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Original article

The influence of the electrodes spacing of a mapping catheter on the atrial voltage substrate map

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ABSTRACT

Background: Detailed substrate mapping is important for catheter ablation. However, the influence of the electrode spacing of the mapping catheter on the substrate map has not been well clarified. The aim of this study was to investigate the influence of the electrode spacing of the mapping catheter on the voltage of the substrate map.
Methods: Protocol 1: We recorded the local atrial potentials of the left atrium (LA) using the ablation catheter during sinus rhythm in six atrial fibrillation (AF) patients. The voltage of each atrial potential was compared between a close-bipolar (1–2 electrode) recording and wide-bipolar (1–4 electrode) recording. *Protocol 2*: Two voltage-maps of the LA were constructed separately using a 20-pole circular catheter and 10-pole circular catheter during sinus rhythm in 42 AF patients. The low voltage zone (LVZ) (<0.5 mV) areas obtained by 2 voltage maps using the 10-pole and 20-pole circular catheters were compared.
Results: Protocol 1: The close-bipolar voltage of the local potentials was significantly smaller than that of the wide-bipolar voltages (0.76 ± 0.39 mV vs. 0.63 ± 0.41 mV, $p < 0.0001$). *Protocol 2*: The size of the LVZ areas identified by the 10-pole and 20-pole catheters was 1.12 ± 1.92 cm^2 (1.47 ± 2.78%) and 8.30 ± 7.80 cm^2 (8.83 ± 8.32%), respectively ($p < 0.0001$).
Conclusions: The voltage of the local atrial potential using the close-bipolar catheter was significantly smaller than that using the wide-bipolar catheter. Care should be given to the electrode spacing of mapping catheters when analyzing the voltage of the atrial myocardial potentials.

Introduction

A low voltage zone (LVZ) during sinus rhythm (SR) represents myocardial damage and plays a crucial role in atrial and ventricular tachyarrhythmias [1,2]. Although the outcomes of the pulmonary vein isolation (PVI) plus superior vena cava isolation strategy were favorable for patients with shorter persistent atrial fibrillation (AF) durations, an alternative approach may be needed for the successful ablation of longer duration of AF [3]. Additional LVZ-based substrate modification after a PVI also improves the outcome of AF ablation [4,5]. In previous studies, the LVZ was defined as an area with a bipolar peak-to-peak voltage amplitude of <0.5 mV [2,4–6], however, the definition of the mapping technique was not always constant [5–7]. Duo-decapolar, decapolar, and ablation catheters have been used to construct the substrate map [5–7]. Although detailed substrate mapping plays an important role in catheter ablation, the influence of the mapping catheter on the atrial substrate voltage maps is still not well understood. Previous studies [8,9] showed that mapping with small closely spaced electrodes can improve the mapping resolution within the low voltage areas and catheters with a smaller inter-electrode spacing can better detect surviving ventricular myocardial tissue in zones with a generally low voltage. However, there have been no detailed studies on the atrium. The aim of this study was to investigate the influence of the electrode spacing of atrial mapping catheters on voltage maps.

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Methods

Study subjects

Patients who underwent catheter ablation of paroxysmal or persistent drug-refractory AF between January 2016 and December 2016 were included in the study. All antiarrhythmic agents were discontinued for at least 5 half-lives before the ablation. Six AF patients (paroxysmal AF, 1; persistent AF, 5) underwent Study Protocol 1 (comparison between a close-bipolar voltage and wide-bipolar voltage). Forty-two AF patients (paroxysmal AF, 17; persistent AF, 25) underwent Study Protocol 2 (comparison of the LVZ areas between decapolar and duo-decapolar catheters) (Table 1).

Ablation procedure

We performed computed tomography (CT) to investigate the anatomy of the pulmonary veins and existence of any thrombi in the left atrial appendage (LAA) before the ablation. Transesophageal echocardiography was performed in those with any undeniable thrombi in the LAA.

All ablation procedures were performed under deep sedation using propofol, dexmedetomidine, and phentanyl. The bispectral index (BIS) was monitored and maintained at 40–60.

Mapping and ablation were performed under the guidance of an electroanatomical mapping system (CARTO 3®; Biosense Webster, Diamond Bar, CA, USA). An open-irrigation 3.5 mm tip electrode catheter (Thermocool SMARTTOUCH®; Biosense Webster) was utilized for the ablation. The inter-electrode space of the SMARTTOUCH catheter is 1-6-2 (1st to 2nd electrode, 1 mm; 2nd to 3rd electrode, 6 mm; 3rd to 4th electrode, 2 mm). A left atrial (LA) voltage map was constructed using a steerable 20-pole (inter-electrode space, 2 mm) circular mapping catheter (LassoNav®; Biosense Webster) and steerable 10-pole (inter-electrode space, 8 mm) circular mapping catheter (LassoNav®). The bipolar electrograms were filtered with a bandpass between 30 and 500 Hz. In the case of a first session, ablation of the ipsilateral superior and inferior pulmonary veins (PVs) was jointly performed with a continuous lesion all around the ipsilateral superior and inferior PVs. In the case of a second session, isolation of all four PVs was performed on the atrial side of the PV antrum using an electrogram-guided approach. The endpoint of the PVI was entrance and exit block from the PVs. No linear or complex fractionated atrial electrogram (CFAE) ablation was performed in any cases. The ablation settings consisted of an upper temperature limit of 43 °C, radiofrequency power of 30–35 W, and flow rate of 17–30 ml/min. The radiofrequency power was reduced to 20–25 W near the esophagus.

After the PVI, LA mapping was performed in accordance with the following study protocol (Protocol 1, Protocol 2).

Table 1
Patient characteristics.

	Protocol 1 (n = 6)	Protocol 2 (n = 42)
Clinical parameters		
Age, years	52.5 ± 9.2	60.2 ± 11.2
Gender, male, n (%)	5 (83.3)	36 (85.7)
Hypertension, n (%)	4 (66.7)	15 (35.7)
Diabetes, n (%)	0 (0)	2 (4.8)
Stroke, TIA, n (%)	1 (16.7)	2 (4.8)
CHF, n (%)	1 (16.7)	11 (26.2)
CHADS2 score	1.17 ± 0.75	0.79 ± 0.72
Persistent AF, n (%)	5 (83.3)	25 (59.5)
Echocardiographic findings		
LA diameter, mm	41.3 ± 6.6	39.4 ± 6.8
LVDd, mm	49.0 ± 7.3	47.7 ± 5.3
LVEF, %	53.0 ± 4.5	58.4 ± 12.9

The continuous variables are shown as the mean ± SD and categorical variables as the number (%). TIA, transient ischemic attack; CHF, congestive heart failure; AF, atrial fibrillation; LA, left atrial; LVDd, left ventricular diastolic diameter; LVEF, left ventricular ejection fraction.

LA mapping

Protocol 1

Protocol 1 study was performed to compare the voltage between the close-bipolar electrograms and wide-bipolar electrograms. After the PVI, we recorded the local atrial potential from more than one hundred points using an ablation catheter during sinus rhythm. The close-bipolar (ablation catheter tip to the 2nd ring electrode) voltage and wide-bipolar (ablation catheter tip to the 4th ring electrode) voltage of each local potential were measured by digital calipers and compared (Fig. 1).

Protocol 2

Protocol 2 study was designed to compare the area of the LVZ between the close-bipolar and wide-bipolar mapping catheters during sinus rhythm. After the PVI, two LA voltage maps were constructed using the 20-pole (close-bipolar) and 10-pole (wide-bipolar) circular mapping catheters during sinus rhythm. The PV and adjacent areas surrounded by the isolation line of the PVs were excluded from those maps. The electrode tip spacing was 2 mm on the 20-pole catheter and 8 mm on the 10-pole catheter. The area of the LVZ was defined as that with a bipolar peak-to-peak voltage amplitude of <0.5 mV. The size of the LVZ was measured by the CARTO 3® software on the display. The corresponding areas and percentage of the LVZ obtained by the 2 voltage maps using the 10-pole and 20-pole circular catheters were compared.

Protocol 1 study was designed to investigate the voltage itself between the close-bipolar and wide-bipolar, and protocol 2 study was designed to investigate the LVZ areas between the close-bipolar and wide-bipolar. In both studies we used the semiquantitative method previously described to assess the LA substrate remodeling [10], that is, the LA surface was divided into six segments: roof between the left superior pulmonary vein (LSPV) and right superior pulmonary vein (RSPV), posterior wall between the left and right pulmonary veins, inferior posterior wall, anterior wall between the roof and mitral annulus above the fossa ovalis, septum under the fossa ovalis and in front of the right inferior pulmonary vein (RIPV), and lateral wall, corresponding to the ridge between the LAA and LSPV and mitral isthmus. We measured the LVZ for each divided area and calculated the LVZ ratio as an LVZ area/each divided area.

Statistical analyses

The statistical analyses were performed using JMP® Pro, version 11.2software (SAS Institute, Cary, NC, USA). The continuous variables were compared using a paired t-test (Protocol 1) and an unpaired t-test (Protocol 2) for parametric data and Mann–Whitney test for non-parametric data. A value of $p < 0.05$ indicated statistical significance. This study was approved by the institutional review board of Saitama Medical University, International Medical Center (17-130).

Results

Protocol 1

Bipolar electrograms were recorded at a total of 640 points in all 6 patients with an average of 107 ± 12 points. After excluding the PV electrograms, a total of 535 points (anterior area, n = 126, inferior area, n = 78, lateral area, n = 88, posterior area, n = 97, roof

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