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Original Article

Detection of sequential activation of left atrium and coronary sinus musculature in the general population

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ABSTRACT

Background: The direction of impulse propagation across the coronary sinus (CS) musculature (CSM) is an important piece of the mechanistic puzzle underlying atrial tachyarrhythmias. We hypothesized that in the general population, the sequence of left atrial (LA) to CSM electrograms recorded in the CS reflects the direction of impulse propagation over the CSM.

Methods: We studied 19 patients with atrioventricular (AV) reentrant tachycardia (RT) utilizing a left-sided accessory pathway (AP) and 21 patients with typical counterclockwise atrial flutter (AFL). Conduction through the CSM during AVRT and AFL is from the left atrial (LA) to the right atrial (RA) and from the RA to LA direction, respectively. CS recordings of retrograde conduction over the AP and of AFL were analyzed in search of far-field, LA potentials.

Results: Among 19 patients with AP, LA potentials were visible in 7 (37%), all in an LA → CSM activation sequence, while among the 21 patients with AFL, LA potentials were visible in 14 (67%), all in a CSM-LA activation sequence ($P<0.0001$). The prevalence of LA potentials was similar between both study groups ($P=0.1119$), and the overall prevalence was 53%.

Conclusions: Far-field LA potentials are often recorded in the CS during sequential LA and CSM activation in the general population. The timing of LA potentials in CS recordings reflected the direction of conduction across the CSM.

1. Introduction

The coronary sinus (CS) musculature (CSM), which is electrically connected to both atria, [1,2] plays the important role of synchronizing their activation during sinus rhythm, [3] as well as perpetuating some atrial tachyarrhythmias [4–6]. Since the direction of wavefront propagation across the CSM varies among atrial tachyarrhythmias, its analysis and elucidation is a critical step toward an accurate interpretation of their mechanisms. For example, during atrioventricular (AV) reentrant tachycardia (RT) utilizing a left-sided AV accessory pathway (AP), the wavefront propagates via a left atrial (LA) connection into and through the CSM toward the right atrium, whereas during typical counterclockwise (CCW) atrial flutter (AFL), the wavefront propagates into and through the CSM in a right atrial (RA) → LA direction (Fig. 1).

A multipolar electrode catheter is usually needed during electrophysiological studies and ablation procedures in order to record the activation sequence from inside the CS. Because of the multiple muscle bundles connecting the CSM and LA, [2] the activation of the CSM and adjacent LA myocardium appears simultaneously. However, we previously found that, in patients whose LA-CSM connections are particularly weak, the far-field LA activation during retrograde conduction over a left-sided AP only, was separated from the near-field activation of the CSM on the CS recordings [7]. If the activation sequence of LA and CSM could be analyzed on the CS recordings of the general population, regardless of differences in conductive properties between LA and CSM, it could be used as an electrophysiological marker of the wavefront propagating across the CSM. Therefore, the present study was conducted to verify our hypothesis that (1) the far-field LA potential recorded in the CS is universally visible in the general population, and (2) the activation sequence of the LA and CSM potentials reflects the direction of impulse propagation over the CSM.

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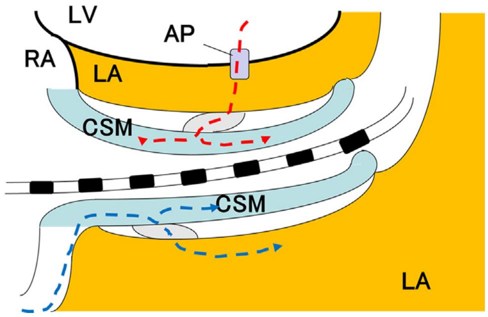

Fig. 1. Representative illustration of activation sequences of LA and CSM during retrograde conduction over left-sided AV AP (red dashed arrow) versus counterclockwise typical AFL (blue dashed arrow). LV=left ventricle; RA=right atrium.

2. Material and methods

We studied 19 patients (51 ± 18 years old, 12 men) presenting with AVRT utilizing a left-sided AP, and 21 patients (67 ± 11 years old, 18 men) presenting with CCW AFL, who all underwent successful catheter ablation. All of ablation procedures were performed from a submitral approach, confirming the presence of an AP. As briefly mentioned earlier, during AVRT utilizing a left-sided AP, the wavefront, after retrograde conduction over the AP, propagates via LA → CSM connections into and through the CSM in a LA → RA direction, and reaches the RA via the ostium of the CS. During typical CCW AFL, the wavefront rotating around the tricuspid annulus propagates via the ostium of the CS into and through the CSM in a RA → LA direction and reaches the LA via CSM → LA connections. Thus, the wavefront across the interatrial connection at the CS propagates in a left → right direction during ongoing AVRT and in a right → left direction during typical AFL (Fig. 1).

This study complied with the guidelines of the Declaration of Helsinki and was approved by the institutional review board of the Gunma University Hospital (approval date; Jun 30, 2010, No. 774). Written informed consent to participate in this study was obtained from all patients.

2.1. Electrophysiological studies and electrogram analyzes

Electrophysiological studies were performed before catheter ablation. A 6-Fr duodecapolar or decapolar electrode catheter with 5-mm interelectrode spacing was placed in the CS via the right subclavicular or femoral vein for the CS recordings. Other multipolar electrode catheters were placed in the high RA, His bundle region, and at the right ventricular apex in patients presenting with AVRT; and at the tricuspid annulus and His bundle region in patients presenting with AFL. Bipolar intracardiac electrograms and a 12-lead surface electrocardiogram were recorded and stored in an EP Work Mate™ system (EP MedSystems, Inc., West Berlin, NJ), after signal filtering between 30 and 500 Hz, and were analyzed at a paper speed of 100 and 400 mm/s. When the activation sequence in the CS during ongoing AVRT was identical to that during ventricular stimulation, the CS recordings were analyzed during ventricular extrastimulation. In patients with AFL, the CS recordings were made during ongoing AFL. The CSM potentials recorded from inside the CS are characteristically high-frequency and near-field, whereas the LA potentials are far-field, low-amplitude, low-frequency signals, with a gradual onset and gradual return to baseline. Based on these characteristics, all CS electrograms during tachycardia and sinus rhythm were scrutinized in search of LA potentials preceding or following the CSM potentials by 2 cardiologists. When there was disagreement regarding the presence of LA potentials and the sequence of LA and CSM potentials, the cardiologists discussed the results to reach an agreement. The amplitude of LA potentials and the intervals between the onset of LA potential and the end of CSM potential or between the onset of CSM potential and the end of LA potential were measured.

2.2. Statistical analysis

Continuous measurements are expressed as mean ± SD. Categorical variables were compared by using Fisher's exact test. The statistical analyzes were performed with the Ekuseru-Toukei 2012 statistical software package (Social Survey Research Information Co., Ltd). A P value < 0.05 was considered statistically significant.

3. Results

As shown in Table 1, the amplitude, and the onset or the end of LA potentials were successfully determined via visual inspection. Among 19 patients with AP, LA potentials were detected in 7 (37%), all in an LA → CSM activation sequence (Fig. 2). In contrast, among 21 patients with CCW AFL, LA potentials were visible in 14 (67%), all in a CSM → LA activation sequence (Fig. 3). This difference was highly significant ($P < 0.0001$). The prevalence of LA potentials was not significantly different between both study groups ($P = 0.1119$), and the overall prevalence was 53%. In the left anterior oblique fluoroscopic projection, most LA potentials were located between 3 and 6 o'clock in patients with AP and between 4 and 5 o'clock in patients with AFL (Fig. 4).

In a single case with left-sided AP presenting CS double potentials, we compared the relative timing of far-field LA potentials in the CS recordings with LA potentials directly recorded during successful ablation procedure, by using trans-septal approach (Fig. 5). The far-field potential was recorded simultaneously with LA potential at the successful ablation site during retrograde conduction over AP, whereas no far-field potential was observed after the elimination of AP, providing further confirmation that the far-field potentials in the CS recordings reflect LA activation. Furthermore, although not enrolled in the present study, we present two interesting cases in which unique CS double potentials were observed. The diagnosis of the first case was a manifest Wolff-Parkinson-White (WPW) syndrome and AVRT attributable to ventricular-CS connection that was confirmed by its successful ablation inside a mid-cardiac vein [8]. During ventricular pacing before the ablation, LA potentials following CSM potentials were noticed in the proximal CS recordings (Fig. 6). The second case had typical clockwise (CW) AFL that was electrophysiologically confirmed. During the ongoing tachycardia, in contrast to typical CCW AFL, LA potentials preceding CSM potentials were registered on the proximal CS recordings (Fig. 7).

Table 1
Electrogram measurements.

	Patients with AP ($n=19$)		Patients with AFL ($n=21$)	
	LA-CSM, ms	Amp (LA), mV	CSM-LA, ms	Amp (LA), mV
6 o'clock	32.5 ± 0.7	0.28 ± 0.01	62.0 ± 20.6	0.12 ± 0.06
5 o'clock	39.2 ± 3.6	0.21 ± 0.21	55.0 ± 9.4	0.17 ± 0.08
4 o'clock	41.7 ± 6.9	0.33 ± 0.07	46.3 ± 2.6	0.15 ± 0.03
3 o'clock	47.3 ± 12.1	0.18 ± 0.08	48.0 ± 1.4	0.08

Amp (LA)=the amplitude of LA potentials; CSM-LA=the interval between the onset of CSM and the end of LA potentials; LA-CSM=the interval between the onset of LA and the end of CSM potentials.

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