A Novel Cardiac MRI Protocol To Guide Successful Cardiac Resynchronization Therapy Implantation

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Cardiac MRI (CMR) is recognized as an important imaging modality for assessing patients with heart failure. With improved segmentation and image registration tools, data acquired using CMR can help with planning and intra-procedural guidance as well as with defining etiology of heart failure and ventricular function. Here, we describe a successful CRT implantation where segmented CMR images were registered with the fluoroscopic images during the procedure to guide device implantation.

A 23-year-old man with a history of repair of hemianomalalous pulmonary venous drainage and biventricular noncompaction (Figure 1A and B) presented with a 3-month history of reduced exercise tolerance and peripheral edema. Despite optimal medical therapy, he remained in New York Heart Association class 3. His ECG showed sinus rhythm with a PR interval of 154 milliseconds (ms), QRS duration of 134 ms, and left bundle branch block (LBBB) morphology. Transthoracic echocardiography showed a dilated left ventricle with severe global impairment, an ejection fraction of 23%, and an end-systolic volume of 141 mL. The patient had significant intraventricular dyssynchrony, with 3D echo assessment giving a systolic dyssynchrony index (SDI) of 16.7%. A CMR examination was performed to assess cardiac function and etiology of his heart failure as well as to ensure that he had normal venous anatomy. The anterior wall was noted to be thinned and akinetic, and unexpectedly, there was subendocardial scar of 50% to 75% transmurality (Figure 1C). A coronary angiogram showed normal coronary arteries. Because the patient had previously had emboli to the kidneys with proven left ventricular (LV) thrombus and because the scar was limited to one coronary territory, the scar was believed to be due to an embolic ischemic event. Because he was on maximal heart failure medication and remaining in New York Heart Association class 3 with prolonged QRS duration, it was decided that he should undergo cardiac resynchronization therapy (CRT).

The whole-heart CMR 3D sequences enabled segmentation of the cardiac chambers and coronary veins (Figure 2). Using late-enhancement imaging, we were able to manually segment the area of scar. The areas of myocardial scar and the segmented LV volumes were coregistered, enabling us to show their interrelationships (Figure 3). Using image registration techniques, the segmented heart with coronary vein and scar delineation was overlaid onto the fluoroscopic image (Figure 4). The operator was able to use the overlay for placement of the left ventricular lead, avoiding areas of scar.

Figure 1. A, Four chamber steady-state free precision image showing noncompaction of the lateral wall. B, Mid-ventricular short-axis view of the LV, showing extensive trabeculation. The ratio of compacted-to-noncompacted myocardium is 5:5:1. C, Mid-ventricular short-axis late gadolinium-enhanced image showing subendocardial anterior scar of 50% to 75% transmurality.
The procedure was uncomplicated, and at 3 months the patient was symptomatically improved to New York Heart Association class 1. LV ejection fraction had improved to 29%, and end-systolic volume decreased to 110 mL with an SDI of 5.0% (Figure 5).

It is well-known that position of LV lead affects response to CRT. Empirical placement of the LV lead in a posterolateral vein is the standard best practice for CRT implantation, which has been shown to result in greater reverse remodeling and reduced dyssynchrony. Furthermore, a recent study showed that CRT is less effective in the presence of posterolateral scar. Currently, the rate of failure to implant an LV lead is between 5% and 12%. Using images acquired from CMR of the coronary venous anatomy and myocardial scar and integrating this during the procedure has the potential to reduce procedure time and radiation exposure as well as contrast dose. Overlaying areas of scar with the coronary veins may allow the operator to avoid placing of the LV lead within nonviable myocardium, thus maximizing response to CRT.

Figure 2. Segmentation of the MRI data using ITK-SNAP software to form a 3D segmentation of the heart with the coronary veins. AIV indicates anterior interventricular vein; CS, coronary sinus; GCV, great cardiac vein; LA, left atrium; LMV, left marginal vein; PIV, posterior interventricular vein; PVLV, posterior vein of the LV.

Disclosures
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References
Figure 3. A, CMR late-enhancement images with anterior scar. B, Manual segmentation of the anterior scar shown in red. C, Segmented scar superimposed on the segmented LV volume. D, E, and F, Three-dimensional segmentation of the LV with the scar and coronary veins in 3 different views showing the relationship of veins to the scar. AIV indicates anterior interventricular vein; CS, coronary sinus; GCV, great cardiac vein; LMV, left marginal vein; PIV, posterior interventricular vein; PVLV, posterior vein of the LV.
Figure 4. Segmented CMR images of the whole heart, coronary veins, and scar superimposed during the CRT implant onto the fluoroscopic image to guide positioning of the LV lead. The anatomic data of coronary veins and myocardial scar are registered in 3D in the various image planes with the movement of the C arm. A and B, How the overlaid coronary venous anatomy and scar relate to the occlusive venogram. C and D, The LV leads within an area of scar. This was not the final LV lead position but shows how the overlay can be used to depict the relationship of the LV lead to areas of scar. RV indicates right ventricle.

Figure 5. The regional volume plots before (A) and after CRT (B). A, Intraventricular dyssynchrony with poorly aligned regional volume curves. B, After CRT, the regional volume curves are much more aligned, indicating improved intraventricular synchrony. This is shown by the decrease in systolic dyssynchrony index from 16.7% to 5.0%.
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