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**CASE REPORT**
*Electrophysiology*

# Dynamics of unipolar J-ST elevation coupled to bipolar delayed potentials on the epicardium in Brugada syndrome: a case report

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**Background** The area of abnormal bipolar potentials in the right ventricular epicardium is recognized as an arrhythmogenic substrate in patients with Brugada syndrome (BrS); however, the correlation between local potentials and Brugada-type surface electrocardiograms (ECGs) remains unclear.

**Case summary** A 49-year-old man with BrS who was hospitalized for refractory ventricular fibrillation underwent an electrocardiographic study with unipolar electrodes with the same bandwidth as surface ECGs. The right ventricular outflow tract epicardium showed abnormal bipolar potentials composed of split sharp and delayed dull components with coved-type J-ST elevation in the unipolar electrodes. The additional stimuli from the atrium gradually decreased the number of unipolar electrodes showing coved-type J-ST elevation along with a shortening of the local bipolar activation time. The pilsicainide provocation test induced a change in unipolar morphology from coved type to convex type and an intermittent local block of the divided and sharp components in bipolar electrodes. Of note, the unipolar J-ST elevation was not changed along with the localized conduction block in bipolar leads.

**Discussion** The unipolar electrode waveforms during sinus rhythm change together with bipolar electrodes, consisting of sharp and blunt components in BrS. However, the convex-type J-ST elevation in unipolar leads persisted irrespective of the local conduction block in bipolar leads after pilsicainide provocation. These findings suggest the complexity of BrS mechanisms.

**Keywords** Brugada syndrome • Case report • Epicardium • Localized conduction block • J-ST elevation

**ESC curriculum** 5.6 Ventricular arrhythmia • 5.10 Implantable cardioverter defibrillators

## Learning points

- The epicardial mapping in Brugada syndrome revealed delayed potentials consisting of two components with dull and sharp potentials in bipolar electrodes in which unipolar electrodes demonstrated coved-type J-ST elevation by setting the band-pass filter same as surface electrocardiograms (ECGs).
- The unipolar J-ST elevation seemed to fluctuate with the duration time of the dull components, irrespective of the localized conduction block of the sharp components.
- These findings might mean that conduction disorder is not the only mechanism of J-ST elevation in Brugada-type ECGs.

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## Introduction

Epicardial substrate ablation targeting fractionated or delayed potentials in the epicardium mainly at the right ventricular outflow tract (RVOT) has been established as a strategy to suppress ventricular fibrillation in patients with Brugada syndrome (BrS).[1] However, the relationship between abnormal bipolar electroactivities and J-ST segment elevation in surface electrocardiograms (ECGs) remains uncertain. We previously reported the correlation between local activation time (LAT) delay in the bipolar recording and J-ST elevation in the unipolar recording using a 0.05–100 Hz bandwidth similar to surface ECGs on the RVOT epicardium in a BrS patient.[2] Haïssaguerre *et al.*[3] proposed a hypothesis that unipolar ST segment changes occur with a multisite conduction block in the epicardium. Meanwhile, Pannone *et al.*[4] reported that epicardial high-frequency and low-frequency potentials demonstrated depolarization and repolarization abnormalities, respectively. These papers suggested that delayed bipolar electrograms influence the manifestation of unipolar J-ST segment elevation. However, the response to pacing and sodium channel blocker testing has not yet been studied in detail.

Herein, we present a unique BrS case with epicardial mapping using unipolar electrodes with the above-described setting and bipolar electrodes.[2] The correlation between unipolar J-ST segment morphology and bipolar delayed potentials in response to programmed pacing and the pilsicainide test was investigated.

## Summary figure

| | |
|---|---|
| 16 days prior to presentation | Aborted sudden cardiac arrest associated with Brugada syndrome, which demonstrated spontaneous coved-type J-ST elevation. Treated with an implantable cardioverter defibrillator (ICD) and bepridil 100 mg daily. |
| 15 days prior to presentation | An appropriate ICD therapy. Bepridil was converted to quinidine 300 mg daily. |
| 1 day prior to presentation | Twice appropriate ICD therapies. Cilostazol 100 mg daily add-on. |
| Hospitalization | Frequent ICD therapies for ventricular fibrillation and emergency hospitalization. |
| Day 5 | Catheter ablation. |
| Day 16 | Discharge with the termination of any antiarrhythmic drugs. |
| Current states | No recurrence of ventricular tachyarrhythmias. |

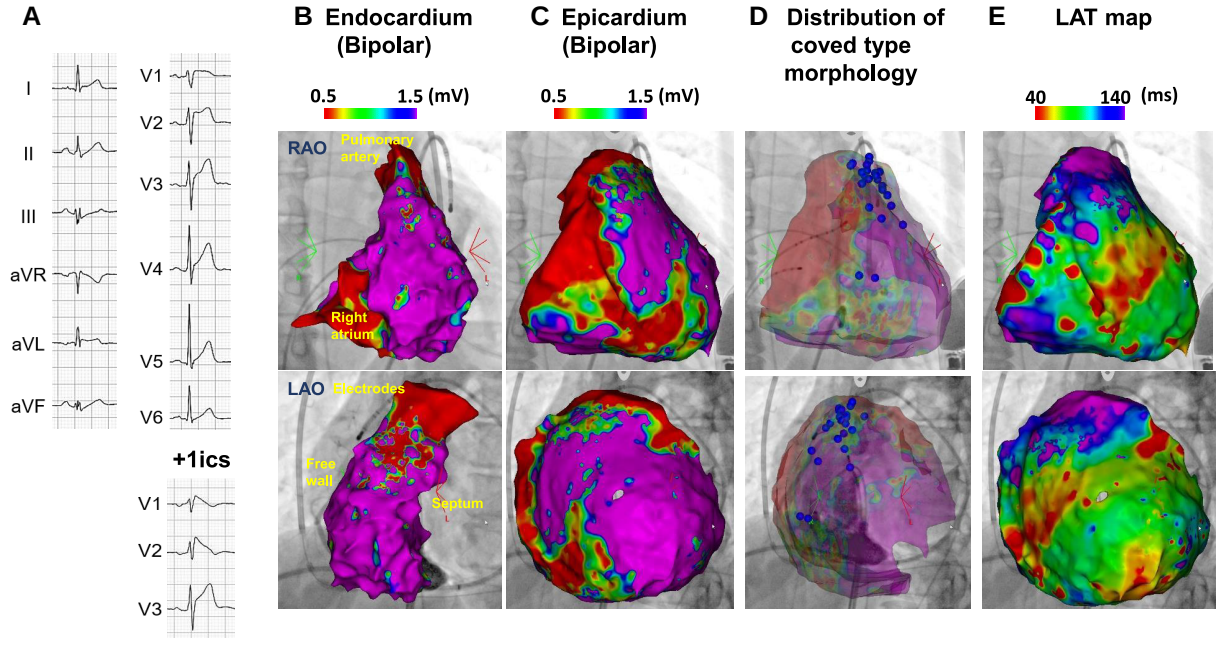



**Figure 1** Twelve-lead electrocardiogram and three-dimensional mapping. (*A*) The surface electrocardiogram demonstrated coved-type J-ST elevation in the upper intercostal space. (*B*) The endocardial bipolar voltage map in the right ventricle. (*C*) The epicardial bipolar voltage map in the right ventricle. (*D*) The distribution of coved-type J-ST elevation in unipolar electrodes in the epicardium. Tags demonstrated the points of coved-type unipolar J-ST elevation. (*E*) The epicardial local activation map in the bi-ventricle. Ice, intercostal space; LAT, local activation time; LAO, left anterior oblique; RAO, right anterior oblique.

## Case presentation

A 49-year-old man had an episode of aborted cardiac arrest leading to the diagnosis of BrS with spontaneous coved-type J-ST elevation on ECG (*Figure 1A*). He was admitted to our institute for frequent appropriate implantable cardioverter defibrillator (ICD) therapies. We decided to perform epicardial catheter ablation due to refractory ventricular fibrillation, which did not respond to quinidine for suppressing Ito channels, bepridil for suppressing Ito channels and increasing sodium current, and cilostazol for suppressing phosphodiesterase III and leading to an increase in calcium current.

The three-dimensional mapping system (CARTO UNIV, Biosense Webster, Diamond Bar, CA) was used for substrate mapping with deep sedation using intravenous propofol and dexmedetomidine. The voltage map and the map of late activation time, which was defined as the time from the beginning of QRS in lead V2 to the offset of the latest local bipolar component, were obtained using DECANAV (Biosense Webster, Diamond Bar, CA). A low voltage was defined as ≤1.5 mV in the bipolar amplitude.[2] A local unipolar J-ST morphology was assessed to confirm coved-type J-ST elevation, which was defined as ≥0.2 mV in J-ST together with a negative T wave.[2]

The bipolar voltage map of the endocardium showed patchy low-voltage areas in the RVOT (*Figure 1B*). Alternatively, the epicardial voltage in the right ventricle was generally decreased except in the free wall (*Figure 1C*). The area of coved-type J-ST elevation in the unipolar electrodes (circular dots in *Figure 1D*) corresponded to the most delayed regions of activation, particularly in the RVOT (*Figure 1E*). The right ventricular epicardial local electrograms, with electrodes arranged as the lines in *Figure 2A*, showed split sharp and delayed dull potentials in the bipolar electrodes, which presented a coved-type J-ST elevation

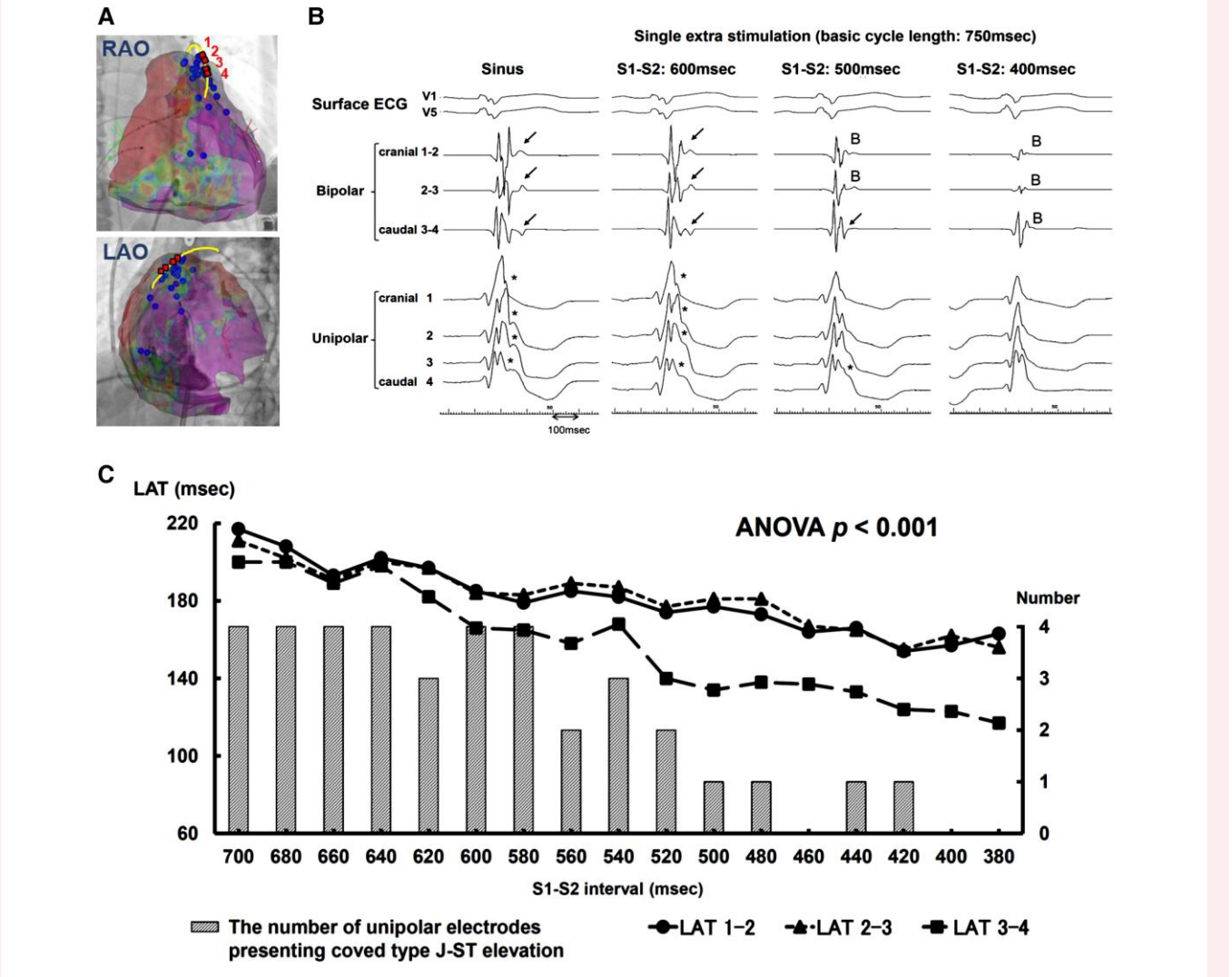



**Figure 2** Dynamic changes of local potentials by single extra stimuli. Dynamic changes of delayed potentials in bipolar electrodes and unipolar morphologies in the right ventricular epicardium during single extra stimuli from the atrium. (*A*) The electrode catheter was arranged in the epicardium on the right ventricular outflow tract as lines. Numbered square dots from 1 to 4 indicate the positions of electrodes. Circular dots indicate as in *Figure 1D*. (*B*) Bipolar electrodes demonstrated split sharp and delayed dull potentials during sinus rhythm. Localized conduction block of the delayed potentials in the bipolar electrodes occurred along with the decrease of J-ST levels in the unipolar electrodes with the shortening of extra stimulation intervals. The asterisk indicates coved-type J-ST elevation in unipolar electrodes; arrows, delayed potentials in bipolar electrodes; and B, blocked delayed potentials. (*C*) Polygonal lines indicate the local activation time of bipolar electrodes; bars, the number of unipolar electrodes presenting coved-type J-ST elevation. ECG, electrocardiogram.

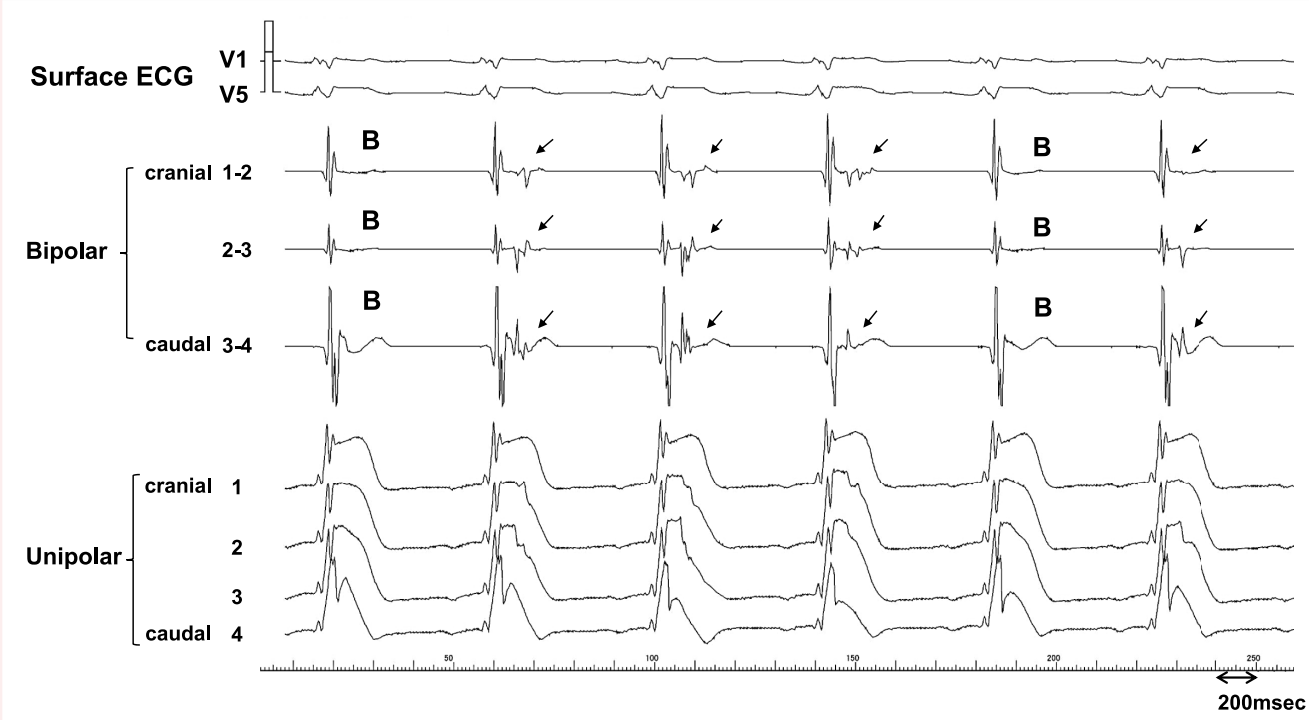



**Figure 3** Pilsicainide provocation test. Localized conduction block of the delayed sharp potentials in bipolar electrodes occurred during sinus rhythm after pilsicainide 50 mg administration. The unipolar electrodes demonstrated continuous convex-type J-ST elevation irrespective of the localized conduction block of the delayed sharp potentials. Arrows and B indicate the same as those in *Figure 2*.

in the unipolar electrodes (*Figure 2B*). The additional stimuli from the right atrium induced a gradual shortening of the delayed potential duration (arrows in *Figure 2B* and polygonal lines in *Figure 2C*). It is noteworthy that the number of unipolar electrodes showing a coved-type J-ST elevation also decreased along with the shortening of the extra stimulus intervals (*Figure 2B* and the bar graph in *Figure 2C*).

The provocation test with pilsicainide (50 mg) induced a change in unipolar morphology from coved-type J-ST elevation to convex-type J-ST elevation, and bipolar electrodes demonstrated an intermittent localized block of the split and sharp delayed potentials (*Figure 3*). The dull delayed potentials in bipolar electrodes showed no significant change. In addition, the unipolar J-ST morphology showed notches at the same time as the bipolar delayed potentials, and they disappeared along with the local conduction block (B in *Figure 3*). It is noteworthy that the convex-type J-ST elevation was ensured even though the localized conduction block occurred.

Catheter ablation was performed on the epicardial substrate, showing delayed potentials in bipolar leads and coved-type J-ST elevation in unipolar leads. Following the procedure, the J-ST levels in surface ECGs returned to the baseline and no episodes of ventricular tachyarrhythmias occurred, even after stopping all antiarrhythmic drugs. Genetic testing using a gene panel developed in the National Cerebral and Cardiovascular Center (Osaka, Japan) was performed; however, no pathogenic mutation including *SCN5A* was identified.

## Discussion

Nowadays, the mechanisms of Brugada-type ECGs are debated between the conduction and repolarization abnormality theories.[5] One of the strong ideas about BrS is the 'conduction abnormality theory'.[6] In some cases of BrS, typical conditions of conduction abnormality, such as right bundle branch block or prolonged His-ventricle intervals, are demonstrated.[5] In addition, recently developed three-dimensional electrophysiological mapping techniques have revealed abnormal local potentials that resemble conduction abnormalities in the epicardium.[3] However, the present case demonstrated a unique phenomenon during extra stimuli from the atrium, which could not be explained by the conduction abnormality theory alone. The sharp and split–delayed potentials in bipolar electrodes were blocked and disappeared along with the shortening of extra stimulation intervals. Furthermore, these delayed potentials were intermittently blocked even during sinus rhythm following pilsicainide provocation. These findings likely demonstrated the relationship between the delayed potentials and the conduction abnormality theory. However, the LAT significantly decreased along with the shortening of extra stimulation intervals (*Figure 2B*). Usually, the prolongation of LAT should be observed under the conduction abnormality theory. Moreover, epicardial planar repolarization heterogeneities, which could be confirmed as differences in the unipolar morphologies, manifested after pilsicainide infusion compared with those before infusion (*Figure 3*).

A more detailed analysis of bipolar potential morphology is required to interpret these findings. As described in the *Figure 2A* legend, bipolar electrodes showed split sharp and delayed dull potentials during sinus rhythm. These split frequency potentials could reflect two different theories of mechanisms. The mechanisms of these two frequency potentials were described as Ito blockade in the epicardium with loss of dome in acute ischaemia animal models.[7] Moreover, Pannone *et al.*[4] reported high-frequency and low-frequency delayed potentials in bipolar electrodes in BrS. Our case also showed two divided frequency components and demonstrated different changes after pilsicainide administration. The high-frequency potentials demonstrated a localized block along with the shortening of extra stimulation intervals and pilsicainide provocation test; however, the low-frequency potentials gradually decreased those amplitudes along with the shortening of extra stimulation

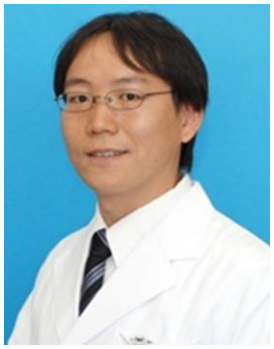
intervals and demonstrated no change in the duration after pilsicainide administration (*Figures 2* and *3*). These findings suggest that other mechanisms, rather than the conduction abnormality theory, influence the behaviour of the low-frequency potentials.[8]

The relationships between unipolar J-ST levels with the same bandwidth as the surface ECG and bipolar abnormal potentials also remain unclear. In our case, the J-ST level decreased along with the shortening of the extra pacing intervals; however, convex-type J-ST elevation remained unchanged even though the bipolar sharp high-frequency potentials were blocked. The findings might indicate that low-frequency potentials, rather than high-frequency potentials, influence unipolar J-ST elevation. Although the measurement of the LAT during single extra stimuli could not separate the two frequency components due to low amplitudes, the gradual decrease in LAT (*Figure 2B*) may reflect the shortening of low-frequency potentials, leading to a unipolar J-ST level decrease. Mapping both endocardial and epicardial unipolar signals will reflect transmural heterogeneity of action potential duration including depolarization and repolarization phases. To better understand the mechanisms of the localized conduction block in bipolar potentials, mapping of both the endocardium and the epicardium, not only before but also after pilsicainide infusion, may be more helpful.

## Conclusion

This case demonstrated that the delayed potentials in the bipolar electrodes consisted of sharp and blunt components, accompanied by coved-type J-ST elevation in the unipolar electrodes. Before the pilsicainide test, J-ST levels showed fluctuation along with the two bipolar components. However, after pilsicainide provocation, convex-type J-ST elevation persisted, irrespective of the local conduction block of the sharp components in bipolar electrodes. We believe that these contradictory findings suggest the complexity of BrS mechanisms.

## Lead author biography



Since 2020, Naoya Kataoka has been an Assistant Professor in the Second Department of Internal Medicine, University of Toyama. In 2016–2019, he was in the National Cerebral and Cardiovascular Center. In 2007–2009, he was a Junior Resident in the Second Department of Internal Medicine, University of Toyama.

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## Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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