Non invasive visualization of cardiac venous system using 64-slice computed tomography before cardiac resynchronization therapy: what cardiac electrophysiologist needs to know

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Purpose

Heart failure has become one of most important public health problems of developed nations representing the third most common cardiovascular cause of death and an important cause of morbidity and hospitalizations.

Cardiac resynchronization therapy (CRT) is an option for patients with heart failure; its benefits have been shown in a number of prospective randomized trials. Improvements have been demonstrated in functional class, quality of life and more recently reduction of overall mortality. Indication for CRT are heart failure NYHA Class III, left bundle branch block with wide QRS (>130 ms) and reduced EF.

Current evidence suggests that stimulation in the lateral region of the left ventricle is that which provides the greatest benefit in CRT. Left ventricular pacing in cardiac resynchronization therapy is generally achieved by positioning the left ventricular lead (LV LEAD) in one of the tributaries of the coronary sinus (CS).

Surgical epicardial left ventricular lead implantation on the free LV wall represents an important option in patients with difficult transvenous approach. The use of intravascular venous access offers a number of advantages over the minimally invasive thoracotomy approach in patients who already present hemodynamic instability.

Despite the rapid evolution of CRT implantation techniques the transvenous approach is not feasible in a percentage between 5% and 8% of the potential candidates; besides in 30% of the cases there is no response to CRT.

To improve the success rate a more accurate selection of potential candidates appears necessary: 1) Location of the area of latest activation (echocardiography with tissue Doppler imaging), 2) Myocardial viability and demonstration of transmural scar tissue in the delayed area (contrast enhanced MR): these patients fail to respond to CRT. 3) Presence of cardiac veins draining the region of latest activation; MSCT is able to identify the presence of target veins: generally posterior vein of the left ventricle and left marginal veins.

Before the introduction of multislice CT (MSCT) retrograde venous angiography represented the conventional technique for studying the coronary veins. The limitations of the technique in terms of invasiveness, examination duration, inability to visualize both the vessels and cardiac wall at the same time, not always optimal depiction of cardiac veins, the need for large amount of contrast agent and impossibility to selectively
catheterize the CS and its tributaries in a significant percentage of cases targeted the efforts of scientific research toward the realization of a non invasive diagnostic tool for the evaluation of the cardiac venous system.

Technological evolution in the field of MSCT has provided scanners with progressive improvement in spatial and temporal resolution that makes them more and more capable analyzing moving organs with high quality anatomic detail.

64-slice-MSCT has been taking on an increasingly important role as non invasive modality in the evaluation of cardiac veins. Non invasive preview of coronary venous anatomy may facilitate the implantation of the LV lead.

In the present study we highlight the information relevant to clinical electrophysiology practice for the preoperative planning before CRT.

**Methods and Materials**

We retrospectively reviewed CT coronary artery angiography of 300 patients and evaluate the different anatomic components and possible variants of the cardiac venous system we were able to identify in the same scans.

Patients with heart rate > 70 bpm received a 100 mg oral dose of metoprolol 60-90 min before the examination.

Imaging study was performed with 64-detector raw Light Speed VCT scan (GE Medical Systems, Milwaukee, USA) using 120 ml of contrast material (Iomeprol, Iomeron 400 mgI/ml, Bracco, Milan, Italy) at an injection rate of 5 ml/min followed by a 50 ml bolus of saline solution at the same flow rate using an 18-gauge needle cannula inserted into an antecubital vein of the arm and a dual-head automatic injector (Stellant D, Medrad, PA, USA).

The beginning of the scan was synchronized with the arrival of contrast agent by using the Smart Prep technique, with a region of interest (ROI) positioned in the ascending aorta and a threshold set at a density value of 100 HU greater than baseline value. No particular venous protocol was used.
Scanning was performed using 64 slices with a collimated thickness of 0.6 mm; multiplanar and volume rendered and virtual angioscopy reconstructions of the venous system and cardiac chambers were then obtained and evaluated both by the radiologist and cardiologist.

In the current report we accepted and used the terminology described by von Lüdinghausen (2003).

**Results**

We highlight the information relevant to clinical electrophysiology practice for the preoperative planning before CRT:

1) presence of target veins suitable for LV-lead placement in CRT: the most frequently used are those veins draining the lateral free wall of the left ventricle like the posterior vein (s) of the left ventricle (PVLV) and the left marginal vein (LMV)) in our experience LMV was demonstrated in 62 % of cases, PVLV in 73%, both in 41% of patients, no target veins in 3% of patient. Patients with previous infarction in the lateral wall are frequently lacking a target vein in the necrotic area. Surgical epicardial placement of the LV-LEAD may be used when in the absence of target veins.

2) It is possible to measure the diameter of the target vein, its length, course and take-off angle from the CS body or from great cardiac vein (GCV). These information are of paramount importance in the pre-operative planning. The knowledge of the diameter of the target vein (>3 mm) guide in the selection of the best electrocatheter to use. The take-off angle influence the difficulty of the cannulation procedure. A take-off angle <90° is generally associated with a more difficult placement of the LV-LEAD with possible need of dedicated devices. Non invasive preview of coronary venous anatomy may facilitate the implantation of the LV lead avoiding retrograde venous angiography and its related complications.

3) The knowledge of the position of the vein (distance from CS) and its course influence the duration of the procedure and incidence of post-interventional complications (infections of the LEAD are partially related to the duration of the procedure). The reduced time for LV LEAD placement results in a reduced dose of radiations both to the patient and to the electrophysiologist.

4) MSCT is able to demonstrate the presence of anatomical obstacles for the CRT procedure:
a) prominent Thebesian Valve: this finding may represent an important obstacle to the procedure with possible need of dedicated technique like, for instance, two catheters to cannulate the CS: the first positioned via femoral vein to open the ostium, the second via subclavian vein to place the LV-LEAD

b) coronary sinus stenosis and GCV stenosis are not rare findings in patients operated for mitral valve disease and following coronary artery bypass graft surgery particularly after CEC with CS cannulation. Stenosis may require angioplasty.

c) complex venous anomalies may represent a problem for LV-LEAD placement; this findings are rare in the general population but show and higher incidence (up to 10% of cases) in patients with congenital heart disease (interatrial and interventricular defects)

5) MSCT is able to detect the left phrenic nerve (LPN) contained within the left pericardiophrenic bundle (which contain the nerve the left pericardiophrenic artery and vein) and its relation to cardiac venous system (GCV, PVLV, LMV). LPN stimulation represents one of the most common complications of intraoperative and perioperative tranvenous LV-LEAD placement. Visualization of LPN and its spatial relation to cardiac venous anatomy before the procedure may help LV-LEAD placement thus avoiding inadvertent PN stimulation and unwanted diaphragmatic pacing.

6) MSCT is able to identify the presence of myocardial transmural scar tissue (hypodense and thin wall portion with late enhancement similar to MR findings) and the relation of the target vein with the necrotic area. Bleeker et al observed that patients with transmural posterolateral scar tissue on contrast enhanced MR fail to respond to CRT; no benefit will result to place the LV-LEAD in the target vein draining the necrotic area.

Images for this section:
**Fig. 1:** Posterior vein of the left ventricle (PVLV) with good diameter (5 mm at the ostium) considered feasible for cannulation in CRT. CS: coronary sinus
Fig. 2: LV-LEAD course: right atrium, Thebesian valve, coronary sinus, PVLV
Fig. 3: Take-off angle of the Posterior vein of the left ventricle (PVLV) from the great cardiac vein >90° considered favorable for cannulation. CS: coronary sinus, IPV: interventricular posterior vein
Fig. 4: Moderately favorable take-off angle (≈90°) of the left marginal vein from great cardiac vein. OM: obtuse marginal branch of the circumflex artery
Fig. 5: Unfavorable take-off angle (
Fig. 6: Prominent Thebesian valve (TV) with significant stenosis of the CS ostium (CS OS)
Fig. 7: Multiplanar reformat in a patient with great cardiac vein (GCV) stenosis.
Fig. 8: Vessel analysis in a patient with great cardiac vein (GCV) stenosis.
**Fig. 9:** Volume Rendering reconstruction in a patient with great cardiac vein (GCV) stenosis following coronary artery bypass graft surgery
Fig. 10: Volume rendering reconstruction in a patient with persistent left superior vena cava (PLSVC) draining into the coronary sinus (CS). OM: obtuse marginal branch of the circumflex artery. PVLV: posterior vein left ventricle. LA: left atrial appendage. *Asterisk: site of surgical epicardial left ventricular lead implantation on the free LV wall in this patient with difficult transvenous approach. MSCT findings proved useful for the surgeon in the pre-operative planning: MSCT showed the course of the circumflex artery and vascular relations with the visual marker represented by the left atrial appendage. It was possible to place the epicardial lead in a place of the left ventricular wall sufficiently far from the obtuse marginal branch of the circumflex artery.
**Fig. 11**: Patient with persistent left superior vena cava (PLSVC) draining into the coronary sinus (CS): post-surgery CXR
**Fig. 12:** Axial image demonstrates the close relation of the distal branch of the posterior vein of the left ventricle (PVLV) and left pericardiophrenic bundle (LPCB) (which includes left phrenic nerve)
Fig. 13: Volume Rendering reconstruction: LPCB crosses the distal branch of the PVLV
**Fig. 14:** Axial image shows the area of transmural necrosis
Fig. 15: The oblique multi planar reconstruction demonstrates two left marginal veins (LMV) draining the necrotic area
Fig. 16: Volume Rendering reconstruction: VMS draining the area of transmural necrosis. This patient will probably fail to respond to CRT.
Conclusion

64-MSCT is able to give the electrophysiologist important information for the preoperative planning: selection of potential candidates for the transvenous approach, selection of catheters for venous cannulation and the best vein to use.

References


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