer variations for the assessment of the CS and its tributaries were determined using the κ coefficient. A p value of <0.05 was considered statistically significant.

4. Results

There were 61 men and 39 women included, with a mean age of 60 ± 15 years. Baseline characteristics of the 4 patient categories are summarized in Table 1. Age, presence of male sex, and prevalence of established coronary artery risk factors – specifically hypertension, diabetes, dyslipidemia, and smoking history – were significantly higher in patients with CAD, compared to controls and patients with non-ischemic cardiomyopathy. Mean LVEF was 30 ± 8% in CABG patients with impaired LV function, 30 ± 9% in patients with non-ischemic cardiomyopathy, 58 ± 3% in CABG patients with preserved LV function and 59 ± 4%in controls (). Significant stenosis of the left anterior descending coronary artery (LAD), left circumflex coronary artery (LCX), and right coronary artery (RCA) was revealed in 98%, 80%, and 80% of CABG patients with CAD, without significant difference between those with impaired and preserved LVEF. In contrast, there was no significant stenosis of these major epicardial arteries in patients with non-ischemic cardiomyopathy and controls.

Radiation dose was calculated to include the topogram and contrast bolus tracking series. Total mean (±SD) radiation dose was 12.0 ± 4.7 mSv.

The image quality to assess the coronary sinus and tributaries was diagnostic in all patients. The CS, PIV, and AIV were demonstrated in all patients (100%), while the PLV was identified in only 68% of CABG patients with impaired LVEF, 96% of CABG patients with preserved LVEF, 92% of patients with non-ischemic cardiomyopathy, and in 100% of controls ($p = 0.001$, see Table 2 and Fig. 2). The LMV was identified in 48% of CABG patients with impaired LVEF, 68% of CABG patients with preserved LVEF, 80% of patients with non-ischemic cardiomyopathy, and 80% of controls ($p = 0.046$). There was a significantly decreased presence of PLV and LMV compared to controls in CABG patients with impaired LVEF, but not in patients with non-ischemic cardiomyopathy or CABG