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IMAGING VIGNETTE

Cardiac Resynchronization Therapy Devices Guided by Imaging Technology

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IN PATIENTS WITH CONGESTIVE HEART FAILURE DUE TO SYSTOLIC DYSFUNCTION WHERE ELECTRICAL AND MECHANICAL DYSSYNCHRONY IS PRESENT, cardiac resynchronization therapy has been shown to make patients "feel better" and "live longer" (1). In these procedures, left ventricular pacing is conventionally achieved via an endovascular approach by placing the lead in a coronary vein. Due to the marked variability in coronary venous anatomy, considerable difficulty can be encountered with this approach. Recent years have witnessed numerous investigations on the ability of imaging technology to delineate various aspects of coronary venous anatomy (2). We discuss the questions that go through the mind of the operator during the implantation procedure and illustrate how imaging technology, especially cardiac computed tomography and cardiac magnetic resonance (CMR), can help answer these questions, often even before the procedure.

Question 1. Are there congenital anomalies of the coronary venous system or of the thoracic veins present that the operator should be aware of?

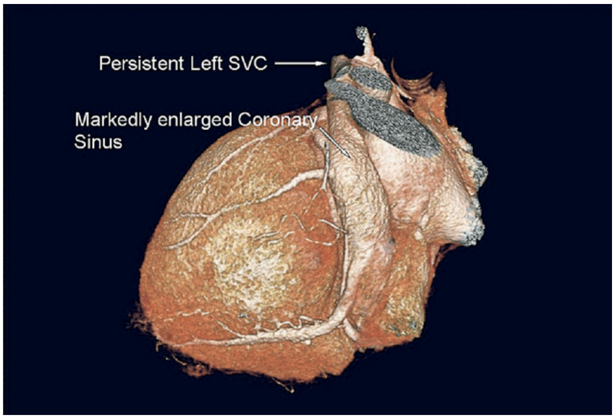

Figure 1. Example of a Persistent Left Superior Vena Cava With a Markedly Enlarged Coronary Sinus

This 3-dimensional (3D) volume-rendered reconstruction was imaged in a patient referred for resynchronization therapy. In these patients, technical difficulties might be encountered especially in placement of the right ventricular "high voltage" or defibrillator lead. Using a left-sided approach often requires that the lead be looped in the right atrium to enter the right ventricle. Many operators prefer the use of a right-sided approach in patients such as these, especially if there is no anastomosis between the left and right superior caval veins. SVC = superior vena cava.

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Question 2. Will I be able to canulate the coronary sinus?

Figure 2. Thebesian Valve Covers the Ostium of the Coronary Sinus

The structure might be fibrous, fibromuscular or muscular, can display significant variability, and can complicate attempts to canulate the coronary sinus. The valve might be absent 25% of the time (as seen in **A**, **arrow**). When present, it often tends to be thin and fenestrated (as seen in **B**). In hearts such as those seen in **A and B**, it should not interfere with attempts at canulation. An example of a potentially complicating Thebesian valve is seen in **C**, where a thick fibrous valve is seen occluding the entire ostium of the coronary sinus **(arrow)**. Autopsy studies show that valves such as those seen in **C**—where it occludes more than 75% of the ostial area and is fibrous, muscular, or fibromuscular—are seen approximately 15% of the time (3). There have been reports of using electron beam computed tomographic angiography to visualize thickened Thebesian valves, but a systematic study is lacking (4).

Question 3. After canulating the CS, can I advance the lead or sheath within the coronary venous system?

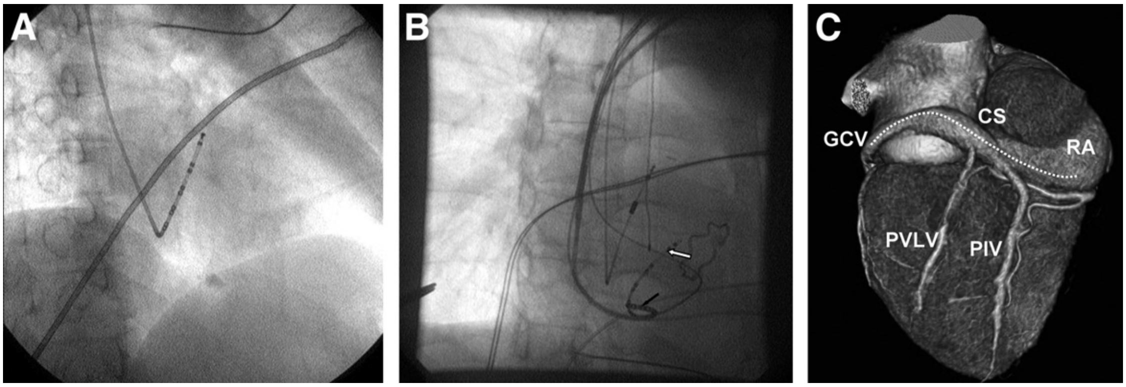

Figure 3. The Course of the Coronary Sinus

(A and B) Right anterior oblique view of the heart during fluoroscopy with a decapolar catheter placed in the coronary sinus (CS). **(A)** The catheter placed in the CS in a normal heart. Notice that the catheter describes a "straight course" after entering the CS. **(B)** Catheter placed in the CS where a compound curve is present. Although it was possible for a thinner, more flexible catheter **(white arrow)** to be placed and advanced in this structure, a thicker catheter **(black arrow)** could not be advanced. In this patient, with an endovascular approach via the left axillary vein, a left ventricular pacing lead could not be placed in the coronary venous system. The difference in the course of the catheter in the normal heart **(A)** versus that in a heart with a compound curve **(B)** is readily apparent. **(C)** Volume-rendered 3D reconstruction of a 64-slice multi-slice computed tomography (MSCT) scan showing the cardiac venous system (5). A "compound" curve of the CS similar to **B** was observed **(white dotted line)**. The proximal CS is atrially displaced, and as a result it becomes excessively tortuous. GCV = great cardiac vein; PIV = posterior interventricular vein; PVLV = posterior vein of the left ventricle; RA = right atrium.

Figure 4. The Valve of Vieussens

The other important anatomical structure that can prevent a lead or a sheath from being advanced within the coronary venous system is the Valve of Vieussens. It is located where the great cardiac vein widens to become the coronary sinus (CS), and the frequency of its presence is reported to vary from 65% to 87%. A still image from a CS balloon occlusive venogram in the left anterior oblique view is shown, demonstrating obstruction to flow of contrast. No contrast is seen to extrude beyond the balloon tip (**black arrow**). This is likely due to the presence of a prominent Valve of Vieussens. In this patient, it was impossible to advance a pacing lead beyond the valve. Studies show that when difficulty was encountered in advancing a catheter within the CS, 80% of the time it was due to a prominent Valve of Vieussens (6).

Question 4. Is it possible to find an appropriate venous branch?

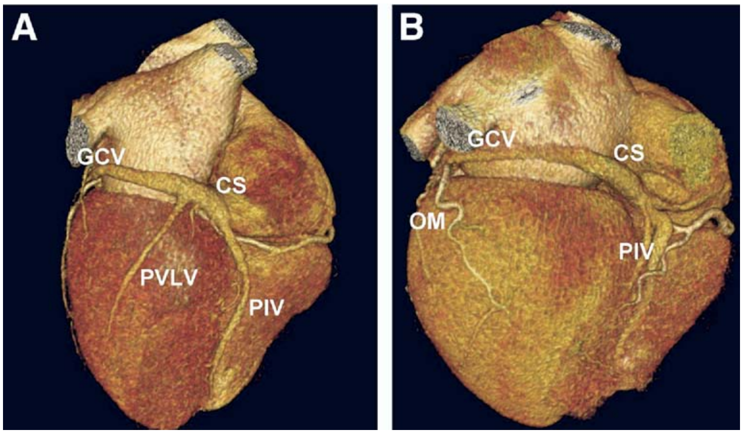

Figure 5. Volume-Rendered 3D Reconstructions of MSCT Scans Demonstrating Venous Anatomy

(A) An MSCT allows noninvasive evaluation of the coronary venous system before left ventricular lead implantation. With the use of 3D volume-rendered reconstructions, as demonstrated in **A and B**, a clear "roadmap" of the CS and its tributaries can be provided. In general, the posterior or posterolateral wall of the left ventricle is targeted for lead placement. In this patient **(A)**, a clear target vein is present on the posterolateral wall (PVLV). **(B)** In this patient, no suitable side branches on the posterolateral wall of the left ventricle could be detected with MSCT. In this patient, an anterior lead placement might be considered or the patient could be referred for minimally invasive epicardial lead placement. Studies show that, in the setting of atherosclerotic coronary heart disease and prior myocardial infarction, there is an increased likelihood of the lateral marginal branch being absent (7). OM = obtuse marginal artery; other abbreviations as in Figure 3.

Question 5. Will it be possible to obtain adequate left ventricular sensing and pacing threshold?

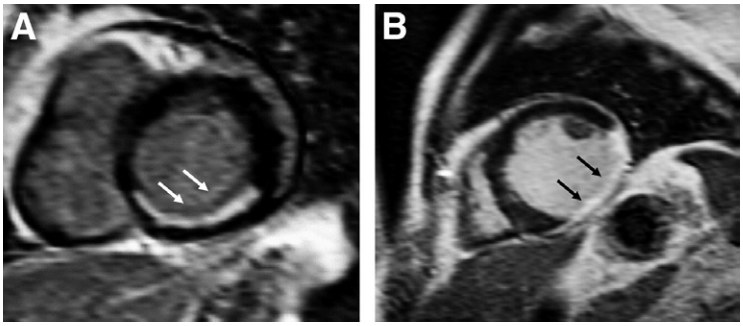

Figure 6. Delayed Enhancement CMR for Detection of Scar Tissue

Scar tissue present in the region of latest activation is another factor that is important for left ventricular lead positioning. With the use of contrast-enhanced cardiac magnetic resonance (CMR), the presence of scar tissue in the target region can be assessed. In this patient **(A)**, nontransmural scar tissue in the posterolateral wall of the left ventricle is visualized with delayed enhancement **(white arrows)**. **(B)** In this patient, delayed enhancement CMR was used to detect the amount of scar tissue in the posterolateral region. As demonstrated, transmural scar in the posterolateral wall was present **(black arrows)**. In these 2 patients, left ventricular lead implantation, especially in the posterolateral wall, has the potential to provide suboptimal results likely due to inadequate sensing and pacing function.

Question 6. What is the likelihood of diaphragmatic capture with the left ventricular pacing lead?

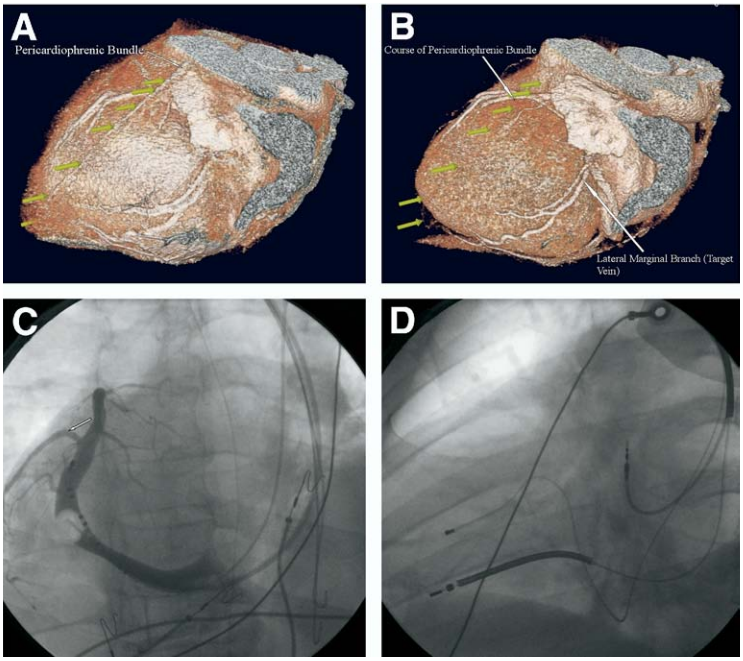

Figure 7. MSCT and Fluoroscopy for Detection of the Course of the Coronary Veins and the Phrenic Nerve

(A to D) Phrenic nerve and diaphragmatic stimulation has been associated with biventricular pacing. This is likely due to the often close proximity between the left ventricular pacing lead placed in the coronary venous system that is an epicardial structure and the phrenic nerve that is adherent to the parietal pericardium. Multislice computed tomography, by imaging the accompanying pericardiophrenic artery and vein that runs along with the phrenic nerve, has been demonstrated to be capable of detecting the precise relationship of the nerve to the target coronary vein before the implantation procedure (8). To visualize the nerves and accompanying vessels, adjustments in the window level settings are necessary to achieve maximum projection intensity. **(A)** Left pericardiophrenic bundle (PCB) created by using these techniques **(yellow arrows)**. **(B)** Window level settings are altered so that the coronary vessels are seen more clearly and the pericardiophrenic bundle is no longer seen. The **yellow arrows** placed to "tag" the PCB are visible and help determine the relationship between the bundle and the lateral marginal vein (target branch), showing that the 2 structures are not adjacent. **(C)** Coronary venography where the target vein is seen. **(D)** Final lead positions including placement of the left ventricular lead in the target vein. No diaphragmatic pacing was seen despite high output pacing from the left ventricular lead.

Conclusions. Cardiac imaging with MSCT scans or with CMR have the potential to be significantly beneficial by providing a roadmap before the procedure in patients undergoing resynchronization therapy. Especially in "problematic" patients, prior planning can make a significant difference, and imaging data can play a big role in preparation for the procedure. Cardiac imaging to guide device implantation is an area of active investigation and justifiably generates considerable excitement.

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