

# A User-Friendly Method of Cardiac Venous System Visualization in 64-Slice Computed Tomography

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**Background:** Previsualization of the cardiac venous system is very important for some techniques, for example, cardiac resynchronization therapy (CRT). The aim of this study was to propose a new, user-friendly method of cardiac venous system visualization in 64-slice computed tomography (CT).

**Methods:** In 112 patients (66 M) aged  $58 \pm 11$  standard deviation, a 64-slice CT with a retrospective electrocardiogram gating was performed due to a suspicion of ischemic heart disease. Special attention was paid to the requirements for image reconstruction useful for CRT.

**Results:** In 74% of the patients, it was possible to obtain similar images to those during the CRT implantation procedure within anterior-posterior, left anterior oblique, and right anterior oblique views. The coronary sinus was clearly visible in all cases, the ostium measured  $12.9 \pm 5.9$  mm, and the angle of entrance  $99 \pm 12$  degrees. In all patients it was possible to demonstrate more than one vein; in 95%, at least one vein was clearly visible in the target area. Among the target veins, the posterolateral vein was visible most frequently (78%) in the cases as well as the lateral vein (78%).

**Conclusion:** The proposed scheme in 64-slice computed tomography enables images to be generated similar to the intraoperative fluoroscopy, which can be useful in techniques where previsualization of the cardiac venous system is recommended. (PACE 2009; 32:323–329)

**computed tomography, coronary veins, target veins, coronary sinus, heart failure, cardiac resynchronization therapy**

## Introduction

Cardiac resynchronization therapy (CRT) is a well-established method of treatment for patients with heart failure (HF).<sup>1–3</sup> Unfortunately, even in centers advanced in this technique, there are a number of difficulties mostly due to problems with coronary sinus (CS) cannulation, or entrance into one of the target veins<sup>4,5</sup> that are related to the anatomical variability of the cardiac venous system.<sup>6–8</sup> Previsualization of the venous system of the heart might help an invasive cardiologist to recognize some anatomical aspects before CRT implantation, such as the CS ostium (angle and direction), the presence of the Thebesian valve,<sup>9,10</sup> the number of target cardiac veins, along with an evaluation of their characteristic features. This kind of knowledge might help them to choose the optimal placement of the left ventricle lead implantation or even sometimes make the decision not to perform the intravenous implantation. It is of

special importance that images during previsualization should be generated at a similar quality as those that can be seen during intraoperational fluoroscopy, thereby potentially facilitating the implantation of the left ventricle lead.

There are only a few methods of visualization of the cardiac venous system. Recording of the retrograde venography during coronary angiography is the most common.<sup>11–13</sup> The advantage of this method is that the image can be seen at a similar quality as on fluoroscopy during CRT implantation. However, as in any invasive procedure, there is a potential for complications. Therefore, several efforts have been made over recent years to introduce new methods of visualization. For example, an echocardiographic evaluation was tested, but its practical usefulness was shown to be limited.<sup>14,15</sup>

The good quality of the image and the noninvasive nature of multislice computed tomography (MSCT) of the heart makes it potentially useful for this purpose. In a few publications, the possibility of the visualization of the venous system of the heart in MSCT has been documented,<sup>16–18</sup> but the method needs to be standardized in order to provide images most useful during left ventricular lead implantation.

The aim of this study was to propose a new, user-friendly method of cardiac venous system

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No conflicts of interests for all authors.

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visualization in 64-slice computed tomography (CT) that would provide images similar to those used during the intraoperative fluoroscopy. An additional purpose was to perform a quantitative analysis of the cardiac venous system by using this method.

## Methods

### Patients

A total of 112 patients (66 males) aged  $58 \pm 11$  standard deviation were included in the study. The study protocol was approved by the local ethics committee. For each patient informed consent was obtained. For each patient, a 64-slice CT was performed because of a suspicion of ischemic heart disease (IHD). Patients were excluded if they presented the following clinical features: atrial fibrillation (permanent or persistent), frequent cardiac extrasystoles, renal insufficiency (serum creatinine  $>1.3$  mg/dL), hyperthyreosis, a known allergy to nonionic contrast agents, or a previously implanted pacemaker with unipolar leads.

### MSCT Protocol

A 64-slice CT of the heart was performed using an Aquilion 64 scanner (Toshiba Medical Systems, Tochigi, Japan). Scanning with retrospective electrocardiogram (ECG) gating was performed using a 64-slice CT with a collimated slice thickness of 0.5 mm during a breath-hold. The helical pitch was 12.8 (best mode) and rotation time was 0.4 seconds. Average scan duration was 20 seconds. Average tube voltage was 135 kV at 380 mA, which was strictly dependent on the patient's body mass index (BMI). We used a preselected region of interest (ROI). In each case the start of the scan was exactly the same as that for routine arterial imaging. All reconstructions were created in the optimal phase for coronary arteries and additionally at 30% to 40% to 50% R-R intervals for cardiac vein imaging.<sup>19</sup> Ten additional reconstructions were created in each case (with a 10% step, layer 2 mm) to confirm the best intervals for the venous imaging. We used 65 beats per minute as the cutoff for heart rate (HR). If the HR was higher, metoprolol succinate (Betaloc, AstraZeneca, Mölndal, Sweden) at a dose 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. On average, 120 mL of nonionic contrast agent (Ioperamid, Ultravist 370, Schering, Germany) was given to each patient during the examination at an average rate of 5.0 mL/s. Contrast was given in three phases: 90-mL contrast agent (average), then 24-mL contrast agent and 16-mL saline flush (60% / 40%), and finally 30 mL of saline.

Reconstructions of the data were performed using Vitrea 2 (software version 3.9.0.0) workstations (Vital Images, Minnetonka, MN, USA). All data were evaluated by two cardiologists experienced in CRT as well as cardiac MSCT with the full cooperation of a radiologist trained in cardiac MSCT.

Measurements of all diameters were performed using Vitrea 2 software. To keep the results comparable, all measurements were always performed in the axial position on multiplanar reconstructions (MPRs; Fig. 1).

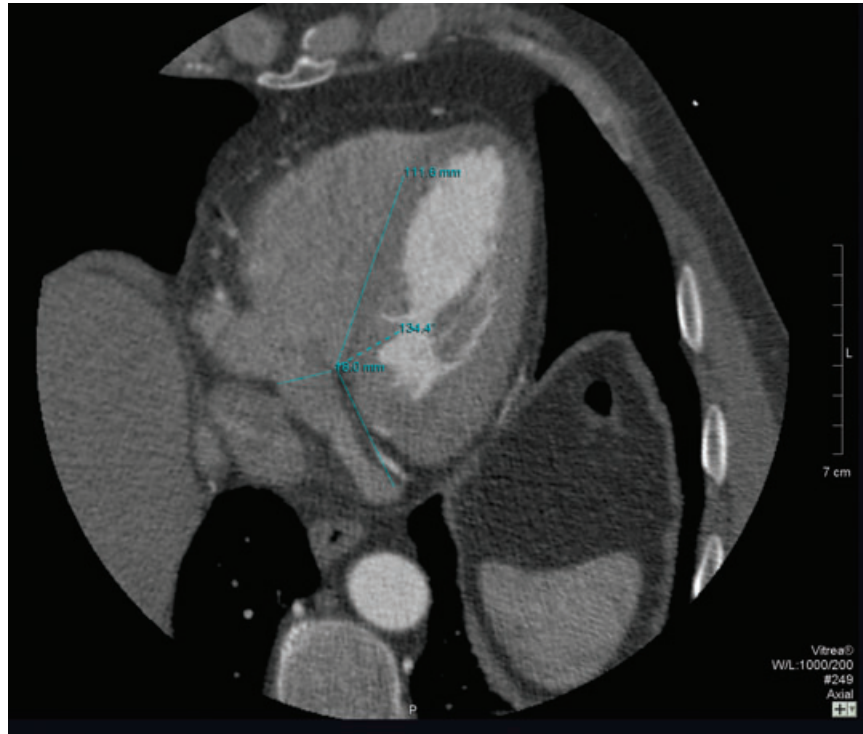
Based on strict cooperation between radiologists and cardiologists performing CRT procedures and their expectations, the following requirements for image reconstruction useful for CRT were identified:

1. be similar in quality to intraoperative fluoroscopy;
2. give a semitransparent view of the heart;
3. show semitransparent bones, sternum, and vertebral column as a position reference for the implanting physician;
4. provide anterior-posterior (AP), left anterior oblique (LAO), and right anterior oblique (RAO) views; and
5. show three-dimensional (3D) views to evaluate all important anatomical aspects.

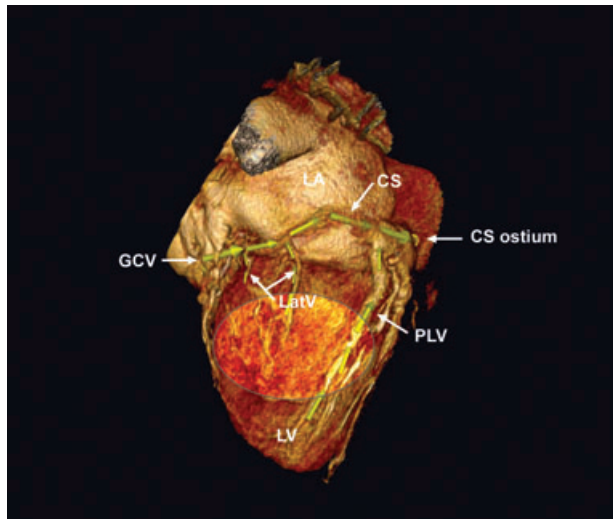
### Study Protocol

In all patients included, various methods of reconstruction and visualization were analyzed in order to develop a scheme for optimal imaging. 3D and 2D images were created in classic electrophysiological projections. Cardiac veins including the CS were indicated using markers available during postprocessing (Fig. 2). All assessments were carried out on multiplanar reformatting (MPR) reconstructions (Fig. 3). The quality of the visualization of cardiac veins was assessed by two independent observers. Good quality was defined as a visible vessel with well-contrasted walls, and without artifacts. The vessels visible fragmentarily or those with artifacts were assigned poor quality.

As the first stage, the 3D view was used to locate the anatomical structures relevant for the CRT implantation, such as the coronary sinus ostium (CSo), the coronary sinus (CS), the great cardiac vein (GCV), and all veins from the target vein area. The 3D volume-rendered reconstructions (VR) were found to be the most useful for this purpose. If the quality of 3D images was inadequate, the MPRs were used. Next, postprocessing was used to obtain images similar to those of intraoperative fluoroscopy. The postprocessing parameters that allow for the optimal



**Figure 1.** Example of measurements: angle of the entrance and size of the ostium of the coronary sinus (MPR, axial).



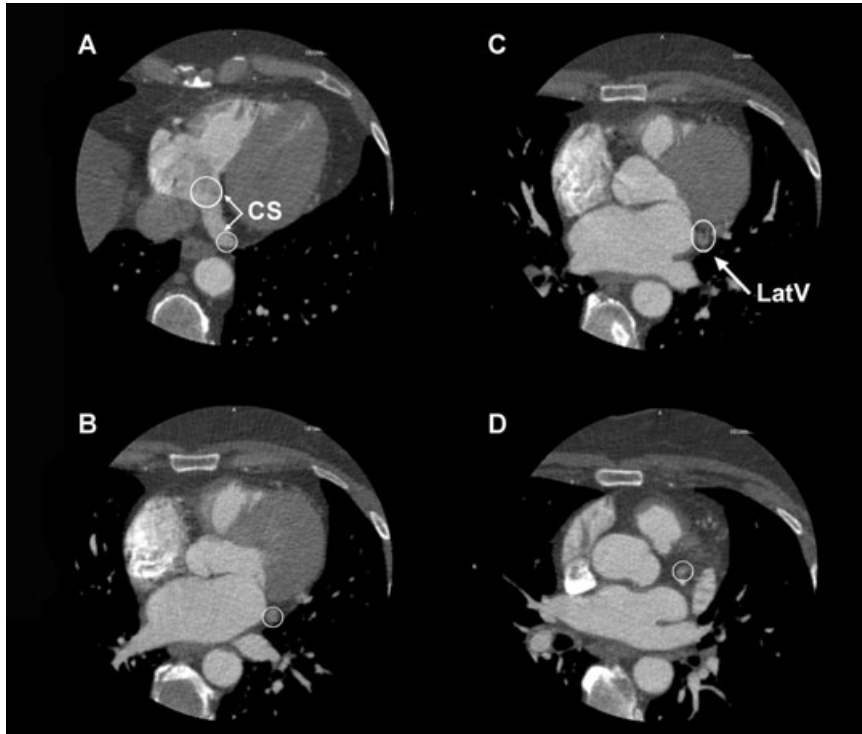
**Figure 2.** Anatomy of the heart—lateral surface. The lighter area indicated the optimal placement of the left ventricle lead based on a PATH-CHF study.<sup>20,21</sup> Abbreviations: AIV = anterior interventricular vein (anterior vein); LatV = lateral vein; CS = coronary sinus; PLV = posterolateral vein; LA = left atrium; GCV = great cardiac vein; LV = left ventricle.

visualization of the cardiac venous system are presented in Table I. Finally, the reconstructions of LAO, RAO, and AP positions were arranged in order to be obtained automatically or semiautomatically using the workstation software.

Nomenclature of the coronary veins analyzed in this study was created by the scheme of localization of the current veins. The scheme is presented in Figure 4.

### Results

The basic view for most intravenous lead implantation procedures is the anterior-posterior (Fig. 5). This single view did not provide an adequate visualization of the venous system, especially in the anterolateral and lateral aspects of the heart. To resolve this problem, the LAO view was used (Fig. 6). In this orientation the left lateral surface of the heart was clearly visible. The RAO view, considered as necessary to visualize right lateral surface of the heart, was also obtained (Fig. 7). Cardiac veins including the CS are indicated using markers (3D arrows) that are added into the image during postprocessing. It is necessary to remember that the markers mark veins very precisely, but still indirectly. The presented examples of the AP, LAO, and RAO views generated in MSCT using our scheme showed that



**Figure 3.** Multiplanar reformatted (MPR) projections in axial 2D. Coronary sinus was marked by white rings. Arrows show divergence of the lateral vein from great cardiac vein.

all of the requirements mentioned above were fulfilled.

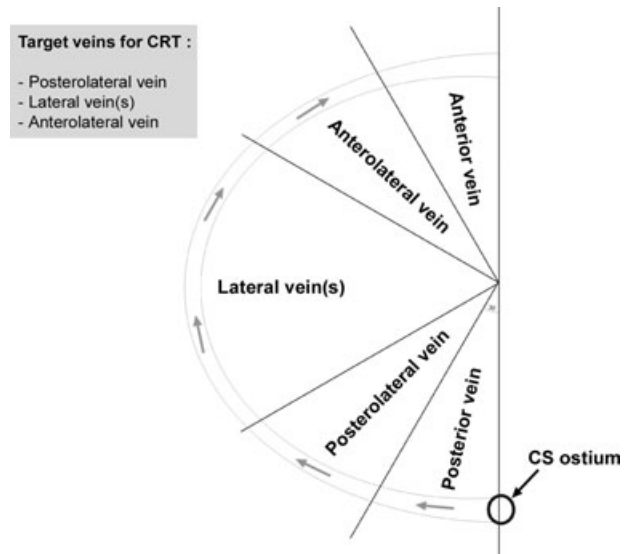
In 83 patients (74%), it was possible to obtain very similar images to those during the CRT implantation procedure within all three views. In 27 (24%) patients, it was not possible to obtain the AP view with coronary sinus and its ostium due to the large amount of contrast agent in the

right heart. Although in those cases it was possible to obtain 3D and AP views, their usefulness was limited. In two patients (2%), technical problems with reconstruction occurred due to arrhythmias

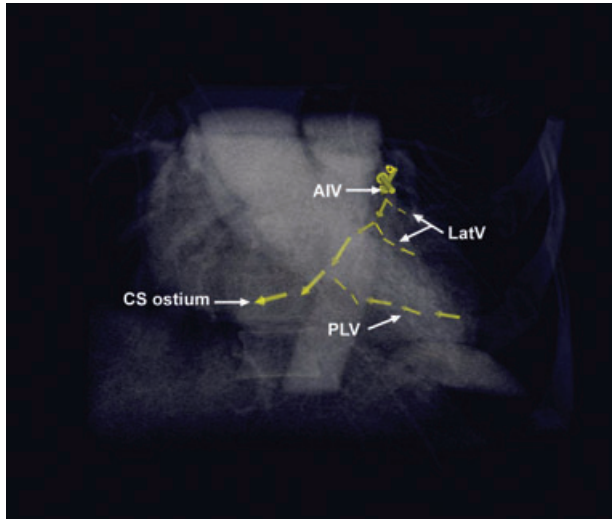
**Table I.**

Parameters of Postprocessing that Give the Best Results in the Visualization of the Cardiac Venous System Before Left Ventricle Implantation

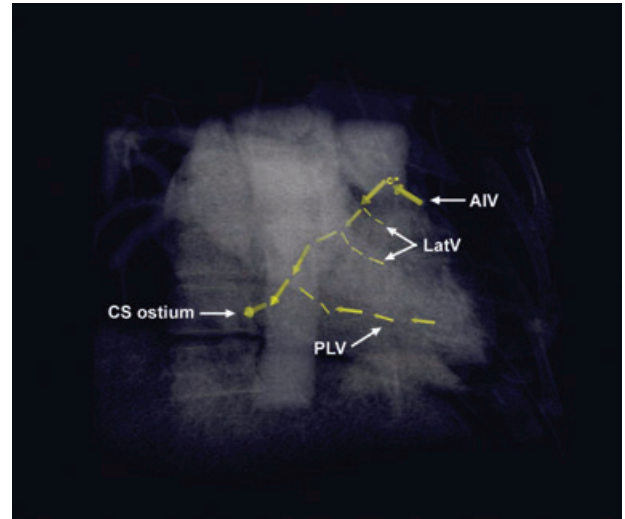
Parameter of Postprocessing	Recommended Value
Surroundings	Include everything surrounding the heart (bones)
Transparency of the surroundings	Semitransparent (30–50%)
Window/level	200/160
Volume rendering	Direct light
Transparency of the heart	Hard ramp 50–70%
Color	Monochrome



**Figure 4.** Scheme of the nomenclature of the coronary veins based on their location in MSCT (left-lateral surface of the heart).



**Figure 5.** Anterior-posterior (AP) view of the heart in 64-slice CT image generated using the proposed scheme. Abbreviations: AIV = anterior interventricular vein (anterior vein); LatV = lateral vein; CS = coronary sinus; PLV = posterolateral vein.

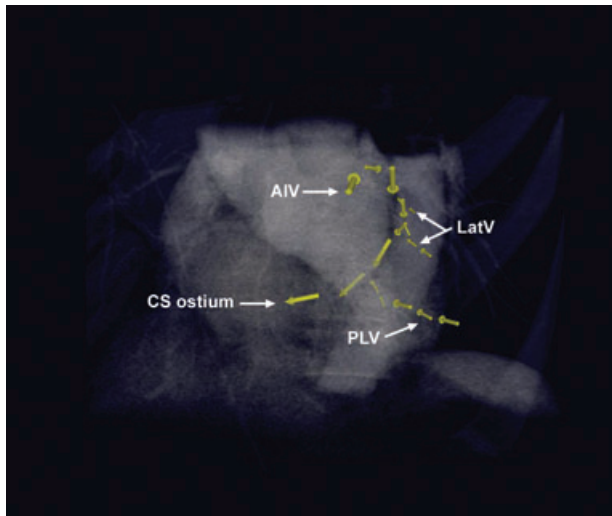


**Figure 7.** Right anterior oblique (RAO) view of the heart in 64-slice CT image generated using the proposed scheme. Abbreviations: AIV = anterior interventricular vein (anterior vein); LatV = lateral vein; CS = coronary sinus; PLV = posterolateral vein.

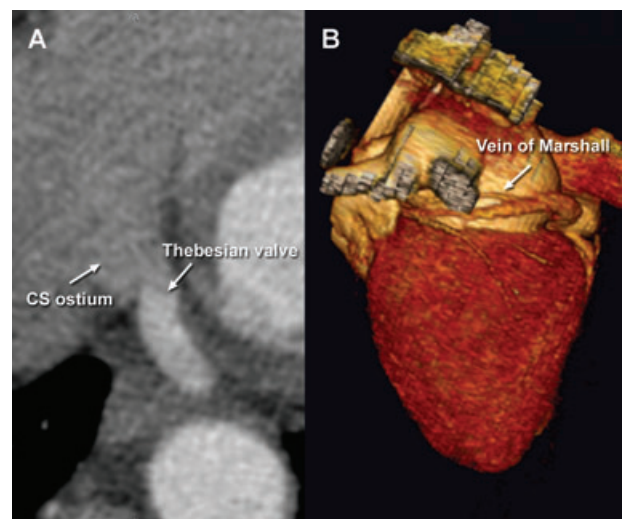
(ventricular premature beats, atrial fibrillation), which appeared just prior to or during MSCT scanning. The overall quality of the images in those cases were not satisfactory enough to be considered reliable for coronary venous system analysis.

The coronary sinus was clearly visible in all cases. Good or very good quality was obtained

in 83% of cases; in the remaining cases, the CS was also visible but artifacts or problems with the visualization of certain parts of the CS occurred. The measured CS ostium was  $12.9 \pm 5.9$  mm and the angle of entrance was  $99 \pm 12$  degrees. Different variants of the Thebesian valve (Fig. 8A) were found in 41% of patients. The vein of Marshall (oblique vein of the left atrium) (Fig. 8B) was found in 23% of patients. In all patients it was possible to visualize more than one vein. In 95%,



**Figure 6.** Left anterior oblique (LAO) view of the heart in 64-slice CT image generated using the proposed scheme. Abbreviations: AIV = anterior interventricular vein (anterior vein); LatV = lateral vein; CS = coronary sinus; PLV = posterolateral vein.



**Figure 8.** Potential sources of problems during cannulation of the CS. (A) Thebesian valve (MPR, axial), (B) Vein of Marshall (3D view, lateral surface of the heart).

at least one vein was clearly visible in the target area for CRT. Among the target veins, the posterolateral vein was visible most frequently, and at least one of them was visible in 78% of the cases. The lateral vein was also visible in 78% of the cases. The anterolateral vein was visible in 29%; however, artifacts were present more often in this area.

### Discussion

During the last decade, visualization of the cardiac venous system has been found to be of special importance for electrocardiological interventions such as catheter ablation<sup>22</sup> or mapping.<sup>23</sup> Also, the visualization of the coronary sinus and target veins before the implantation of the LV lead during CRT was shown to be relevant. The main source of potential difficulties during CRT implantation is the anatomical variability of the CS ostium and target veins, as well as ventricular remodeling that may influence the shape and size of the heart. The latter feature is especially marked in patients with heart failure, the population for whom resynchronization therapy is considered.<sup>24</sup>

Up to now, retrograde venography has been the standard method for cardiac venous system visualization. Muhlenbruch et al. compared this imaging modality to 64-slice CT<sup>25</sup> and concluded that MSCT of the heart could serve as an alternative. Based on the available data,<sup>16–19</sup> it is justified to say that reliable visualization of cardiac venous system using MSCT is possible.

Many authors, including Jongbloed et al.<sup>16</sup> and Abbara et al.,<sup>26</sup> proved that the measurement of the angle and width of the coronary sinus ostium to evaluate the possibility of cannulation, the presence of target veins in the region optimal for left ventricular pacing, or even the angle of divergence of the potential target vein(s) are feasible by means of MSCT. In spite of such clear evidence, this method is still considered investigational, and its clinical use is limited, probably because of the X-radiation threats.

In our study, based on 64-slice CT images, a scheme was proposed that in most patients allowed images similar to those obtained during intraoperative fluoroscopy to be created. We found that the use of 3D markers to indicate the position of the CS and cardiac veins, and changing the MSCT view into the projections used during CRT implantation (AP, LAO, and RAO), is especially useful. The visualization of all the structures surrounding the heart is also important. During intraoperative fluoroscopy, an operator is able to recognize other anatomical details (vertebral column, sternum, ribs, etc.) that might be considered useful as position reference points during the implantation. Although in the postprocessing stage

of MSCT images (during 3D reconstructions) the surrounding structures are automatically removed in order to facilitate the assessment of coronary vessels, a simple algorithm can be used to restore the structures surrounding the heart. This method was used when creating 2D monochromatic fluoroscopic-like images. In our opinion, MSCT could be more helpful than the venous phase of angiography in some circumstances since the position of 3D markers might give additional information about the anatomy.

In this study, a detailed quantitative analysis, with the exception of the CS ostium, was not performed. Its practical usefulness—from the implanting physician's point of view—is limited as the placement in a given vein is only partly dependent on its size. In our opinion, an accurate evaluation of the CS ostium, taking measurements of the size of the ostium (which is a key element for cannulation), and a determination of the angle of the entrance to the CS is of special importance. The presented measurements of the CS ostium are in agreement with findings of other authors (e.g., diameters of CS ostium  $12.6 \pm 3.6$  mm,<sup>16</sup>  $13.9 \pm 3.2$  mm<sup>26</sup> vs  $12.93 \pm 5.9$  in our study).

The presence of any form of Thebesian valve would also seem to be of importance. This valve can make cannulation significantly more difficult, as noted by Shinbane et al.<sup>27</sup> A similar issue arises with the existence of the Marshall's vein. Accidental implantation, or even only entrance to this vein, has been shown to carry an increased risk of perforation. In our study, this vessel was present in 23% of the cases.

The importance of multislice computed tomography, as a method of coronary venous system visualization, will probably continue to increase along with technical progress in the construction of new generations of CT scanners and postprocessing algorithms.

### Limitations of the Study

There are several issues regarding the clinical utility of this technique even if the images correspond well with those achieved during implantation. Most of these are connected with multislice CT as a method itself. Excluding patients with arrhythmias is a limitation, especially given that among patients with CHF they are very common. The dose of radiation as well as the amount of contrast agent used in the process is substantial. Many patients will require  $\beta$ -blockers to diminish the heart rate, which may be poorly tolerated and require continuous HR and blood pressure monitoring. Finally, as most of the patients included were examined because of a suspicion of IHD and, for example, had a good ejection fraction and there

were only a few patients with advanced HF, it will be necessary to evaluate the proposed scheme in a target CRT population.

### Conclusions

A 64-slice CT appears to be a promising method of previsualization of the coronary ve-

nous system. The scheme proposed in this paper enables images similar to the intraoperative fluoroscopy to be generated, which can be useful in techniques where previsualization of cardiac venous system is recommended. Additional studies are necessary to verify its usefulness in clinical practice.

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