The Coronary Venous Anatomy
A Segmental Approach to Aid Cardiac Resynchronization Therapy

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The coronary sinus is the gateway for left ventricular (LV) epicardial lead placement for cardiac resynchronization therapy. The implanting electrophysiologist is usually challenged by a high degree of variability in the coronary venous anatomy, making it important to have a more consistent and uniform segmental approach to describe the coronary venous tree and its branches. Classifying the coronary sinus branches and tributaries by the segment of their location rather than by conventional anatomic names (i.e., middle cardiac vein, great cardiac vein, and so on), would provide more relevant anatomic and functional information at the time of LV lead placement. This would enable the implanting physician to proactively correlate the venous anatomy with the segmental wall motion abnormalities or dyssynchrony, as defined by echocardiography and other imaging modalities. The current viewpoint calls for a more systematic segmental approach for describing the coronary venous anatomy. (J Am Coll Cardiol 2005;46:68–74) © 2005 by the American College of Cardiology Foundation

The cardiac venous system, which has always been overshadowed by the proximate presence of the coronary arterial tree, has recently begun to attract more attention. Its role in invasive cardiology has been directed at either targeted drug delivery (1) or retrograde cardioplegia administration (2). Of late, there has been increasing interest in the role of the cardiac venous system, toward providing a potential conduit to bypass coronary artery stenosis (3) and to delivery of stem cells to infarcted myocardium (4).

In the arena of electrophysiology, the cardiac venous system has always been of strategic interest. Coronary sinus cannulation has allowed access to the left atrial and left ventricular (LV) epicardium, enabling a spectrum of diagnostic and mapping maneuvers to aid in the determination of the type of arrhythmia as well as permit the delivery of ablative energy (5,6). More recently, the coronary sinus has become the gateway to LV epicardial lead placement to achieve biventricular pacing. The recent surge in the number of implanted biventricular pacemakers and defibrillators stems from numerous studies that have clearly shown the significant benefit provided by cardiac resynchronization therapy in patients with congestive heart failure (7,8). To achieve this therapeutic goal, it is critical that the LV epicardial lead be positioned appropriately in the region with delayed electrical activation and mechanical dyssynchrony (9). So far, the approach for lead positioning has been rather simplistic and has been mostly directed at placement of the lead along the lateral wall of the LV (10). Recent data have suggested that mechanical asynchrony is variable and that a simplistic approach may not always provide the maximal hemodynamic benefit. The optimal site for LV lead implantation may vary depending on the region and/or extent of dyssynchrony (11,12). Transvenous LV lead placement is dependent on the availability of a vein, and because of the variable coronary venous anatomy, there may not always be a suitable major vein in the region of interest that can accommodate a pacing lead with acceptable pacing parameters.

Conventional coronary venous anatomy has primarily focused on the site of origin of various venous branches from the main body of the coronary sinus rather than the particular segment of myocardium that a particular vein or venous tributary overlies. Although this conventional anatomic classification remains important, the great variability in the course of coronary veins and tributaries makes it difficult to directly correlate conventional coronary venous anatomy with specific regions of the underlying LV.

In the present review of the coronary venous anatomy and its variability, this report highlights the need for a segmental classification to map the coronary veins and tributaries in relation to the LV wall in a manner comparable to that of echocardiography and LV angiography. This stresses the need for an organized practical approach to coronary sinus angiography (similar to that of coronary arteriography), with careful attention being paid to the tributaries of main venous branches and emphasis put on their course and dimensions to facilitate LV lead placement. This classification system attempts not to supplant but rather to add information to the conventional coronary venous anatomic classification...
CONVENTIONAL CORONARY VENOUS ANATOMY

Based on the region being drained, cardiac veins can be grouped into the following: 1) the coronary sinus and its tributaries, which return blood from almost the whole heart; 2) the anterior cardiac veins, which primarily drain the anterior regions of the right ventricle and the right cardiac border; and 3) the thebesian veins (venae cordis minimae), which open directly into any of the four chambers. Although the coronary sinus invariably lies in the atrioventricular groove, its branches and their locations are far more variable than the those of the coronary arterial system (13,14). The coronary sinus opens into the right atrium posteromedially, with its opening being guarded by the highly variable thebesian valve, which can hinder cannulation of the coronary sinus ost (15). The coronary venous system can be considered as first-order tributaries originating from the main coronary sinus (i.e., the small, great, posterior, and middle cardiac veins), which then branch into second- and third-order tributaries (Fig. 1). The anterior interventricular vein ascends in the anterior interventricular sulcus (parallel to the left anterior descending coronary artery) from the apex toward the base of the heart and ends in the great cardiac vein. It then turns laterally at the base of the heart along the left atrioventricular groove (parallel to the left circumflex coronary artery) and wraps around the left side of the heart, going posterior to merge with the coronary sinus. In addition to several smaller tributaries from the left atrium and ventricles, the great cardiac vein receives two main branches, namely the large left marginal vein, along the lateral border of the heart, and the posterior LV branch (also known as the posterolateral branch). The great cardiac vein terminates in the coronary sinus, a junction defined by the presence of the left atrial oblique vein. This transition point is usually marked by the presence of intravenous valves, which can obstruct catheter and lead placement. Another important branch is the middle cardiac vein, which runs in the posterior interventricular groove, parallel to the posterior descending coronary artery.

Abbreviations and Acronyms

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<tr>
<td>CT</td>
<td>computed tomography</td>
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<td>LV</td>
<td>left ventricle</td>
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Of all of the branches of the coronary venous system, the great cardiac and middle cardiac vein are the two most consistently present branches (16). Unlike the middle cardiac vein, the great cardiac vein varies considerably in its course (17,18). Lateral and posterior venous branches together are seen in <50% of human hearts, unlike the anterior interventricular and middle cardiac veins, which are seen in more than 90% (19). Although Ortale et al. (13) have indicated that the left marginal vein may vary in its course in relation to the lateral wall of the heart and drain either into the great cardiac vein (81%) or into the coronary sinus (19%), this may not be definitive (20). Implantation of the coronary sinus lead usually involves the lateral and posterior branches, which are quite variable in their number, tortuosity, dimensions, and angulation with respect to the main trunk of the atrioventricular venous ring (16).

The coronary sinus is the most constant feature of the cardiac venous system, although several congenital anomalies have been described (21). There is also a high degree of variability in the number of branches between the middle cardiac vein and the anterior interventricular vein. Other variable features of the coronary venous anatomy include the presence of ostial valves of the cardiac veins (Vieussens valves), inter-branch collateralization, and intramural versus epicardial course, all of which may significantly impact selection and cannulation of a cardiac vein, as well as the stability and pacing threshold of an implanted lead.

This conventional anatomic classification of the coronary venous tree is limited by the large variability in its branches and their course across the epicardial surface of the heart. Lately, because of the increased need to identify LV veins for lead implantation, there has been a resurgence of interest in the anatomic variations of the cardiac venous circulation.

Figure 1. Coronary sinus angiogram of a cadaveric human heart. This heart is splayed out in an anterior view to show the entire length of the atrioventricular venous ring on the left side of the heart. The dotted lines depict the near-equal segmental divisions along the horizontal (short) axis. The horizontal line extends from the coronary sinus ostium (origin of MV) to the point where the AV terminates into the great cardiac vein. Each of the segments are defined as follows: A = anterior segment; B = lateral segment; C = posterior segment. The segment refers to the region under the respective letters A, B, and C. Conventional branches are labeled as follows: AV = anterior interventricular vein; LV = lateral marginal vein; PV = posterior cardiac vein; MV = middle cardiac vein. This figure highlights the second- and third-order tributaries and collateral circulation.
Previous attempts to categorize different patterns have ascribed more importance to variations in the direction of drainage rather than the presence or absence of the above-mentioned tributaries and their branches. What is most important for the invasive electrophysiologist is a classification system that is simple and is directed primarily at identifying the LV site underlying a particular vein or tributary.

**SEGMENTAL CLASSIFICATION**

Classifying the regions of drainage of the coronary venous system in a segmental manner will appropriately help to identify and match the location of the left-sided cardiac venous tree to the underlying LV myocardial segment. This correlation is important from the electrophysiological aspect because it will allow a more precise positioning of the LV lead for enhancing cardiac synchrony. This method of classification separates the left-sided cardiac veins according to a horizontal (short) axis, a vertical (longitudinal) axis, and the course of the tributaries.

Along the horizontal (short) axis, the atroventricular venous ring from the coronary sinus ostium to the anterior interventricular groove can be divided into three equal segments: anterior, lateral, and posterior (Fig. 1). Subclassification along the longitudinal axis (from base to apex) refers to the origin of second-order tributaries and also incorporates three zones: basal, mid, and apical (Fig. 2). This classification creates nine segments of the LV in a $3 \times 3$ grid, which is comparable to that described by other LV imaging modalities. The regions of the LV described by this system reflect the entire zone that may be approached by LV leads implanted via the coronary sinus, but excludes the ventricular septum. It is bordered superiorly by the main body of the coronary sinus, anteriorly by the anterior interventricular vein, posteriorly by the middle cardiac vein, and inferiorly by the apex of the LV.

According to this classification system, the anterior interventricular vein will always lie in an anterior position and the middle cardiac vein will always lie in a posterior position, with both major veins coursing from base to apex. Although the middle cardiac vein typically originates from the coronary sinus, occasionally it has a separate ostium. Various branches originating from the main body of the coronary sinus can be classified as anterior, lateral, or posterior according to their site of origin. The course of the tributaries can be further described as coursing medially or laterally, away from main branches in the anterior and posterior segments or anteriorly or posteriorly from main branches in the lateral wall segment (Figs. 1 and 3). Importantly, this approach identifies the course of these veins and their tributaries across the LV epicardial surface. In this way, a particular branch can be described both by conventional nomenclature (i.e., a branch from the middle cardiac vein . . .) and by segmental classification (i.e., . . . a second-order tributary of the posterior segmental branch that courses across the lateral region of the LV at the
mid-ventricular level). These two pieces of information are complementary; they both describe how to access a region (i.e., via the middle cardiac vein) and describe the region in relation to the LV epicardium (i.e., the mid-lateral LV). Classification in this way will provide maximal information to the invasive cardiologist and electrophysiologist attempting to use the coronary venous system to access specific regions of the LV. This is also advantageous especially in circumstances in which there is no conventionally named major venous branch in the region of interest. The segmental approach is also of value when trying to cross-reference the venous anatomy to the LV segment with maximal dyssynchrony. This approach also emphasizes the importance of recognizing the presence of second- and third-order branches, which may course over the lateral wall and serve as a good site for lead placement, especially in the absence of a first-order lateral branch.

**CORONARY VENOUS IMAGING**

Retrograde venography via conventional balloon occlusion angiography has enabled the delineation of the number and caliber of the large venous branches (16). This technique requires central venous access and cannulation of the coronary sinus. Unlike anterograde coronary arteriography, coronary venography is often limited by the vigorous backwash of the injected contrast, which impairs the ability to define the detailed anatomy of the tributaries and collateral circulation. Cardiac venous angiography, like coronary arteriography, must be systematic with appropriate fluoroscopic angulations to clearly define the second- and third-order tributaries for coronary sinus lead implantation. Although the posterior and lateral branches are usually first choices for lead placement, their presence, position, and size is variable. Therefore, it is also important to define second-order tributaries from the anterior and posterior segmental veins (inclusive of the anterior interventricular vein and middle cardiac vein), which cross laterally over the myocardial segment of interest. This segmental approach also calls for a more systematic approach to cardiac venous angiography. Coronary venous angiography performed in at least two different views with the necessary caudal or cranial angulations to separate the branches and display the course of the main branches is key to the segmental approach. Patients receiving cardiac resynchronization therapy devices have an underlying cardiomyopathy and may have had extensive remodeling and rotation of the heart. Importantly, the interventricular septum can be consistently profiled by delineating the middle cardiac vein (posteriorly) and the anterior interventricular vein (anteriorly) branches. Using these as reference veins, the lateral wall venous branches can be profiled by individualizing the different radiologic views (with craniocaudal angulations). Sub-selective angiography of the main branches is often important to clearly define the pattern of distribution of the second- and third-order tributaries.

The transverse diameter of the epicardial veins remains constant during systole and diastole, with flow occurring as a bolus during each cardiac cycle. Therefore, uniform opacification of the entire cardiac venous system including tributaries is difficult with a single bolus of contrast delivered at the proximal end (22). To address this problem, better catheterization and more systematic angiographic techniques are currently being developed. Newer investigational angiographic techniques with a double balloon occlusive approach can specifically isolate the branch and tributaries of interest in a particular segment (Fig. 4). These branches play a key role in positioning the guidewires for support and LV lead for pacing during the implantation procedure. Furthermore, because there may be no first-order lateral segment branches, it is important to recognize second-order tributaries from the anterior and posterior segment branches, which may course over the desired segment of interest. As seen in Figure 3, the second-order tributaries originating in the basal, mid, and apical third of the lateral segmental branch course both anteriorly and posteriorly, providing several sites for lodging the lead. Notably, the dimensions of the coronary sinus and its tributaries are directly affected by the LV end-diastolic pressure and may differ considerably between patients with cardiomyopathies that differ in severity and duration.

![Volume computed tomography image of the coronary veins in a cadaveric heart. Double balloon occlusive venography was performed to isolate the lateral segment of the coronary venous tree. The lateral vein (LV) and its tributaries can be seen in great detail. 1 = the LV, which is the first-order tributary; 2 = second-order tributary; 3 = third-order tributary.](image-url)
Recent developments in rotational contrast venography (Allura FD 10) offer a dynamic multi-angle visualization of the coronary venous tree. The coronary sinus angiograms can be obtained using a 4-s isocentric rotation of the imaging camera over a 110° arc. The rotational images can then be reviewed over a full range of angles, providing the operator with considerably more information about the coronary venous tree and its branches than standard images. Also, three-dimensional models of the venous tree can be reconstructed (Figs. 5A and 5B) to give more information regarding the size of the coronary sinus, its main branches, and the second-order tributaries. This information should prove useful both to define an individual patient’s coronary venous anatomy and to tailor an LV lead implant strategy that targets a myocardial segment of interest.

Electron beam computed tomography (CT) and multi-detector row CT enable three-dimensional reconstruction of tomographic images of the beating heart and provide a detailed, minimally invasive definition of the coronary venous anatomy (19,23). Unlike retrograde venography, CT angiography allows for simultaneous imaging of the coro-

![A](image1.png) ![B](image2.png)

**Figure 5.** Rotational venous angiogram, with still frames in anteroposterior (A) and left anterior oblique 30° (B). PV = posterior vein; MV = middle cardiac vein; GV = great cardiac vein; AV, anterior cardiac vein. Alongside are three-dimensional reconstructed images of the coronary venous tree, facilitating segmental visualization of the coronary venous anatomy. The coronary venous ring is divisible into three segments: posterior (C), lateral (B), and anterior (A), in both views. (B) The mid-ventricular position of a lateral segmental branch (1), closely corresponding to the second-order lateral tributary from an anterior segmental branch, extending over the mid-ventricular region (2).
Coronary Venous Anatomy

Conclusions

This paper calls for a more systematic approach to detailing the LV regions supplied by branches of the coronary venous system. The high degree of variability in coronary venous anatomy makes it important to have a uniform segmental classification system for approaching these vessels. It will be useful to the electrophysiologist to classify coronary sinus branches and tributaries by their epicardial location in addition to their anatomic classification. Correlating the venous anatomy with the segmental wall motion abnormalities or dysynchrony, as defined by echocardiography and other imaging modalities, may provide more relevant anatomic and functional information at the time of LV lead placement.

Future approaches to epicardial lead placement may involve a noninvasive preprocedural definition of the coronary venous anatomy, followed by more selective angiographic techniques to enable better definition of the venous anatomy for LV lead placement. Further recognition of the venous tributaries in terms of their distribution, angulation, tortuosity, and dimensions will enable the development of lead positioning tailored to each individual patient. This will allow for translation of current advances in our understanding of regional mechanical dysynchrony into the clinical practice of LV lead implantation.

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