Technical failure to perform cardiac resynchronization therapy: Use of cardiac magnetic resonance imaging techniques to clarify a left-sided superior vena cava and coronary sinus morphology

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W Keeble, R Mohiaddin. Technical failure to perform cardiac resynchronization therapy: Use of cardiac magnetic resonance imaging techniques to clarify a left-sided superior vena cava and coronary sinus morphology. Can J Cardiol 2008;24(7):589-590.

The most common reason for failure to implant a left ventricular lead to deliver cardiac resynchronization therapy is the presence of unfavourable coronary venous anatomy. The present report illustrates the use of cardiac magnetic resonance imaging to delineate the anatomy of a left-sided superior vena cava in two patients in whom permanent cardiac pacing was unattainable.

Key Words: Cardiac resynchronization therapy; CMR; Persistent left superior vena cava

Significant survival benefits may be derived from cardiac resynchronization therapy (CRT) in individuals with moderate to severe congestive heart failure and ventricular dyssynchrony (1).

Typically, an individual with an impaired left ventricle (LV), prolonged atrioventricular conduction delay, left bundle branch block and mitral regurgitation receives three pacing leads: to the right atrial (RA) appendage, to the right ventricular (RV) apex, and retrogradely through the coronary sinus (CS) from the RA and advanced posteriorly around the atrioventricular ring to a venous tributary overlying the LV free wall. Optimized pacing of the LV and RV coordinates mechanical function, improves cardiac output and reduces mitral regurgitation.

The most common reason for failure to implant an LV lead, however, is the presence of unfavourable coronary venous anatomy. A prospective study (2) of venous anatomy with bilateral digital subtraction angiography in 273 patients referred for conventional pacing or defibrillator implantation found 12 patients (4.4%) with asymptomatic, complete venous occlusion associated with collateral vessels and one patient (0.4%) with persistent left-sided superior vena cava (LSVC) (2).

During embryogenesis, the left anterior cardinal vein fails to obliterate. The LSVC remains and communicates with the RA via the CS in 90% of cases. In rare instances, the LSVC drains directly into the roof of the LA, resulting in partial anomalous systemic venous return. However, unless associated with other congenital anomalies, the discovery of an LSVC may only occur during cardiac pacing, when a lead descends unexpectedly left of the thorax after its introduction into the left subclavian vein.

Should a CRT procedure be unsuccessful, the decision of performing a second procedure depends on whether noninvasive imaging can answer several key questions:

- Is the LSVC associated with an absent right-sided SVC (RSVC), thereby removing the option of a procedure from the right subclavian vein?
- Is an innominate vein connecting the LSVC to the RSVC present? In 30% of individuals with LSVC, the entire upper left venous system drains through the LSVC and CS to the RA (3).

Échec technique d'un traitement de resynchronisation cardiaque : Utilisation de l'imagerie par résonance magnétique cardiaque pour clarifier la morphologie de la veine cave supérieure gauche et du sinus coronaire

La raison la plus fréquente de l'échec de l'implantation d'une électrode ventriculaire gauche pour administrer un traitement de resynchronisation cardiaque est la présence d'une anomalie anatomique affectant le système veineux coronaire. Le présent rapport illustre l'utilisation de l'IRM pour délimiter l'anatomie de la veine cave supérieure gauche chez deux patients pour qui l'entraînement cardiaque à demeure a été abandonné.

Figure 1) Normal study. A Two-chamber cine image showing a coronary sinus (CS) coursing posteriorly in the atrioventricular groove. **B** Perpendicular transverse cine images demonstrating entry of the CS into the right atrium (RA) adjacent to the inferior vena cava (IVC) (plane cut below level of left atrium [LA]). LV Left ventricle; RV Right ventricle

- Is there CS ostium atresia denying access to the CS from the RA? During the procedure, this may only be identified by studying the venous phase of coronary angiography to observe left intercostal vein drainage (3).
- Will a large occlusion balloon be required in a dilated CS to aid the retrograde opacification of the left lateral CS tributaries under fluoroscopy? (3)

Cardiac magnetic resonance (CMR) imaging has the advantage of a wide field of view of intrathoracic structures and does not use ionizing radiation. With an early 0.35 Tesla machine, three cases of LSVC were originally shown with spin echo pulse sequences. Using stacked transaxial images, anomalous vessels may be identified as 'black blood' (4). Modern coils allow acquisition in any plane. Cardiac electrocardiogram gating with breath hold techniques allows cine image acquisition. Figure 1 demonstrates a coronary sinus in a normal subject. Gadolinium contrast injection allows temporal study of blood flow through vessels and postanalysis with three-dimensional multiple intensity projection images. It is this current multimodality CMR approach that allows

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Received for publication April 26, 2006. Accepted July 3, 2006

Figure 2) Patient 1. **A** Coronal cine image demonstrating the presence of equal-calibre left- and right-sided superior venae cavae (LSVC and RSVC, respectively). **B** Symmetry of the LSVC and RSVC was shown in the transverse spin echo images. No connecting innominate vein was seen. **C** The coronary sinus (CS) appeared dilated on two-chamber cine imaging. **D** The RSVC was seen normally entering the right atrium (RA). **E** The LSVC, however, coursed around the left atrium (LA) and entered the CS. **F** Flow-map cine imaging confirmed the flow around the LA into the CS. Asc Ao Ascending aorta; Desc Ao Descending aorta; LPA Left pulmonary artery; RV Right ventricle

real-time noninvasive problem solving to clarify venous anatomy. Furthermore, nonresponse to CRT may be predicted by the presence of scar tissue in the posterolateral LV segments. These fail to respond to LV pacing, leading to inadequate LV resynchronization (5).

Observation of an enlarged CS raises the question of LSVC directing the whole left upper venous return to the RA via the CS. This may be confirmed by injection of agitated saline contrast from the left antecubital vein and imaging bubbles in the CS and RA. Should injection from the right antecubital vein have similar results, then there is absence of the RSVC. The sign of a dilated CS on echo being associated with LSVC is reported in 10 patients imaged by echo and then confirmed by CMR (6). The negative predictive accuracy of determining whether LSVC is absent on the basis of a nonenlarged CS has not been established.

CASE PRESENTATIONS

Patient 1

An 82-year-old man was referred for conventional, dual-chamber cardiac pacing. The trajectory of the first lead raised the possibility of a persistent LSVC, and the operator requested CMR imaging to avoid a prolonged procedure with undefined anatomy. This demonstrated the presence of equal-calibre left and right SVCs. No communicating innominate vein was seen. The LSVC was kinked as it traversed around the left pulmonary artery, and then entered the dilated CS as it coursed around the atrioventricular groove. This was demonstrated with cine images and flow mapping (Figure 2).

Figure 3) Patient 2. **A** A small left-sided superior vena cava (LSVC) was demonstrated after three-dimensional reconstruction of contrast-enhanced magnetic resonance angiography. Gadolinium diethylenetriaminepentaacetic acid was delivered via the left antecubital vein. **B** Transverse spin echo image demonstrating the coronary sinus (CS) remaining of normal character and position. The grossly dilated and poorly functioning left ventricle (LV) was evident. This displaced the descending aorta (Desc Ao) to the right. IVC Inferior vena cava; LPA Left pulmonary artery; RA Right atrium; RPA Right pulmonary artery; RSVC Right-sided superior vena cava; RV Right ventricle

Patient 2

A 74-year-old man with a hugely dilated, impaired LV and dyssynchronous contraction was referred for CRT. The operator suspected an LSVC on fluoroscopy and planned to perform CRT, delivering two leads into the RA from the CS. The RV lead was to be looped around the RA free wall and prolapsed through the tricuspid valve to reach the RV apex. An appropriate atrial lead was to be delivered superiorly to the appendage or the RA wall. The LV lead to the lateral free wall of the LV was also to be approached downstream from the LSVC.

However, lead manipulation proved to be limited, and the procedure was aborted. The extent of the technical challenge to deliver three leads to stable positions with optimal electrical parameters is evident from the MR images (Figure 3). Contrast-enhanced MR angiography via the left antecubital vein revealed that the LSVC was significantly smaller than the RSVC. This was most evident close to the left pulmonary artery before joining a nondilated CS and entering the RA.

SUMMARY

Anatomical considerations can be demonstrated while attempting repeat pacing using a multimodality CMR approach.

Patient 1 might have had the option of conventional dual-chamber pacing from the right or left subclavian approach. In patient 2, the CS ostium was patent; however, a further attempt to pass three leads through the small and tortuous LSVC and CS was not likely to be successful. The procedure might have been achievable from the right subclavian and RSVC. This case illustrates an LSVC with undilated CS, which would have appeared normal on echocardiography.

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