



Anatomical Variants of Coronary Venous System on Cardiac Computed Tomography

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Background: In a few studies, huge anatomical variability of coronary venous system (CVS) has been documented without analysis of its variants. The aim of the present study was to evaluate anatomical variants of CVS in multislice computed tomography (MSCT).

Methods and Results: In 199 patients (114 males, age 56.6 ± 11.5 years), a 64-slice computed tomography (Aquilion 64) was performed due to coronary artery disease suspicion. A scan with electrocardiogram-gating was performed using a slice thickness of 0.5 mm during a breath-hold. In each case, 3D volume rendering and 2D multi-planar reformatting reconstructions of CVS were created (Vitrea 2). As target veins for cardiac resynchronization therapy (CRT), the posterolateral, lateral and anterolateral veins were recognized. Coronary sinus was well visualized in all cases. A total of 27 anatomical variants of CVS were identified, 9 of them are most common (in 148/199 cases; 74.4%). In 4 out of these 9 variants, a single coronary vein in the target area for CRT appeared, 2 target veins in 3 variants and 3 veins in 2 variants occurred. In 6 cases (2 seldom variants—3.0%) no veins in the target area were identified.

Conclusions: In the majority of the examined patients, at least one vein in the target area for CRT was observed. Anatomical variability of CVS strengthens the potential role of MSCT in CVS visualization before CRT implantation.

Key Words: Cardiac resynchronization therapy; Computed tomography; Coronary veins

The variety of cardiac devices for transvenous implantation has increased in the years, mostly due to evidence of effectiveness of this therapy in chronic heart failure. Special attention is placed on cardiac resynchronization therapy (CRT) or combination of those devices with implanted cardioverter defibrillator.¹⁻⁵ During these procedures, the implantation of left ventricle lead is necessary. The only way for transvenous left ventricle lead implantation is coronary sinus (CS) cannulation from the right atrium, and finally implantation of the lead into one of the coronary veins.⁶ Effectiveness and success of implantation have been shown to depend mainly on a proper placement of the left ventricle electrode into the coronary target vein.^{7,8} Lateral, posterolateral and anterolateral veins (PLV and ALV) provide optimal hemodynamic benefits. Meanwhile, most operators are faced with the problem of huge anatomical variability of coronary veins. Knowledge of the coronary venous system (CVS) anatomy is an important factor before many electrophysiological procedures, such as CRT or ablations. The CVS was the subject of a few research groups, but most of the research came from post mortem studies.^{9,10} In a few studies, a huge anatomical variability of CVS was docu-

mented; however, its variants have only rarely been classified.¹¹ Recent data indicated a potential of the latest generation multislice computed tomography (MSCT) scanners for CVS anatomy visualization;^{12,13} however, anatomical variants with emphasis on target veins for CRT have not been examined yet.

The purpose of the present study was to evaluate anatomical variants of CVS in MSCT in the context of target veins for CRT.

Methods

A total of 199 patients (114 males, 57.3%), aged 56.6 ± 11.5 with suspected coronary artery disease (CAD) were included in the study. A suspicion of CAD was based on clinical symptoms such as chest pain, shortness of breath when exercising or during other vigorous activities and other typical/atypical symptoms co-existing. Non-specific electrocardiogram (ECG) changes and positive results of exercise testing was also a basis for performing MSCT. Arterial hypertension and hyperlipidemia were the most prevalent CAD risk factors, present in 143 (71.8%) and 94 (47.2%) patients, respec-

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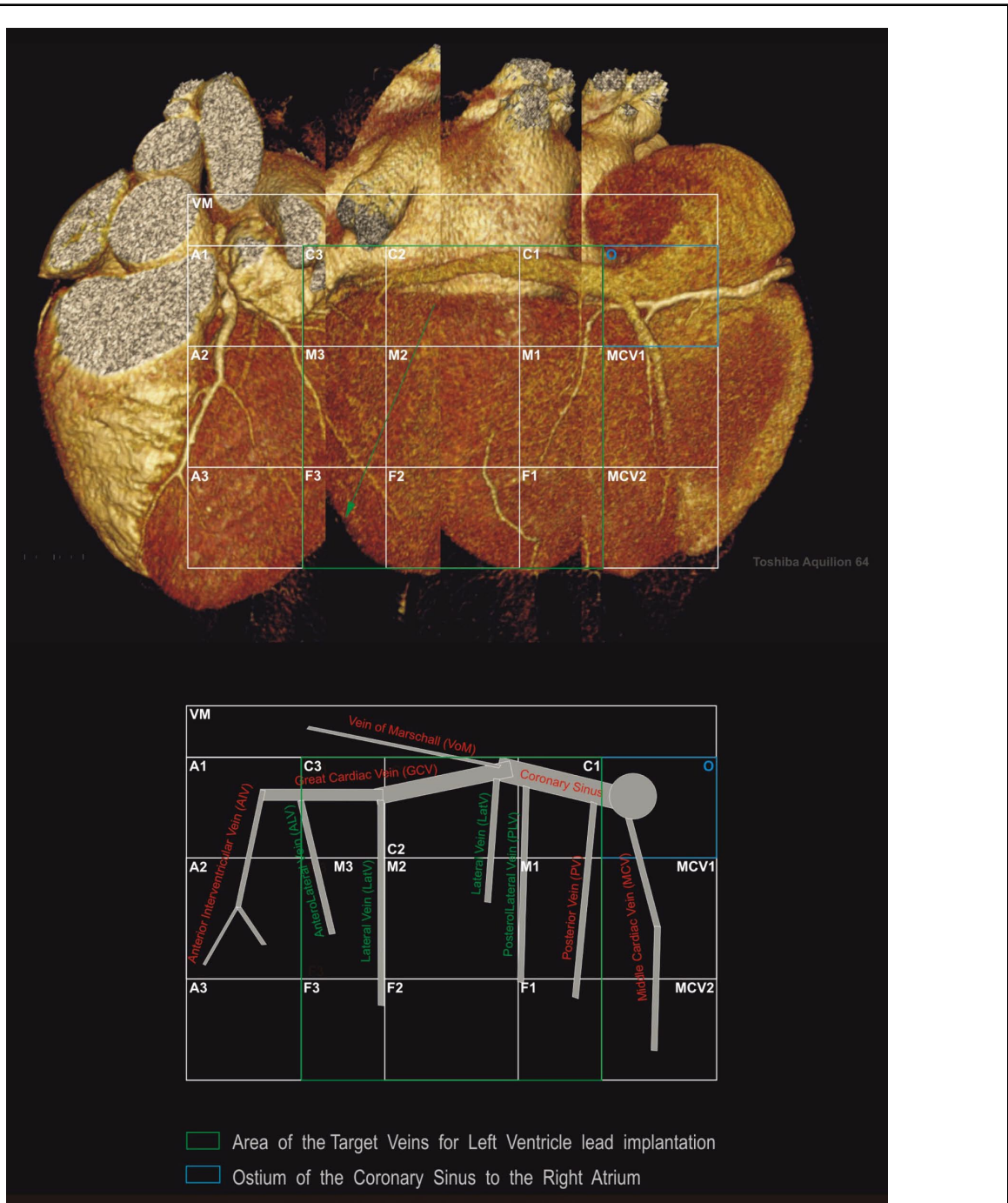


Figure 1. Multislice computed tomography analyzing matrix (own project) created to facilitate nomenclature of coronary veins.

tively. Diabetes (57/114, 28.6%), smoking (75/114, 37.7%) and cardiovascular diseases in the family (44/114, 22.1%) were additional risk factors. Exclusion criteria were: the presence of atrial fibrillation, frequent premature heartbeats, renal insufficiency (serum creatinine >1.2mg/dl), hyperthyreosis, known allergy to non-ionic contrast agents and a previously implanted pacemaker with unipolar leads. Patients after coronary artery bypass surgery were also excluded. The local Ethics Committee approved the study protocol. Informed consent was obtained in each case.

In each patient, a 64-slice computed tomography (CT) was performed using an Aquilion 64 scanner (Toshiba Medical Systems, Tochigi, Japan). Scanning with retrospective ECG-gating was performed using 64 slices with a collimated slice thickness of 0.5mm during a breath-hold. A breath-hold examination was performed to adjust the scanner settings. The helical pitch was 12.8 (best mode) and rotation time was 0.4s. The tube voltage was strictly dependent on a patient's body mass index (BMI): for BMI<23.9 it was 120kV at 330mA, for BMI=24.0–29.9 it was 135kV at 380mA and

for BMI>30.0 it was 135 kV at 430 mA. ECG-dependent dose modulation—an algorithm, which modulates the tube current according to the ECG during the scan, was not used in this study. This algorithm reduces the tube current during systole. In systolic phases quality of coronary arteries reconstructions is usually not acceptable, but quality of coronary veins reconstructions is usually optimal.^{13,14} A pre-selected region of interest in the descending aorta was used. The start of triggering was at 180 Hounsfield units. On average, 100 ml of non-ionic contrast agent (Ioperamid, Ultravist 370, Schering, Germany) was given to each patient during the examination at an average rate of 5 ml/s. The contrast agent was given in 3 phases: 90 ml of contrast agent (average), then 24 ml of contrast agent and 16 ml of saline flush (60%/40%) and finally 30 ml of saline. The cut-off for heart rate (HR) was set at 65 beats/min. If the HR was higher, metoprolol succinate (Betaloc, Astra Zeneca, Sweden) at a dosage of 5–10 mg was administered intravenously, if not contraindicated. If the expected HR slowing was not achieved, the patient was excluded from the study. Sublingual nitroglycerin was not given before image acquisition.

Reconstructions of data were performed on Vitrea 2 (software version 3.9.0.0) workstations (Vital Images, USA). In each case in the study presented, 10 axial image series, as well as 3D volume rendering reconstructions, using a 2.0 mm slice thickness to reduce a large amount of data, were created from 0% to 90% R-R intervals (step 10%). Our earlier experience from results for a large group of patients, showed that in most cases the quality of the visualization of coronary veins is the best at the systolic phase (30–40% R-R interval), and in some patients at the 50% phase. In a small group of patients (10.1%), the best results were obtained at other phases. To create variants of CVS the best image quality was the true requirement.^{13,14} The optimal interval was always confirmed using multi-planar reformatting images. On selected intervals, the main coronary veins were searched and analyzed.

All data were evaluated by 2 investigators experienced in MSCT of CVS, as well as in cardiac resynchronization system implantation.^{13,14}

Coronary Veins Nomenclature

Based on previous data^{15,16} with some modifications the following nomenclature was used:

Coronary Sinus (CS) Originates from the great cardiac vein and drain in the atrio-ventricular groove to the right atrium by CS ostium. CS ostium is located in the postero-septal right atrium. Sometimes CS ostium is covered by the Thebesian valve.⁹

Great Cardiac Vein (GCV) Originates in the anterior vein

Table 1. Hemodynamic Characteristics of the Included Patients

	Hemodynamic parameters
Ejection fraction (%)	63.42±7.98
EDV (ml)	143.64±42.98
ESD (ml)	56.10±35.92
Stroke volume (ml)	87.29±19.51
Cardiac output (L/min)	5.39±1.56
Myocardial mass (g)	137.19±44.55
Myocardial volume (ml)	129.94±42.35

(AV) near the left anterior descending artery and end as CS in the ostium vein of Marshall.

Middle Cardiac Vein (MCV) Originates close to the apex of the heart and follows the posterior interventricular groove toward the base.

Posterior Vein (PV) (Referred Also as Left Marginal Vein) Originates either from the posterior or lateral aspects of the left ventricle and drain into the CS.

Posterolateral Vein (PLV) Fifteen degree area of lateral ventricle between PV and lateral vein (LatV). Usually drains into the CS.¹³

Lateral Vein (LatV) It runs in the lateral wall of the left ventricle to terminate in the CS or great cardiac vein.

Anterolateral Vein (ALV) Fifteen degree area of lateral ventricle between AV and LatV. Usually drains into the great cardiac vein.¹³

Anterior Vein (AV) (Referred Also as Anterior Interventricular Vein) Originates at the lower or middle third of the anterior interventricular groove. It follows the groove toward the base of the heart and then turns posterior at the atrio-ventricular groove to enter the great cardiac vein.

Vein of Marshall (VM) (Referred Also as Oblique Vein of the Left Atrium) It is a small vessel, which descends obliquely on the back of the left atrium and ends in the CS near its left extremity.

To facilitate nomenclature with MSCT, the analyzing matrix was created (**Figure 1**). This matrix was used on flat images, which were created from 5 to 6 3D images by using a specific graphic software. Each matrix consists of 15 areas. PV, LatV and ALV were defined as CRT target veins.

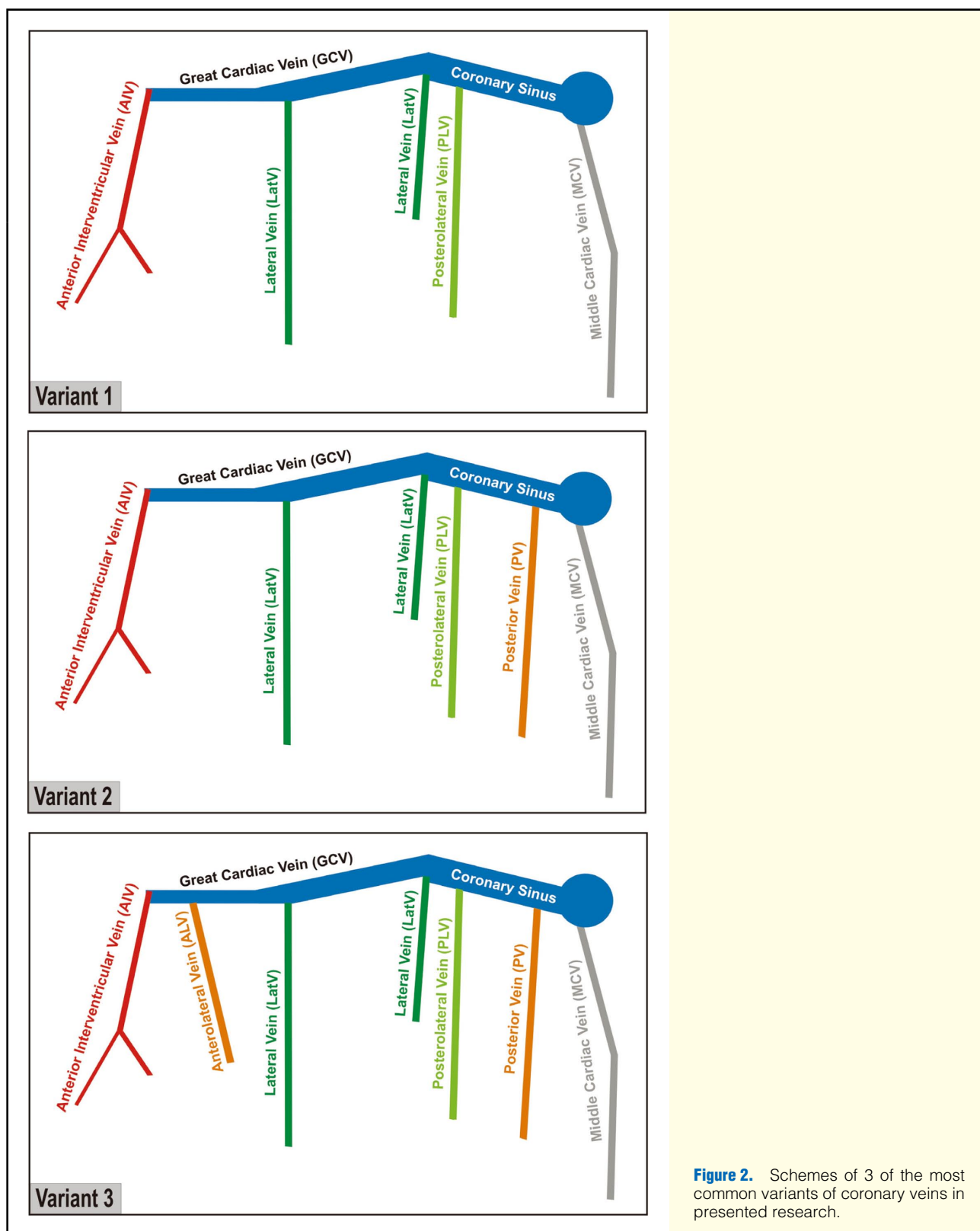
Results

The cardiac function parameters of the group examined are presented in **Table 1**. CS and middle cardiac vein were well visualized in all cases. AV was the most common vessel and

Table 2. Common Variants of Coronary Venous System Which Were Found in This Research

Variant	PV	PLV	LatV	ALV	AV	Number of cases	Frequency (%)
1	No	Yes	Yes	No	Yes	26	13.1
2	Yes	Yes	Yes	No	Yes	23	11.6
3	Yes	Yes	Yes	Yes	Yes	18	9.1
4	No	Yes	Yes	Yes	Yes	16	8.1
5	Yes	No	Yes	No	Yes	16	8.1
6	No	No	Yes	No	Yes	16	8.1
7	No	Yes	No	No	Yes	13	6.6
8	Yes	No	Yes	Yes	Yes	10	5.1
9	No	No	Yes	No	No	10	5.1

PV, posterior vein; PLV, posterolateral vein; LatV, lateral vein; ALV, anterolateral vein; AV, anterior vein; Yes, vein is present; No, vein is absent.



was visualized in 160/199 cases (80.4%). With the same frequency, the LatV was visualized, which is important as one of the target veins for cardiac resynchronization. Another important vein—PV—was identified in 124 patients (62.3%). Alternatively PV was visible in 94 cases (47.2%). The most

seldom visible target veins was the ALV—69/199 (34.7%).

Twenty-seven anatomical variants of CVS were identified, 9 of them are the most common. They were identified in 148 from 199 cases (74.4%). Exact frequency of identified variants are presented in **Table 2**. Schemes of 3 of the

most common variants are presented (Figure 2). In 4 out of these 9 variants, a single coronary vein in the target area for CRT appeared, 2 target veins in 3 variants and 3 veins in 2 variants occurred. In 6 cases (2 seldom variants–3.0%) no veins in the target area were identified.

There was no correlation between occurrence of specific variants and cardiac function parameters.

Discussion

Although CVS seems to have a relatively low interest from a clinical point of view (if compared to the coronary arteries), during the past decade there are some groups of electrophysiologists for which this knowledge could be especially important. According to Vogt et al, 3 important aspects regarding CVS are most relevant.¹⁷ Access to the specific anatomical variants of the CS and handling of complex target vein anatomy are directly connected with CVS anatomy. Evaluation of CVS anatomy might be of special interest before the procedure CRT implantation. There is agreement that MSCT can precisely evaluate the anatomy of the heart. In the appropriateness criteria, the MSCT for non-invasive coronary vein mapping prior to the placement of a biventricular pacemaker is marked as A(8), so it is recommended.¹⁸

Coronary venous anatomy is highly variable.^{19–21} The first author who described coronary venous variations in detail by means of invasive angiography was Tori in 1952.²² Since then, mostly anatomic-pathological papers occurred. Some papers which described anatomical variant of coronary veins by using other methods were published. Gilard et al examined 100 patients with venous phase in analysis during coronary angiography. The results indicated that MCV and GCV (or CS) were consistently present on all venograms.²¹ They pointed out an interindividual variation of coronary veins with a special emphasis placed on PV. They concluded that in less than 5% of patients, the absence of target veins (in their study posterior and lateral) might practically limit the ability of left ventricle lead implantation. Despite different techniques of visualization, the results are similar to that presented in our investigations—we also confirmed huge variability of CVS with the highest variability of PV. We also confirmed that in a small proportion of patients no veins in the target area can be found (6 patients; 3% of all).

Abbara et al were the first investigators who used MSCT for CVS evaluations by using a 16 slice scanner.²³ They noticed that in 7.4% of cases no LatV could be found and in 20.4% of cases no PV could be found; however, in all included patients the posterior or LatV was visualized. In our study, the LatV was absent in almost 20% and PV in 53% of cases. The discrepancy between findings might result from differences in the nomenclature, as we recognized additional PV, which might correspond to the PV in the study of Abbara et al.

Another study using a 16 slice scanner was performed by Jongbloed et al.²⁴ As most authors found, CS was well visualized in all cases. PV was visualized in 86–90%. They designated all included patients to 1 of 3 anatomical groups. They used modified variants proposed previously by von Lüdinghausen.¹⁹ As this division was strictly anatomical, in the presented work a special emphasis was placed on finding variants based on characteristic features for electrophysiological (as CRT implantation) purposes. It is difficult to compare those 2 different kinds of classification.

A Japanese study performed by Tada et al using 8 detectors CT scanner also showed the usefulness of MSCT in

visualization of CVS.²⁵ According to their results, the CS and middle cardiac vein were visible in all patients. The left marginal and PVs were visualized in 84% and 94%, respectively. Japanese authors did not performed analysis of variants of coronary veins.

As presented investigations performed on 8 and 16 slice scanners, the use of 64 slice scanner (our research) might be more accurate due to higher resolution. Importance seemed to be placed also on the different methods of image post-processing to improve image quality. Novel techniques can play an important role in CVS visualization.²⁶

Visualization of the CVS by using 64 slice scanners is sometimes difficult because the scan period is relatively long. As a consequence, coronary veins can potentially be opacified by the contrast agent. In the new era of ultra fast 256 or 320 detector-row scanners that require only one gantry rotation for coronary artery imaging, visualization of coronary veins can be better.

Huge anatomical variability of coronary veins was also confirmed by Bales.²⁷ The author presented great cardiac vein variation based on intertwined variation found by a medical student during medical anatomy in one case.

In the era of percutaneous interventions, such as left ventricle lead implantation during cardiac resynchronization, the variability in the coronary venous anatomy is the real challenge.¹⁵ The correct interpretation of the coronary venous anatomy derived from such non-invasive methods, such as MSCT and magnetic resonance of the heart, can potentially facilitate cardiac resynchronization implantation, by understanding variations and clinical meaning.

Study Limitations

There were no patients with advanced heart failure included into this study. Most of patients were examined because of a suspicion of CAD and had normal or near normal ejection fraction.

Other limitations are related to MSCT as a method itself. Excluding patients with arrhythmias is a limitation, especially because they are very common among patients with heart failure. The dose of radiation is substantial, particularly that ECG-dependent dose modulation algorithm was not used. The amount of contrast agent used in this study is significant—some protocols with a lower rate than 5 ml/s were tested by us, but the results in coronary arteries visualization was unsatisfying—coronary veins visualization was added to routine coronary arteries visualization due to CAD suspicion. Patients might require a β -blocker use for HR reduction, which could be poorly tolerated and require continuous HR and blood pressure monitoring.

This is a descriptive anatomical study that can be useful for electrophysiologists. Success of CS cannulation is more based on the operator's skills and experience than on the findings in MSCT; however, pre-procedural visualization of CVS can potentially change procedure and/or treatment strategy.

Conclusions

For invasive cardiologists, knowledge about CVS anatomy could add value before and during electrophysiology procedures. Most of the examined patients have at least one vein in the target area for CRT. Huge anatomical variability of CVS strengthen the role of MSCT in visualization CVS before CRT implantation. In patients with no coronary vein in the target area, renouncement from intravenous implantation of CRT device should be considered.

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