New applications of cardiovascular magnetic resonance to guide cardiac resynchronization therapy

Joanna Petryka1, Artur Oręziak1, Andrzej Przybylski1, Jolanta Miśko1

1Department of Coronary Artery Disease and Structural Heart Diseases, Institute of Cardiology, Warsaw, Poland
2Magnetic Resonance Unit, Institute of Cardiology, Warsaw, Poland
3Department of Arrhythmia, Institute of Cardiology, Warsaw, Poland

Postep Kardiol Inter 2012; 8, 3 (29): 234–238
DOI: 10.5114/pwki.2012.30403

Key words: cardiovascular magnetic resonance, resynchronization therapy, delayed enhancement, right ventricle

Introduction

Cardiac resynchronization therapy (CRT) is a treatment of proven efficacy in patients with heart failure, impaired left ventricular ejection fraction and wide QRS complex. It has been demonstrated that CRT has a good effect on left ventricular remodelling, and improves outcome and quality of life. However, in 1/3 of patients this therapy brings no expected benefit. There are many variables that may influence the response to resynchronization described in the literature. Among others, the presence of mechanical dysynchrony of the left ventricle and the amount of myocardial fibrosis assessed with cardiovascular magnetic resonance (CMR) have been mentioned [1]. The assessment of left ventricular contraction dyssynchrony in CMR is based on post-processing multi-stage data, which makes this method difficult to use in clinical practice. In contrast, evaluation of delayed enhancement (DE), which corresponds with myocardial fibrosis, is a relatively simple and well-documented technique. The CMR study with fibrosis imaging guides the procedure of left ventricular lead placement to avoid the scar. Furthermore, the assessment of the scar enables one to evaluate the amount of viable left ventricular myocardium ready to undertake synchronised contractile activity after CRT implantation. Along with the dynamic development of magnetic resonance imaging technique and better understanding of its clinical usefulness, new applications of CMR in patients referred for CRT have been reported. Apart from previously mentioned methods of dyssynchrony and delayed enhancement assessment, the growing role of evaluation of right ventricular function and scar homogeneity has been shown.

Assessment of right ventricle

The interest of scientists in multi-centre randomized clinical trials on patients with CRT has been mainly focused on the assessment of left ventricular systolic function prior to device implantation and the evaluation of left ventricular remodelling as a result of the therapy. Therefore the guidelines of the European Society of Cardiology, which are based on the data from clinical trials, contain only the criterion of left ventricular ejection fraction. Whereas right ventricular dysfunction and its impact on the response to CRT are not fully documented.

The presence of systolic dysfunction of the right ventricle is a strong and independent predictor of death in patients with chronic heart failure [2, 3]. The results of studies on limited patient populations suggest an improvement in functional and volumetric parameters of the right ventricle after implantation of the CRT device [4, 5], while the improvement of systolic function of both ventricles leads to better patient outcome [6, 7]. There have been papers published in recent years documenting the impact of baseline assessment of right ventricular systolic function on the response to resynchronization therapy [8-10]. Significant impairment of right ventricular function may limit the beneficial remodelling of the left ventricle after therapy. However, the interdependence of left and right ventricular contractility and the reason for a different degree of improvement for each ventricle in patients after CRT remain not fully described.

Because of the anatomy and complex geometry, the role of echocardiographic and scintigraphic methods in evaluation of the right ventricle is limited. Cardiovascu-
Cardiovascular magnetic resonance on the other hand provides imaging of the right ventricle in a freely chosen view (Figure 1) and the assessment of its volumetric and functional parameters in a 3D model (Figure 2), which guarantees better precision and reproducibility of the results [11]. In a study published last year [12] it was demonstrated that right ventricular dysfunction assessed with cardiovascular magnetic resonance was associated with a lack of response to resynchronization therapy and with more frequent occurrence of cardiovascular events including deaths and hospital admissions. It should be noted that there was a wide range of the degree of right ventricular systolic function impairment in patients undergoing CRT, whereas the degree of left ventricular function impairment was relatively homogeneous as it was one of the criteria for the therapy. Therefore, right ventricular ejection fraction was an independent factor distinguishing this population. Lower ejection fraction of the right ventricle was associated with lower ejection fraction of the left ventricle, higher significance of mitral regurgitation and higher mean pulmonary artery pressure. The authors suggest that the right ventricular dysfunction arises in this population in two main mechanisms: either as a result of biventricular impairment of myocardial contractility or as a result of pulmonary hypertension secondary to elevated left ventricular filling pressure and mitral regurgitation. Among patients with the ejection fraction of the right ventricle below 30%, only 20% of subjects fulfilled the criteria of a response to resynchronization therapy.

The disadvantage of cardiovascular magnetic resonance is a lack of possibility to routinely perform serial assessment of the right ventricle in patients with previously implanted devices. However, the evaluation of the right ventricle should become a routine element of complex CMR.
Arrhythmia and delayed gadolinium enhancement

Most of the patients referred for CRT fulfil the criteria for cardioverter-defibrillator (ICD) implantation. Therefore, a significant percentage of implanted resynchronisation devices, around 70-80%, are also equipped with a defibrillator (CRT-D) [13]. However, the advantage of CRT-D over CRT-P (cardiac resynchronization therapy with pacemaker) with regards to the outcome of patients with an implanted resynchronization device is not well documented. It has been proven that implantation of a CRT-P device leads to the limitation of ventricular arrhythmia, reduces the risk of sudden cardiac death and improves the outcome [6]. Also the number of adequate cardioverter-defibrillator interventions is relatively low in this patient group [14]. Furthermore, CRT-D implantation is more expensive and associated with additional risk of complications, including
inadequate ICD interventions, than in the case of CRT-P. It is thus essential to develop algorithms identifying patients with a high risk of sudden cardiac death in whom the benefit from CRT-D would be maximized.

Cardiovascular magnetic resonance with the use of delayed gadolinium enhancement provides the evaluation of myocardial structure and identification of fibrotic tissue (Figure 3). It has been suggested that the assessment of scar extent and its heterogeneity in CMR enables the stratification of the risk of arrhythmia in patients after myocardial infarction [15]. So far the published studies indicate the key role of the zone of intermediate degree of fibrosis between the normal myocardium and the central part of the scar – the grey zone/border zone [15-18]. A greater amount of grey zone in the scar was associated with worse outcome and more frequent ventricular arrhythmia in patients with coronary artery disease. Recently, a study assessing the presence of scar with its components in CMR in patients referred for resynchronization therapy has been published [19]. It was found that the analysis of delayed enhancement can be applied to identify patients of low risk of ventricular arrhythmia. Those patients are characterised by a grey zone of smaller extent and lower percentage of scarred myocardium or totally viable myocardium in CMR. Furthermore, the presence of a homogeneous scar, that is a scar with a smaller grey zone, was associated with less frequent arrhythmia occurrence than the presence of a scar with a high percentage of myocardium of borderline degree of fibrosis. Interestingly, in the cited paper the extent of delayed gadolinium enhancement was a predictor of ventricular arrhythmia and adequate ICD intervention independently of the aetiology of heart failure. If those results are confirmed in further studies, in the future the analysis of the extent of delayed gadolinium enhancement and certain components of the scar in CMR could enable identification of patients at low risk of malignant ventricular arrhythmia, in whom ICD implantation together with a resynchronization device would not bring additional benefits.

Conclusions
The key to maximise the benefit from resynchronization therapy is adequate patient selection and optimal performance of the CRT implantation procedure. Cardiovascular magnetic resonance may turn out to be a useful tool to guide optimal left ventricular lead placement, to identify high-risk patients due to right ventricular systolic dysfunction, and to support the clinical decision between CRT-D and CRT-P devices.

References
3. Ghio S, Gavazzi A, Campana C, et al. Independent and additive prognostic value of right ventricular systolic function and


