1. Introduction

Intracardiac echocardiography (ICE) is being used increasingly to guide ventricular tachycardia (VT) ablation. We assessed whether signal intensity values and their distribution on ICE images can be used to characterize the scar substrate in the left ventricle (LV) in cases of substrate-based VT.

2. Materials and methods

2.1 Study patients

Included in the study were 12 patients (10 men and 2 women ranging in age from 49 to 81 years) undergoing ablation for recurrent drug-refractory VT (Table 1). All provided informed consent for the mapping and ablation procedures. The study protocol was approved by the Institutional Review Board of Nihon University Hospital (May 25, 2016; RK-160614-10).

2.2 ICE and electroanatomic mapping

ICE was performed with a Vivid q cardiac ultrasound system (GE Healthcare, Little Chalfont, England) and 9-Fr Sound Star 3D ICE catheter (Biosense Webster, Diamond Bar, CA, USA). All ICE parameters were obtained in identical fashion between patients. System settings were identical between patients (frequency = 7.5 MHz, time gain compensation = 7 dB, unchanged depth gain compensation dial position).

Two-dimensional (2D) ultrasound images were obtained for 3D reconstruction of the LV, which was performed with the CartoSound image integration module (Biosense-Webster). Voltage mapping was performed before ablation by means of a Navistar Thermo-Cool open irrigated-tip catheter (Biosense-Webster) positioned in the LV. Standard endocardial voltage criteria were used to identify tissue as scar (bipolar voltage < 0.5 mV), low voltage zone (0.5–1.5 mV), or normal myocardium (> 1.5 mV).

2.3 Analysis of ICE images

From each 3D reconstruction image, 2D slice images that included a low-voltage zone (< 1.5 mV) were selected for further analysis. For the 8 patients for whom CE-CMR images were obtained, 2D slice images that included zones of positive contrast enhancement were selected, retrospectively. The signal intensity of each area of interest on the ICE images, low-voltage zones on the electroanatomic maps, and late gadolinium-enhancement areas on the CE-CMR images corresponded. Thus, ICE may be useful for identifying LV scar substrate.

Key words: left ventricular scar, intracardiac echo, CE-CMR, left ventricular voltage map
signal intensities of all pixels in the area) and the standard deviation. Simultaneous analysis of still ICE images and endocardial voltage in the LV in each of the 12 patients and of late gadolinium-enhanced (LGE) areas in the 8 patients who underwent CE-CMR imaging was performed.

2.4 Contrast-enhanced cardiac magnetic resonance (CE-CMR) imaging

CE-CMR images were obtained with a 1.5-T scanner, as previously described, in 8 of the 12 patients.

2.5 Data collection and analysis

In addition to the study variables described above, left ventricular ejection fraction and the type of cardiomyopathy (CM) observed in each study patient were recorded. Differences in SIUs between low-voltage and normal-voltage segments and between LGE-negative and LGE-positive segments were analyzed by means of Mann-Whitney U test, with \( p < 0.05 \) considered significant.

3. Results

3.1 Patients’ echocardiographic characteristics

Mean left ventricular ejection fraction in the total patient group was 41.4 ± 9.5%, and the CMs were either nonischemic (dilated CM: \( n = 2 \), hypertrophic CM: \( n = 1 \), cardiac sarcoidosis: \( n = 2 \)) or ischemic (\( n = 7 \)).

3.2 SIUs of areas of interest on 2D ICE images

A total of 23 electroanatomic voltage mapping-derived areas of interest singled out on 2D ICE images were analyzed (Figs. 1, 2). Quantified, the scar tissue (\( n = 13 \)) and healthy myocardium (\( n = 10 \)) were 89.9 ± 15.3 SIUs and 56.9 ± 18.0 SIUs, respectively (\( p = 0.001 \)).

3.3 SIUs of late gadolinium-enhanced areas of interest on 2D-ICE images

A total of 15 MR contrast enhancement-derived areas of interest singled out on 2D ICE images were analyzed (Figs. 1, 2). Quantified, the LGE-positive (\( n = 8 \)) and LGE-negative segments (\( n = 7 \)) were 89.6 ± 6.6 SIUs and 65.3 ± 25.6 SIUs, respectively (\( p = 0.0159 \)).

4. Discussion

4.1 Major finding

Our most important study finding was that abnormal myocardium in the LV detected by electroanatomic mapping and CE-CMR imaging can also be detected by calculating signal intensity on ICE images.

4.2 Assessment of VT substrate

It is possible that anatomical structures located near the ultrasound probe increased the signal intensities. Nevertheless, results of our study suggest that ICE has potential to assist in substrate identification for VT ablation. Abnormal myocardium identified on endocardial voltage maps and CE-CMR images was found to have increased echogenicity compared to normal myocardium in patients with either ischemic or nonischemic CM. In a previous study that involved patients with nonischemic CM, increased echogenicity was seen in the anatomical VT substrate\(^3\). The echogenicity was assessed qualitatively, however. Hussein et al. compared low-voltage zones on electroanatomic maps and ICE-derived signal intensities and showed that it was possible to identify the anatomical substrate of VT electroanatomically\(^4\). However, they did not analyze LGE-positive and -negative segments in relation to ICE-derived signal intensities. LV electroanatomic voltage map is derived from endocardial electrogram. Therefore, LV electroanatomic voltage map does not always reflect mid-myocardial or epicardial scar. CR-MRI is useful to identify scar irrespective of the location, how-

| Patient # | Age (y/o) | Sex | Diagnosis            | LVEF (%) | Location of LV hypo/akinesis | VT type       |
|-----------|-----------|-----|----------------------|----------|-----------------------------|---------------|
| 1         | 70        | M   | DCM                  | 35       | diffuse                     | pleomorphic   |
| 2         | 79        | M   | Cardiac sarcoidosis  | 40       | diffuse                     | pleomorphic   |
| 3         | 49        | M   | OMI                  | 45       | apex, inferior, posterior   | RBBB, superior axis |
| 4         | 70        | M   | OMI                  | 42       | diffuse                     | RBBB, superior axis |
| 5         | 60        | F   | Cardiac sarcoidosis  | 45       | anterior, anteroseptum      | RBBB, inferior axis |
| 6         | 77        | M   | OMI                  | 38       | inferior, posterior, postero-septum | RBBB, inferior axis |
| 7         | 75        | M   | HCM                  | 46       | anterior, anteroseptum      | pleomorphic   |
| 8         | 76        | M   | OMI                  | 42       | inferior, posterior, lateral| RBBB, inferior axis |
| 9         | 81        | M   | OMI                  | 32       | apex, inferior, posterior   | RBBB, inferior axis |
| 10        | 68        | M   | DCM                  | 32       | diffuse                     | RBBB, inferior axis |
| 11        | 66        | M   | OMI                  | 64       | inferolateral                | RBBB, inferior axis |
| 12        | 73        | M   | OMI                  | 29       | inferoposterior             | RBBB, inferior axis |

M: male, F: female, DCM: dilated cardiomyopathy, OMI: old myocardial infarction, LVEF: left ventricular ejection fraction, VT: ventricular tachycardia, RBBB: right bundle branch block
Fig. 1  Electroanatomic voltage map (left panel), contrast-enhanced cardiac magnetic resonance (CE-CMR) image (upper right), and intracardiac echocardiogram (ICE) (lower right) of the left ventricle obtained from a patient with ventricular tachycardia associated with a healed antero-septal myocardial infarction. Comparison of the 3 images shows that the signal intensity units (SIUs) on the ICE image correspond to the scar substrate depicted as a low-voltage zone (red, with a yellow border zone) on the electroanatomic map and as late gadolinium enhancement on the CMR image.

Fig. 2  Intracardiac echocardiogram (ICE) showing signal intensity units (SIUs) (upper left), contrast-enhanced cardiac magnetic resonance (CE-CMR) image (lower left), and electroanatomic voltage maps (upper and lower right) of the left ventricle obtained from a patient with ventricular tachycardia associated with a healed inferior myocardial infarction. Comparison of these images shows that the area of late gadolinium enhancement on the CMR image corresponds to the SIU-defined scar zone on the ICE image and areas of low voltage on the electroanatomic maps.
ever, CE-MRI is contraindicated in patients with renal failure, and in patients with pacemaker and ICD. Recently, MRI compatible cardiac devices became available, but large noise due to the presence of atrial and/or ventricular leads makes MRI images difficult to interpret. Our study is the first to assess ICE-derived signal intensities in relation to voltage maps and LGE images. However, development of the online display of the quantification of scar by ICE is necessary to guide VT ablation.

5. Conclusion

Results of our study suggest that ICE can be used to identify the scar substrate in cases of substrate-based VT.

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References

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