Insights into the location of type I ECG in patients with Brugada syndrome: Correlation of ECG and cardiovascular magnetic resonance imaging

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BACKGROUND Brugada syndrome is characterized by ST-segment abnormalities in V1–V3. Electrocardiogram (ECG) leads placed in the 3rd and 2nd intercostal spaces (ICSs) increased the sensitivity for the detection of a type I ECG pattern. The anatomic explanation for this finding is pending.

OBJECTIVE The purpose of the study was to correlate the location of the Brugada type I ECG with the anatomic location of the right ventricular outflow tract (RVOT).

METHODS Twenty patients with positive ajmaline challenge and 10 patients with spontaneous Brugada type I ECG performed by using 12 right precordial leads underwent cardiovascular magnetic resonance imaging (CMRI). The craniocaudal and lateral extent of the RVOT and maximal RVOT area were determined. Type I ECG pattern and maximal ST-segment elevation were correlated to extent and maximal RVOT area, respectively.

RESULTS In all patients, Brugada type I pattern was found in the 3rd ICS in sternal and left-parasternal positions. RVOT extent determined by using CMRI included the 3rd ICS in all patients. Maximal RVOT area was found in 3 patients in the 2nd ICS, in 5 patients in the 4th ICS, and in 22 patients in the 3rd ICS. CMRI predicted type I pattern with a sensitivity of 97.2%, specificity of 91.7%, positive predictive value of 88.6%, and negative predictive value of 98.0%. Maximal RVOT area coincided with maximal ST-segment elevation in 29 of 30 patients.

CONCLUSION RVOT localization determined by using CMRI correlates highly with the type I Brugada pattern. Lead positioning according to RVOT location improves the diagnosis of Brugada syndrome.

KEYWORDS Brugada syndrome; Right ventricular outflow tract; ECG; Diagnosis; Cardiovascular magnetic resonance imaging

ABBREVIATIONS **BSPM** = body surface potential map; **CMRI** = cardiovascular magnetic resonance imaging; **ECG** = electrocardiogram; **HASTE** = half-Fourier acquired single-shot turbo spin echo; **ICS** = intercostal space; **LV** = left ventricle; **RV** = right ventricle; **RVOT** = right ventricular outflow tract

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Introduction

The Brugada syndrome is electrocardiographically characterized by specific ST-segment elevation in the right precordial leads V1–V3.[1,2] The Brugada type I electrocardiogram (ECG) pattern can be concealed or may fluctuate between diagnostic and nondiagnostic patterns.[3] Sodium-channel blocker challenge is used to unmask the diagnostic ECG pattern of Brugada syndrome.[4,5] Several experimental and clinical studies using invasive and noninvasive electrophysiological modalities have shown that the right ventricular outflow tract (RVOT) is crucial in the arrhythmogenesis of Brugada syndrome.[6–13]

The body surface potential map (BSPM) has been used as a diagnostic tool at baseline condition and after sodium-channel blockage in patients with suspicion of Brugada syndrome.[14] It increases the sensitivity of detecting the diagnostic ECG pattern of Brugada syndrome. The BSPM covers the whole right ventricle (RV) and not only parts of it with the use of 2 leads in the 4th intercostal space (ICS) in left-parasternal and right-parasternal positions as it is commonly done during standard 12-lead ECG recording. Based on these findings, single modified ECG leads in the right precordium have been introduced to detect the diagnostic type I ECG pattern.[15,16] The yield of both baseline ECG and ECG after sodium-channel blocker challenge increased if the leads V1 and V2 are additionally recorded from the 3rd and 2nd ICSs. This indicates that the location of the RVOT in the chest is variable. However, the specificity of leads in higher ICS is discussed controversially.

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Furthermore, a type I ECG detected in higher ICS is not an established diagnostic criterion according to the consensus statement.[2]

Cardiac magnetic resonance imaging (CMRI) is an accurate and reproducible tool for the evaluation of left ventricular and right ventricular function, volumes, and myocardial pathologies. Especially imaging of the RV and the RVOT is a domain of CMRI.[17] CMRI is able to visualize detailed anatomic structures of the heart and allows putting them in relation to the body surface.

The aim of the present study was to explain the observation of a higher sensitivity of modified ECG leads in patients with Brugada syndrome. First, we used a simplified approach of a right precordial BSPM to cover crucial parts of the RVOT. Second, we determined the location of the RVOT in the chest by using CMRI and evaluated the correlation of the right precordial extent of diagnostic type I ECG with the anatomic extent of the RVOT.

Methods

Study population

A total of 20 consecutive patients (mean age 42 ± 9 years; 13 males) with positive ajmaline challenges and 10 consecutive patients (mean age 40 ± 11 years; 10 males) with spontaneous type I ECG were included in the analysis. All patients (N = 30) underwent CMRI following ajmaline challenge or ECG recording.

ECG lead positioning and analysis

Ajmaline tests were performed following the recommendation of the Brugada consensus conference.[2,5] ECG recordings were performed by using an ECG recorder (Cardiovit CS-200, Schiller, Switzerland) with leads V1 and V2 placed in the 4th ICS in the parasternal position. Additional leads were placed in the 5th, 3rd, and 2nd ICSs in parasternal and sternal positions (Figure 1). All ECGs were analyzed digitally. In each right precordial lead, ST-segment elevation was measured and classified as Brugada type I, saddleback type (type II and type III), or normal according to the criteria of the Brugada consensus conference.[2] After analysis of the single right precordial leads, leads were grouped with respect to ICS (2nd, 3rd, 4th, and 5th ICSs) and position in relation to the sternum (right parasternal, sternal, and left parasternal). An ECG was considered diagnostic of Brugada syndrome if type I pattern with ST-segment elevation ≥ 0.2 mV was observed in ≥2 right precordial leads. All ECGs were analyzed by electrophysiologists (C.V. and R.S.) blinded to patients' and clinical data.

Cardiac magnetic resonance imaging

All studies were performed by using a 1.5-T whole-body imaging system (Magnetom Avanto 32×76, Siemens, Erlangen, Germany). During CMRI, patient's arms rested at one's sides compared to ECG recording. A dedicated 6-element, phased-array cardiac matrix coil in combination with 2 elements of the inbuilt spine matrix coil was used. Images were acquired during repeated end-expiratory breath holds.

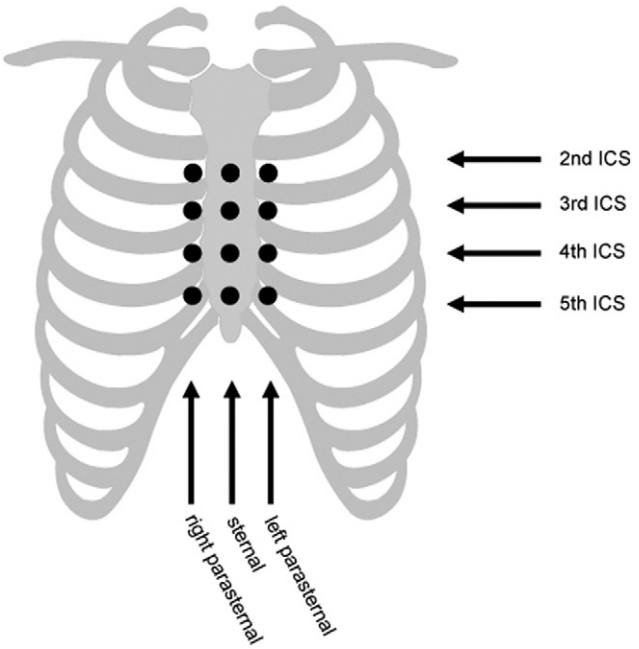

Figure 1 Positions of the right-precordial leads. ECGs were recorded from the 2nd, 3rd, 4th, and 5th ICSs in right-parasternal, left-parasternal and sternal positions. ECG = electrocardiogram; ICS = intercostal space.

Scout images (coronal, sagittal, and axial planes) were obtained for planning of the final double-oblique long-axis and short-axis views. To evaluate functional parameters, diastolic ECG-gated cine images were then acquired by using a segmented steady-state-free precession sequence (True-FISP; echo time (TE)/repetition time (TR) 1.2/3.2 ms, temporal resolution 35 ms, in-plane spatial resolution 1.4 × 1.8 mm^2, slice thickness 8 mm, interslice gap 2 mm). Seven to 12 short-axis views covering the whole left ventricle (LV) and RV were obtained. In addition, stacks of ECG-gated cine images in axial orientation covering the whole RV, including the RVOT, were assessed.

To validate the correct positioning of the ECG leads in the corresponding ICS, a dedicated imaging protocol was first used in 3 patients. Following ajmaline challenge and prior to CMRI, vials with fluid were attached on the sternum of each patient to mark the position of the ECG leads in the 2nd, 3rd, 4th, and 5th ICSs (Figure 2). To define cardiac anatomy and localize the RVOT with respect to the 2nd, 3rd, 4th, and 5th ICSs, diastolic ECG-gated multislice images using half-Fourier acquired single-shot turbo spin echo (HASTE) were obtained in 2 orthogonal planes (axial and coronal) with acquisition extending from the diaphragm to the level of the right coronary artery (ie, to include the pulmonary outflow tract; Figure 3) in end-inspiratory and end-expiratory positions. The best correlation between the vials with fluid marking the position of the ECG leads in the 2nd, 3rd, 4th, and 5th ICSs and the ribs on the coronal HASTE images was found in the end-expiratory state.

Image analysis was performed by experienced observers blinded to patients' characteristics (T.P. and C.D.). Each study was examined for abnormalities in the morphology of