Utility of coherent and ripple mapping for post-mitral valve plasty biatrial macro-re-entrant tachycardia: a case report

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Background
Biatrial tachycardia (BiAT) is a rare form of atrial macro-re-entrant tachycardia. Precise identification of interatrial connections and circuits of the BiAT is difficult. And incomplete understanding of the re-entrant circuit may lead to unnecessary ablation, thus increasing the risk of complications.

Case summary
A 69-year-old man with a history of mitral valve plasty for mitral regurgitation due to mitral valve prolapse was admitted for persistent atrial tachycardia. Electrophysiological examination using the CARTO mapping system was performed. A coherent map revealed an atrial tachycardia with a cycle length of 304 ms and a re-entrant circuit involving the left atrial septum and right atrial septum, while a ripple map suggested an epicardial interatrial connection between the right atrium and left atrium. Radiofrequency ablation on the epicardial connection successfully terminated BiAT without complications.

Discussion
In BiAT using both atrial septum as a re-entrant circuit, an interatrial connection or an atrial septum can be the target site for ablation. However, septal ablation can be challenging because of the risk of atrioventricular block or interatrial conduction delay, and minimal line or point ablation is needed. Coherent and ripple mapping can accurately determine the re-entrant circuit and interatrial connection of BiAT and reduce complication risks by terminating the atrial tachycardia with minimal ablation.

Keywords
Biatrial tachycardia • Epicardial interatrial connection • Coherent map • Ripple map • Case report

Learning points
• Coherent mapping may help characterize the re-entrant circuit of biatrial tachycardia (BiAT).
• Ripple mapping may identify epicardial interatrial connections during BiAT.
• Complete understanding of the BiAT circuit by the two mapping methods may facilitate identification of the appropriate target site for ablation.
Introduction

A rare form of macro-re-entrant tachycardia involving two interatrial connections, biatrial tachycardia (BiAT) is usually found in patients undergoing cardiac surgery,1 correction of congenital heart disease,2 or catheter ablation for atrial fibrillation (AF) or atrial tachycardia (AT).3 A recent detailed study on nine cases of BiAT using the Rhythmia mapping system classified BiAT into three types and examined the optimal site of ablation.4 However, reliable identification of the re-entrant circuit has not been possible in all cases in said study, and a complete understanding of the BiAT circuit remains difficult. Furthermore, in BiAT, in which the atrial septum is part of the re-entrant circuit, the septum can be the target site for ablation. However, extensive ablation of the atrial septum carries the risk of atrioventricular block or interatrial conduction delay, therefore, requiring a minimal line or point ablation. If an interatrial connection can be clearly identified, its ablation in BiAT using the atrial septum can help avoid complications from unnecessary extensive ablation. Herein, we show that a coherent map created by a PentaRay catheter is very useful for describing the re-entrant circuits of BiAT and that ripple mapping can identify epicardial interatrial connections in BiAT, thus reducing the risk of procedure-related complications.

Timeline

| Time Event | Description |
|------------|-------------|
| Nineteen years before the ablation | Mitral valve plasty for mitral regurgitation due to mitral valve prolapse and coronary artery bypass graft for angina pectoris were performed. |
| Eighteen years before the ablation | Paroxysmal atrial fibrillation was documented. |
| Starting at 14 years before the ablation | Atrial tachycardia (AT) frequently occurred and cardioversion was performed each time. |
| On admission | Patient was admitted for radiofrequency catheter ablation (RFCA) of AT, since AT persisted and the brain natriuretic peptide levels tended to rise. |
| During the procedure | AT was diagnosed as biatrial tachycardia by coherent and ripple mapping, and AT was successfully terminated by RFCA on the interatrial connection without any complications. |
| Follow-up at 3 months | No recurrence of any arrhythmias was documented. |

Case presentation

A 69-year-old man was referred to our institution for the treatment of persistent AT. He had a history of mitral valve plasty for mitral regurgitation due to mitral valve prolapse and coronary artery bypass grafting for angina pectoris 19 years before the ablation and paroxysmal AF was first diagnosed in the following year. The frequency of AT has increased starting at 14 years before the ablation, and cardioversion was performed each time. He was admitted for radiofrequency catheter ablation of AT because of palpitations during exercise and increased brain natriuretic peptide levels. A 12-lead electrocardiogram showed an AT with a tachycardia cycle length (TCL) of 304 ms and positive P-waves in leads I, II, III, aVF, V4, V5, and V6 (Figure 1). With informed consent, the patient underwent an electrophysiological study and ablation.

Endocardial mapping of the atrium was performed using a PentaRay catheter (Biosense Webster, Diamond Bar, CA, USA) with the CARTO mapping system (Biosense Webster). Checking the activation map of the left atrium (LA) during AT with a TCL of 304 ms and activation on the CS propagating from distal to proximal, we suspected that the AT was localized re-entrant tachycardia in the LA anterior wall (Figure 2A). However, because a small part of the TCL was still not covered by the LA mapping, a second map was acquired in the right atrium (RA). The activation map of the RA showed a focal activation pattern starting from the RA septum. When the maps of both atriums were combined, the propagation of the tachycardia on the activation map exhibited the centrifugal activation from the LA anterior wall, and the conduction from the RA to LA was not well understood (Video 1). While, a coherent map demonstrated that the propagation ran from the RA high septum to the LA anteroseptum via an interatrial connection, and turned to the RA septum from the LA septum via the Bachmann bundle with clockwise rotation. Furthermore, the high-septum interatrial connection appeared to have a conduction delay because conduction velocity vectors near the connection were thicker relative to the surrounding areas (Figure 2B and Video 2). On a voltage map, a wide low-voltage zone (LVZ) extending from the LA anterior wall to the LA and RA septums was documented (Figure 2C). Entrainment mapping revealed a short post-pacing interval (PPI) [PPI-TCL <20 ms] in the RA and LA septums, and finally, the AT was diagnosed as BiAT with a re-entrant circuit involving both atrial septums (Figure 2B). On the ripple map of both atriums, a propagation reciprocating near the assumed high-septum interatrial connection was visualized (Video 3), and clear double potentials were recorded near the site (Figure 3). The preceding potentials were considered to be far field potentials due to amplitude lower than the following potentials, and the TCL (304 ms) was completely covered by adding the activation time of the preceding potentials (36 ms) to the activation time of the endocardial potentials of both atriums (268 ms). Given these, the preceding potentials were considered to be potentials of an epicardial interatrial connection. Ablation began with 35 W of radiofrequency using an irrigated catheter (ThermoCool SmartTouch™ Surround Flow, Biosense Webster) on the epicardial interatrial connection with a conduc-
ablation, BiAT was terminated and sinus rhythm (SR) was restored without pause (Figure 4B). Additional burns at the area near the successful site of ablation were applied; subsequently, pulmonary vein isolation and LA roof ablation were also performed using a 28-mm cryoballoon (Arctic Front Advance, Medtronic, Minneapolis, MN, USA). All procedures were completed without any complications. No AT was induced by atrial burst pacing under isoproterenol infusion. After the ablation, the patient was followed up without any antiarrhythmic drugs, and SR was maintained during 3 months of follow-up.

Discussion

A coherent map is suitable for the visualization of macro-re-entrant tachycardia, and in this report, we clarified a BiAT circuit for the first time using a coherent map describing both atriums. BiAT depends on an obstacle to conduction located in the atrial septum, which is usually created after various procedures performed at the atrial level.\(^1\)\(^-\)\(^5\) Previous mitral valve surgery resulted in an LVZ located near the septum of both atriums and forming conduction blocks in this area, possibly leading to BiAT. BiAT depends on two separate interatrial electric connections.\(^3\)\(^,\)\(^4\) In this case, the Bachman bundle and atrial high septum were responsible for the interatrial connections. A study examining 26 heart specimens found interatrial connections in the atrial high septum in 73% of cases.\(^6\) BiAT using the atrial high septum and Bachman bundle is not rare;\(^4\) however, no reports have clearly described the interatrial electrical conduction, and this case report is the first to present its conduction by ripple mapping.

The optimal ablation site for BiAT remains controversial. However, performing ablation without complications is a prerequisite for treatment. Therefore, an accurate understanding of the tachycardia circuit to exclude any unnecessary ablation is very important. In BiAT, in which the atrial septum is part of the re-entrant circuit, as in this case, the septum can be the target site. However, extensive ablation of the atrial septum carries the risk of atrioventricular block or interatrial conduction delay; therefore, if interatrial connections with conduction delays are identified, these sites should be targeted for ablation.

**Figure 1** Twelve-lead electrocardiogram. An atrial tachycardia with a tachycardia cycle length of 304 ms and positive P-waves in leads I, II, III, aVF, V4, V5, and V6 can be seen.
Figure 2 Electroanatomic mapping of atrial tachycardia. (A) In the activation map of the left atrium during atrial tachycardia, atrial tachycardia was suspected to localized re-entrant tachycardia in the anterior wall of the left atrium. (B) The coherent map of both atriums shows the propagation of the tachycardia circuit running from the right atrial high septum to the left atrial septum via an interatrial connection, and turning to the right atrial septum from the left atrial septum below the right superior pulmonary vein via the Bachmann bundle with clockwise rotation. The high-septum interatrial connection appears to have a conduction delay because conduction velocity vectors near the connection are thicker (red arrow) relative to the surrounding areas. Entrainment mapping shows a short post-pacing interval (tachycardia cycle length—post-pacing interval) <20 ms) in right atrial septum and left atrial septum. (C) The voltage map shows a wide low-voltage zone extending from the left atrial anterior wall to the left and right atrial septums.
to avoid complications related to unnecessary extensive ablation (such as linear ablation or homogenization). In this case, the procedure was completed without complications by ablating the epicardial interatrial connection visualized by the ripple map. A relatively long time was required to terminate tachycardia because the epicardial site, which was located away from the energized site, was targeted. Therefore, epicardial interatrial connection ablation should be performed firmly without being impatient even if tachycardia is not terminated quickly. In conclusion, coherent and ripple mapping may facilitate complete understanding of the BiAT circuit and suggest the appropriate ablation target site with minimum risk of complications.

Lead author biography

Yuichiro Sagawa graduated from Tottori University in 2010. He was Junior Resident in Internal Medicine at Ome Municipal General Hospital from 2010 to 2012 and Senior Resident in Cardiology at Tokyo Medical and Dental University Hospital in 2012. Subsequently, he worked as cardiac electrophysiologist at Yokosuka Kyosai Hospital from 2013 to 2016, at Japanese Red Cross Musashino
Figure 3  Left atrial activation map and intracardiac electrophysiology during atrial tachycardia. Clear double potentials can be seen at the site of the PentaRay catheter contact. The preceding potentials (1, 2, 3, 4) are epicardial potentials, while the following potentials (5, 6, 7) are left atrial endocardial potentials.

Video 1  Propagation on an activation map.

Video 2  Propagation on a coherent map.

Video 3  Ripple map.
Hospital from 2016 to 2020, and at Japan Red Cross Yokohama City Bay Hospital in 2020.

**Supplementary material**

**Supplementary material** is available at European Heart Journal - Case Reports online.

**Slide sets:** A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

**Consent:** The authors confirm written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with COPE guidance.

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![Figure 4](https://example.com/f4.png) Intracardiac electrophysiology of successful ablation site. (A) Radiofrequency ablation was performed at the site of double potentials, which can be considered an interatrial connection on the high septum. (B) Biatrial tachycardia is terminated after 17 s of ablation and sinus rhythm is restored without pause.