Magnetic resonance imaging and computed tomography in assessing cardiac veins and scar tissue

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The success of cardiac resynchronization therapy is influenced by several issues including cardiac venous anatomy and myocardial scar tissue. This article discusses non-invasive imaging modalities that could contribute significantly to the selection process of cardiac resynchronization therapy (CRT) candidates: multi-slice computed tomography to depict the coronary sinus tributaries and magnetic resonance imaging to identify scar tissue.

Introduction

In order to improve the response rate, several issues need to be addressed during the selection process of cardiac resynchronization therapy (CRT) candidates. Echocardiographic evaluation of mechanical dyssynchrony is certainly a key issue to predict response after CRT implantation. This article deals with two other important issues that influence success of biventricular pacing: cardiac venous anatomy and myocardial scar tissue.

Importance of non-invasive evaluation of cardiac venous anatomy with multi-slice computed tomography in CRT candidates

The most challenging part of a CRT device implantation through an endovascular approach is positioning the left ventricular (LV) lead in a branch of the coronary sinus. In most textbooks on human anatomy, emphasis is on coronary arteries and cardiac veins are discussed superficially. A systematic approach to cardiac venous anatomy has been published by von Lüdinghausen. He describes the major tributaries of the coronary sinus as follows: the first tributary is the posterior interventricular vein or middle cardiac vein, running in the posterior interventricular groove. The second tributary of the coronary sinus is the posterior vein of the left ventricle. The next tributary is the left marginal vein. The great cardiac vein will then continue as anterior cardiac vein in the anterior interventricular groove. According to von Lüdinghausen, important inter-individual variations are observed regarding origin and the presence of these tributaries.

Obviously, pre-procedural knowledge of the cardiac venous anatomy of an individual patient could contribute significantly to the success of the implantation. Until recently, invasive venography was the only method to depict the cardiac veins in vivo. Two invasive techniques are available. Direct venography is based on direct manual injection of contrast into the guiding catheter. Most cardiologists prefer an alternative invasive technique: occlusive venography. An occlusion catheter is advanced through the guiding catheter, and a balloon is inflated with 1–1.5 ml air immediately beyond the distal tip of the guiding catheter. Occlusive venography causes more dissections, uses more contrast, has a longer procedure time but has more success to identify the anatomy. Similar to the post-mortem series, variations in cardiac venous anatomy have been reported with invasive venography. Owing to its invasive nature, venography is generally not used in advance but during the CRT implantation procedure itself. A prerequisite for a technique that provides information on venous anatomy during the selection process rather than during the CRT implantation should be its non-invasive nature. Some authors reported on the feasibility of electron beam computed tomography (EBCT) to depict the cardiac veins non-invasively. Meanwhile, EBCT has been replaced by new technology to assess obstructive coronary artery disease: multi-slice CT (MSCT). This promising non-invasive technique provides three-dimensional information on cardiac structure, including cardiac veins (Figure 1).
After an initial case report, several authors published preliminary data using 16-slice MSCT. Jongbloed et al. also using 16-slice technology, described a marked variability in venous anatomy, confirming previous post-mortem and invasive studies. In current clinical practice, 64-slice MSCT has become the standard to study cardiac structure, offering a higher spatial resolution with a decreased acquisition time. Recently, the feasibility of 64-slice MSCT to depict the cardiac venous system was retrospectively demonstrated in 100 subjects referred for non-invasive coronary angiography. One hypothesis of this particular study was that the absence of coronary sinus tributaries might be related to scar formation secondary to a previous myocardial infarction in the region drained by these specific veins. The study demonstrated that none of the patients with a previous lateral infarction had a left marginal vein, and patients with anterolateral myocardial infarctions and especially Q-wave infarctions were frequently lacking the left marginal vein. In a study using high-speed rotational venography, Blendea et al. also found a lower prevalence of the left marginal vein in patients with a history of a lateral myocardial infarction.

If suitable cardiac veins are absent, this might hamper transvenous LV lead positioning and a surgical approach should be preferred. If suitable veins are present, then it is also important to position the LV lead in the area of latest mechanical activation. In a preliminary study, 21 consecutive heart failure patients scheduled for CRT implantation were prospectively enrolled to undergo 64-slice CT to visualize the venous system, invasive venography during device implantation and tri-plane tissue synchronization imaging (TSI) before and after implantation. There was an excellent agreement between MSCT and invasive venography. In 12 patients, a match was observed between the area of latest activation (on TSI) and LV lead position. These patients showed a significant decrease in LV dyssynchrony with acute reduction in LV end-systolic volume and improvement in LV ejection fraction. Patients with a mismatch between the area of latest activation and LV lead position remained dyssynchronous without improvement in LV function. These findings underscore the important role of non-invasive imaging to determine LV lead implantation strategy. With three-dimensional echocardiographic technology, the precise area of latest mechanical activation can be derived, whereas MSCT depicts the cardiac venous system on a three-dimensional LV volume-set. Transvenous LV lead implantation is preferred if a suitable tributary of the coronary sinus matches the area of latest mechanical activation. In the absence of a suitable coronary sinus tributary in the area of latest mechanical activation, a surgical approach may be preferred.

Importance of non-invasive evaluation of scar tissue with magnetic resonance imaging in CRT candidates

Another important reason for non-response to CRT (in patients with ischaemic cardiomyopathy) may be the presence of scar tissue in the region where the LV pacing lead
is positioned. Pacing in non-viable or scarred myocardium may result in less effective or even ineffective pacing and as a result failure of LV resynchronization and no response to CRT. One imaging modality that permits non-invasive assessment of viability is nuclear perfusion imaging. De Winter et al. studied patients with an ischaemic cardiomyopathy and poor systolic function with single photon emission CT (SPECT). They found that non-viable tissue in the inferior or lateral wall was more frequently present in patients with a QRS ≥ 120 ms than in patients with a QRS < 120 ms (29 vs. 7%; P < 0.01). Ypenburg et al. evaluated the presence of scar tissue with gated SPECT using 99mTc-tetrofosmin before CRT implantation. Patients without scar tissue in the LV pacing target region significantly improved in functional class, quality of life, 6 min walk test, LV volumes and ejection fraction, whereas no improvement was observed in patients with scar tissue.

Another non-invasive imaging modality to evaluate myocardial scar is cardiac magnetic resonance imaging (MRI). Contrast-enhanced MRI allows precise determination of the spatial and transmural extent of scar tissue. Bleeker et al. studied 40 coronary artery disease patients with non-ischaemic patients than in ischaemic patients. This suggests that not only the location but also the size of infarcted myocardium—total scar burden—is important for response to CRT. Ypenburg et al. studied 34 patients with an ischaemic cardiomyopathy scheduled to undergo CRT. Contrast-enhanced MRI was used to determine total scar burden, using a 17-segment model with a 5-point hyperenhancement scale. There was a significant correlation between total scar burden at baseline and change in LV end-systolic volume after 6 months of CRT. Patients not responding to CRT had significantly more scar tissue than responders. A scar burden >1.20 resulted in complete functional non-response. Cardiac MRI could potentially provide information on both myocardial scar tissue and cardiac venous anatomy. In a recent publication, Nezafat et al. report on the technical aspects of imaging the cardiac veins with MRI. Further clinical validation is needed before integrating MRI cardiac venography into clinical practice.

Conclusion

Non-invasive imaging modalities can contribute significantly to the selection process of CRT candidates by providing answers to three crucial questions determining LV lead position. What is the area of latest mechanical activation? Does the target region for LV pacing contain viable myocardium? Is there a suitable tributary of the coronary sinus draining that area, allowing a transvenous approach? State-of-the-art non-invasive imaging modalities such as advanced echocardiography, MSCT, nuclear imaging, and cardiac MRI can provide this information.

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References


