Assessing myocardial circumferential strain using cardiovascular magnetic resonance after magnetic resonance-conditional cardiac resynchronization therapy

Arai, Hideo
Fukuokaken Saiseikai Futsukaichi Hospital

Kawakubo, Masateru
Department of Health Sciences, Faculty of Medical Sciences, Kyushu University

Sanui, Kenichi
Fukuokaken Saiseikai Futsukaichi Hospital

Nishimura, Hiroshi
Fukuokaken Saiseikai Futsukaichi Hospital

他

https://hdl.handle.net/2324/4110732

出版情報：Radiology Case Reports. 15 (10), pp.1954-1959, 2020-08-19. Elsevier
バージョン：

Radiology Case Reports 15 (2020) 1954–1959

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/radcr

Case Report

Assessing myocardial circumferential strain using cardiovascular magnetic resonance after magnetic resonance-conditional cardiac resynchronization therapy☆,☆☆,★

Hideo Arai, RT[a], *Masateru Kawakubo, PhD*[b,*], *Kenichi Sanui, RT*[a], *Hiroshi Nishimura, MD, PhD*[a], *Toshiaki Kadokami, MD, PhD*[a]

[a] *Fukuokaken Saiseikai Futsukaichi Hospital, Chikushino, Japan*
[b] *Department of Health Sciences, Faculty of Medical Sciences, Kyushu University, 3-1-1 Maidashi Higashi-ku Fukuoka 812-8582 Japan*

ARTICLE INFO

Article history:
Received 8 June 2020
Revised 22 July 2020
Accepted 24 July 2020

Keywords:
Arrhythmia
Diagnostic
Magnetic resonance-conditional device
Strain imaging
Cardiac resynchronization therapy
Dyssynchrony

ABSTRACT

Nondrug therapy for arrhythmia patients had been developed dramatically until recent years. Cardiac resynchronization therapy (CRT), a nondrug therapy for arrhythmia, is especially utilized for the treatment of left ventricular (LV) severe heart failure caused by cardiac dyssynchrony. Prolonged QRS duration (≧130 ms) is strongly used as a CRT indication criterion, but QRS is not the direct clinical index of mechanical contraction delay of the LV myocardium. Therefore, identifying the presence of dyssynchrony by diagnostic imaging is necessary. Echocardiography is widely used for the assessment of dyssynchrony as a standard diagnostic imaging. Several studies have addressed the efficacy of cardiovascular magnetic resonance feature tracking (CMR-FT) in the diagnosis of dyssynchrony for arrythmia patients. In addition, cardiac implantable electronic devices (CIEDs) were not available to examine CMR until recent years; however, new MR-conditional CIEDs have become available for use before and after CRT. Recently, diagnostic imaging using CMR-FT has been attracting attention for the assessment of dyssynchrony. However, a strong metal artifact caused by CIEDs may make the analysis difficult after CRT implantation. Strain analysis using short-axis (SA) cine CMR overcame this issue of artifact by enabling slice selection by avoiding artifact. Moreover, circumferential strain has superiority over other strain methods with respect to sensitivity, and we focused on these advantages. This case illustrates that

☆ Funding: This work was supported by JSPS KAKENHI Grant Number JP20K16729. This research did not receive any specific grant from funding agencies in the commercial or not-for-profit sectors.
☆☆ Competing Interests: The authors have no conflict of interest to disclose.
★ Our institutional review board approved the study, and we obtained written informed consent from the patient.
* *Corresponding author.*
E-mail address: k-mstr@hs.med.kyushu-u.ac.jp (M. Kawakubo).
https://doi.org/10.1016/j.radcr.2020.07.063
1930-0433/

circumferential strain with CMR-FT using SA cine CMR is useful in the assessment of improvement of myocardial motion after CRT and can provide useful additional information with imaging to determine the responders of CRT.

Introduction

Nondrug therapy for arrhythmia patients had been developed dramatically until recent years [1,2]. Cardiac resynchronization therapy (CRT), one of the nondrug therapies for arrhythmia, is especially utilized for the treatment of left ventricular (LV) severe heart failure caused by cardiac dyssynchrony [3]. Although prolonged QRS duration (≧130 ms) is strongly used as a CRT indication criterion, QRS is not the direct clinical index of mechanical contraction delay of the LV myocardium [4,5]. Therefore, cardiovascular magnetic resonance-feature tracking (CMR-FT) has been proposed as a novel tool for predicting response to CRT [6]. CMR-FT would be clinically useful for the evaluation of the treatment effect of CRT or determination of treatment strategy in a long-term follow-up. However, assessment with CMR-FT after CRT has not been performed because magnetic resonance (MR)-conditional CRT devices were not available. Traditional cardiac implantable electronic devices (CIEDs) could cause electrical or thermal induction in implanted leads or an unpredictable intermittent effect on the activity of the reed switch during magnetic resonance imaging (MRI). In recent years, MR-conditional CIEDs have become available [7]. However, patients with CIEDs have contraindication to MRI within 6 weeks after implantation because MR-conditional CIEDs could be attracted by the static magnetic field of MRI. Therefore, appropriate use of MR-conditional CIEDs should be established so that patients with CIEDs can undergo MRI safely. The assessment of cardiac dyssynchrony using cine CMR involves the use of 4-chamber (4CH) longitudinal strain, similar to echocardiography before CRT. However, CMR images of 4CH orientation are not appropriate for the assessment after CRT due to strong artifacts caused by MR-conditional devices [8,9]. In contrast, short-axis (SA) cine CMR has an advantage, in that it enables the selection of the slice for analysis from the whole LV data, thereby avoiding artifact (Fig. 1). Moreover, it has been previously reported that circumferential strain (CS) is superior to longitudinal strain in sensitivity of dyssynchrony [10]. Focusing on these advantages, we report a case in which SA cine CMR was used for the detection of dyssynchrony, which is difficult to detect using echocardiography.

Case report

A 79-year-old man developed his first heart failure 7 years ago and underwent a detailed examination in our hospital. He was clinically diagnosed with dilated cardiomyopathy, along with the absence of coronary artery disease, LV dilatation, and impaired contractility. He had never developed signs and symptoms of heart failure. Recently, he complained of fatigue and edema in both feet after a job that involved standing and underwent a detailed examination in our hospital again. Based on the results of this examination, the patient was clinically diagnosed with indication for CRT defibrillator (CRT-D) from wide QRS with complete left bundle branch block (CLBBB), recurrence of heart failure, nonischemic cardiomyopathy, low cardiac function, positive late gadolinium enhancement (LGE), and presence of dyssynchrony with cine CMR. However, traditional assessment of dyssynchrony using M-mode echocardiography showed no significant values (septal-to-posterior wall motion delay [SPWMD]: 92 ms; interventricular-delay: 11 ms; intraventricular-delay: 50 ms) (Fig. 2A). A previous report showed that normal ranges of CMR functional analysis findings were as follows: left ventricular ejection fraction (LVEF), 60 ± 5%; LV volume with end-diastole, 128 ± 28 mL; LV volume with end-systole, 51 ± 14 mL; and LV wall mass, 76 ± 22 g [11]. Our CMR findings were as follows: reduced LVEF (26%) and enlarged LV volume with end-diastole and end-systole of 210 mL and 155 mL, respectively; LV wall mass was 155 g, and in addition, LGE detected myocardial fibrosis at the junction of the ventricular septum (Fig. 2 upper panels in B). As for dyssynchrony, strain imaging with CMR could detect a remarkable contractile delay of the intraventricular septum (IVS): 257 ms (Fig. 3). Subsequently, an MR-conditional CRT-D implantation was implanted in the patient. Echocardiography and CRT-D findings 1 month after CRT-D implantation were as follows: LVEF, 42%; enlarged LV volume with end-diastole, 145 mL; enlarged LV volume with end-systole, 84 mL; atrioventricular delay, 130 ms; and LV only pacing, 47%.

The patient with CRT-D device implanted was scanned using a whole-body 1.5T MRI scanner (Ingenia, Philips Healthcare, Best, the Netherlands) according to a recommended guideline and appending paper [12]. The interrogation and programing before and after MRI by a cardiologist, monitoring of the patient using MRI by a nurse, and MRI parameter setting as per the guidelines by a radiological technologist were appropriately performed (specific absorption rate (SAR) <2.0 W/kg, maximum gradient slew rate <200 T/m/s). Cine CMR based on steady-state free precession with electrocardiogram gating was used to localize SA orientation of the heart. The cine CMR series consisted of 12 slices spanning the cardiac apex through the ventricular base with temporal resolution approximately 50 msec. Slices were acquired 4 times during approximately 15 seconds of breath-holding. The cine CMR parameters were as follows: field of view = 350 × 350 mm, TE = 1.89 ms, TR = 3.8 ms, flip angle = 50, receiver bandwidth = 1356 Hz/pixel, matrix size = 1.82 × 1.99 mm, slice thickness = 8 mm, and number of phases = 20. LGE parame-

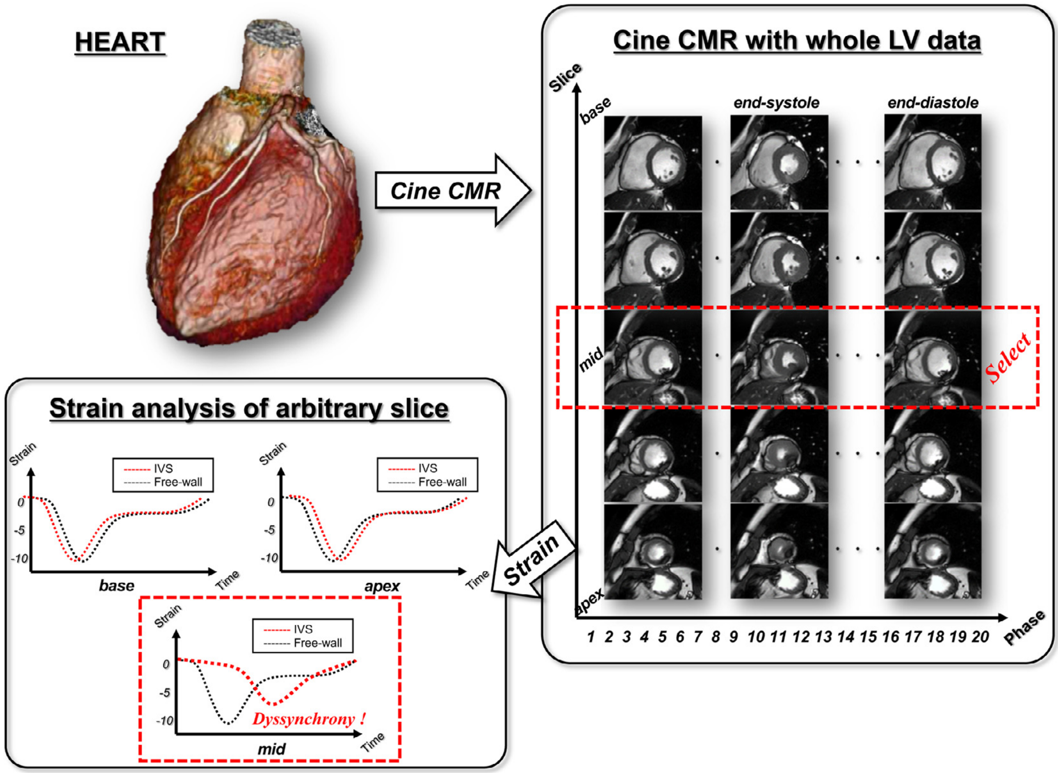

Fig. 1 – Because short-axis cine cardiac magnetic resonance (CMR) includes whole left ventricular data, CMR allows the selection of arbitrary slice for circumferential strain analysis with feature-tracking, avoiding strong artifact from magnetic resonance-conditional devices.

ters were as follows: field of view = 350 × 350 mm, TE = 2.7 ms, TR = 5.5 ms, flip angle = 15, receiver bandwidth = 410 Hz/pixel, matrix size = 1.56 × 1.74 mm, and slice thickness = 10 mm. LV strain was analyzed using an in-house-developed off-line feature-tracking application that had been validated in a previous clinical study [13].

Follow-up CMR examination at 1 year after CRT-D implantation showed improved dyssynchrony, improved systolic strain, reduced LV volume, and a similar extent of fibrosis as before CRT (Fig. 2B and Fig. 3). In particular, dyssynchrony analysis using CMR strain imaging revealed drastic improvement from 257 ms to 38 ms in cardiac synchrony the contractile delay of the IVS (Fig. 3). In addition, CS of the IVS improved from −6.4% to −11.4%.

Discussion

In the present report, we assessed the improvement of LV dyssynchrony by comparing CMR strain parameters before and after the implantation of MR-conditional CRT device. Improvements in the systolic myocardial strain and contraction delay are observed in the IVS. This assessment ability of regional myocardial motion is a great advantage of CMR-FT with respect to global indicators such as LV volume and LVEF. In the reported case, the wall motion showed no typical CLBBB pattern with pre-ejection septal shortening but showed atypical CLBBB pattern followed by rebound and late systolic stretches [14]. Moreover, the presence of LGE in the basal inferoseptal is matched with the region of this motion abnormality. The atypical wall motion could be attributed to the linear LGE at the right ventricular insertion point. CMR-FT could assess the improvement of CS and contraction delay in IVS even in such an atypical CLBBB case, similar to findings of a previous report about CS before CRT [10]. This result indicates that CMR-FT is expected to be a useful tool to assess detailed myocardial motion before and after CRT.

Currently, echocardiography is widely used for the assessment of dyssynchrony as a standard diagnostic imaging. Although echocardiography showed wide QRS (>150 ms) in the reported case, echocardiography with SPWMD was indicated to be normal. In contrast, CS-derived CMR-FT showed degraded septal motion and contraction delay before CRT and improvements after CRT. Thus, CMR could provide information that strongly supported the acquisition of responders. These results can be attributed to the fact that the analysis was demonstrated using both CMR imaging, including whole LV wall motion data, and CS with a high sensitivity [10].

In clinical practice, even if CRT is performed as per the guidelines, approximately 30%-40% of patients are nonresponders to CRT, which remains a challenging issue [15]. Recently, it was reported that CRT aids in the treatment of pa-

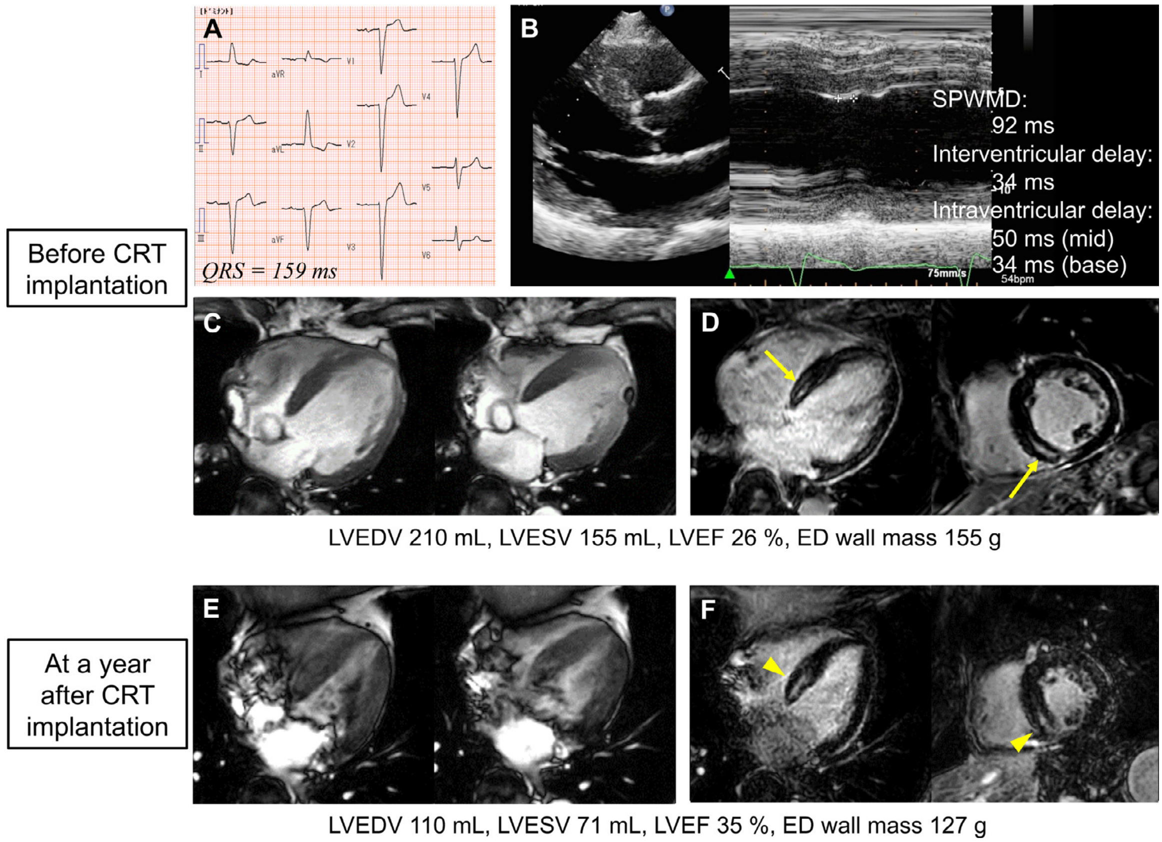

Fig. 2 – Physiological findings before cardiac resynchronization therapy (CRT) are shown in (A) electrocardiogram with wide QRS duration, (B) echocardiogram with normal septal wall motion delay, (C) 4-chamber cine cardiac magnetic resonance (CMR) (left: end-systole, right: end-diastole), and (D) the presence of late gadolinium enhancement (LGE) in the basal inferoseptal (yellow arrows) (left: 4-chamber, right: short-axis). Significant CMR findings at 1 year after CRT are shown in (E) reduced ventricular volumes and myocardial mass, and (F) remaining of LGE shown as yellow arrow heads.

tients with both wide and narrow QRS. Appropriate indications for the presence and improvement of dyssynchrony are necessary to be shown by clinical imaging because the QRS width does not always indicate mechanical contraction delay [16]. MR-conditional CIEDs for CMR have been available, allowing for detailed wall motion analysis using CMR before and after CRT implantation. As CMR has excellent advantages of high reproducibility and wide field of view, CMR strain analysis may be expected to provide significant evidence to add to the indicators of QRS, which is the strongest indication for CRT implantation in the guidelines [4]. Hereafter, we will assume that nondrug therapy for arrythmia patients has been more widely used and indication patients for CRT will be increasing. If the assessment of dyssynchrony using CMR before and after CRT becomes easy and is considered a standard imaging assessment for dyssynchrony, many patients before and after CRT will receive appropriate treatment due to detailed CMR assessment. In the near future, it may lead to reduce the number of nonresponders of CRT.

We acknowledge that there are some limitations in this case report. The first one is a lack of strain data of echocardiography. Speckle tracking strain echocardiography provides evidence, although its use in clinical practice is limited. M-mode, blood Doppler, and tissue Doppler are widely use in clinical practice, and we utilized M-mode SPWMD in this study. Another method that can be used is 4CH cine CMR, which could not be utilized for longitudinal strain analysis due to the artifact from CRT-D. However, it is expected that longitudinal strain analysis can be performed using an imaging technique for reducing metal artifacts, such as T1-weighted image, or by the optimization of MR-imaging parameters. Therefore, the applicability of strain analysis after CRT can be expected to improve.

In summary, CS analysis with CMR-FT is useful for the assessment of improvement of myocardial motion after CRT and can provide useful additional information with imaging to determine the responders of CRT.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number JP20K16729. We would like to thank Editage (www.editage.com) for English language editing.

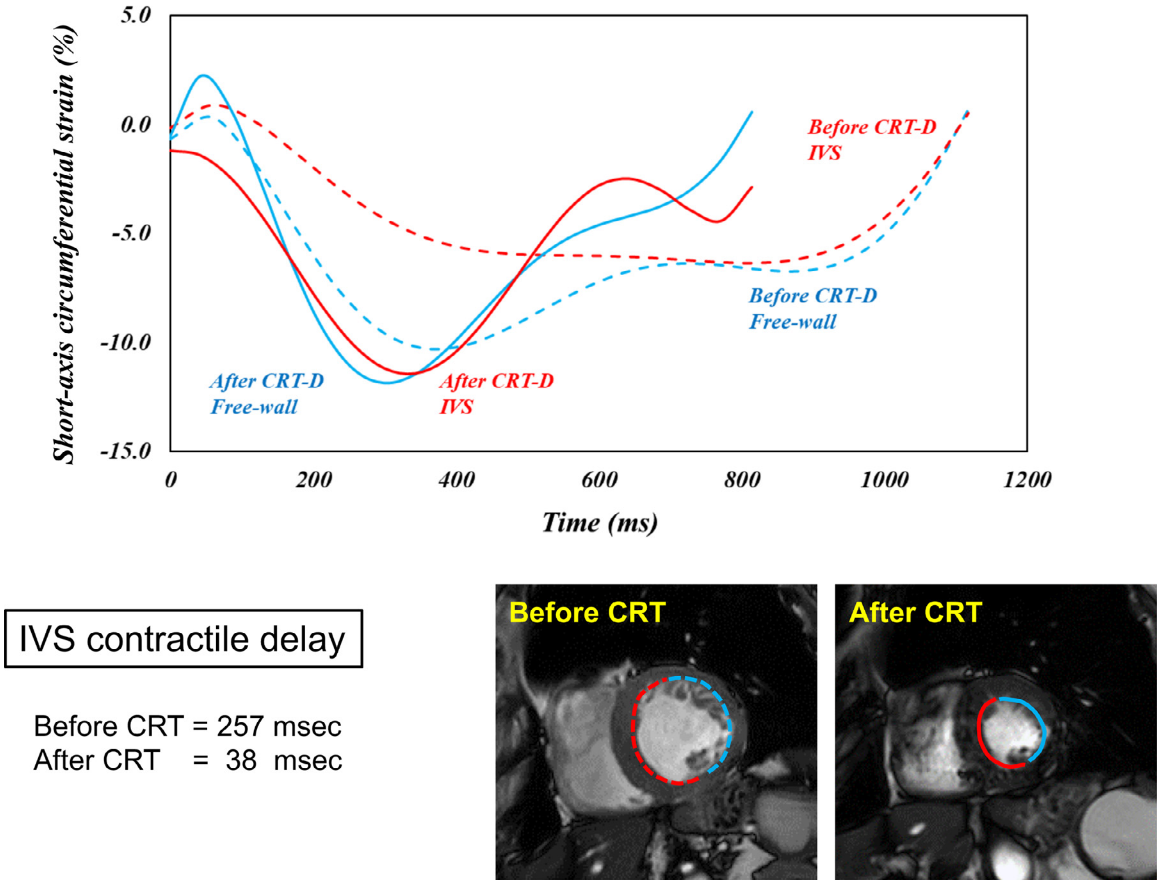

Fig. 3 – Circumferential strain-derived cardiac magnetic resonance-feature-tracking (CMR-FT) before and after CRT is shown (free-wall: dashed and solid blue lines, interventricular septum: dashed and solid red lines). Strain parameters significantly improved: contractile delay of the interventricular septum improved from 257 ms to 38 ms and systolic circumferential strain improved from −6.4% to −11.4%.

REFERENCES

[1] Jaïs P, Cauchemez B, Macle L, Daoud E, Khairy P, Subbiah R, et al. Catheter ablation versus antiarrhythmic drugs for atrial fibrillation: the A4 study. Circulation 2008;118:2498–505. https://doi.org/10.1161/CIRCULATIONAHA.108.772582.

[2] Kuck KH, Brugada J, Fürnkranz A, Metzner A, Ouyang F, Chun KRJ, et al. Cryoballoon or radiofrequency ablation for paroxysmal atrial fibrillation. N Engl J Med 2016;374:2235–45. https://doi.org/10.1056/NEJMoa1602014.

[3] Bristow MR, Saxon LA, Boehmer J, Krueger S, Kass DA, De Marco T, et al. Cardiac-resynchronization therapy with or without an implantable defibrillator in advanced chronic heart failure. N Engl J Med 2004;350:2140–50. https://doi.org/10.1056/NEJMoa032423.

[4] Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JGF, Coats AJS, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. Eur Heart J 2016;37:2129–200. https://doi.org/10.1093/eurheartj/ehw128.

[5] Auricchio A, Fantoni C, Regoli F, Carbucicchio C, Goette A, Geller C, et al. Characterization of left ventricular activation in patients with heart failure and left bundle-branch block. Circulation 2004;109:1133–9. https://doi.org/10.1161/01.CIR.0000118502.91105.F6.

[6] Kawakubo M, Nagao M, Kumazawa S, Chishaki AS, Mukai Y, Nakamura Y, et al. Evaluation of cardiac dyssynchrony with longitudinal strain analysis in 4-chamber cine MR imaging. Eur J Radiol 2013;82:2212–16. https://doi.org/10.1016/j.ejrad.2013.06.014.

[7] Poh PG, Liew C, Yeo C, Chong LR, Tan A, Poh A. Cardiovascular implantable electronic devices: a review of the dangers and difficulties in MR scanning and attempts to improve safety. Insights Imaging 2017;8:405–18. https://doi.org/10.1007/s13244-017-0556-3.

[8] Amil MS, Brian C, Nancy KS, Sanjiv JS, Inder SA, Li L, et al. Prognostic importance of impaired systolic function in heart failure with preserved ejection fraction and the impact of spironolactone. Circulation 2015;132:402–14. https://doi.org/10.1161/CIRCULATIONAHA.115.015884.

[9] Romano S, Judd RM, Kim RJ, Kim HW, Klem I, Heitner JF, et al. Feature-tracking global longitudinal strain predicts death in a multicenter population of patients with ischemic and nonischemic dilated cardiomyopathy incremental to ejection fraction and late gadolinium enhancement. JACC Cardiovasc Imaging 2018;11:1419–29. https://doi.org/10.1016/j.jcmg.2017.10.024.

[10] Kass DA, Ozturk C, Leclercq C, McVeigh E, Lardo AC, Faris OP, et al. Cardiac dyssynchrony analysis using circumferential versus longitudinal strain: implications for assessing cardiac

resynchronization. Circulation 2005;111:2760–7. https://doi.org/10.1161/circulationaha.104.508457.
[11] Le TT, Tan RS, De Deyn M, Goh EPC, Han Y, Leong BR, et al. Cardiovascular magnetic resonance reference ranges for the heart and aorta in Chinese at 3T. J Cardiovasc Magn Reson 2016;18:1–13. https://doi.org/10.1186/s12968-016-0236-3.
[12] Nazarian S, Hansford R, Roguin A, Goldsher D, Zviman MM, Lardo AC, et al. A prospective evaluation of a protocol for magnetic resonance imaging of patients with implanted cardiac devices. Ann Intern Med 2011;155:415–24. https://doi.org/10.7326/0003-4819-155-7-201110040-00004.
[13] Masateru K, Michinobu N, Umiko I, Yumi S, Kei I, Yuzo Y. Feature-tracking MRI fractal analysis of right ventricular remodeling in adults with congenitally corrected transposition of the great arteries. Radiol Cardiothorac Imaging 2019;1:19–26.
[14] Smiseth OA, Aalen JM. Mechanism of harm from left bundle branch block. Trends Cardiovasc Med 2019;29:335–42. https://doi.org/10.1016/j.tcm.2018.10.012.
[15] Ishii S, Inomata T, Fujita T, Iida Y, Ikeda Y, Nabeta T, et al. Clinical significance of endomyocardial biopsy in conjunction with cardiac magnetic resonance imaging to predict left ventricular reverse remodeling in idiopathic dilated cardiomyopathy. Heart Vessels 2016;31:1960–8. https://doi.org/10.1007/s00380-016-0815-0.
[16] Fukuoka S, Dohi K, Ichikawa Y, Tanigawa T, Sakuma H, Ito M. Narrowing of the QRS complex, elimination of late gadolinium enhancement and remarkable reverse remodeling achieved by optimal medical treatment in non-ischemic dilated cardiomyopathy. J Cardiol Cases 2018;17:59–62. https://doi.org/10.1016/j.jccase.2017.09.009.