Atrial Tachycardia Originating from the Upper Left Atrial Septum: Demonstration of Transseptal Interatrial Conduction Using the Infolded Atrial Walls

KOJI KUMAGAI, M.D.,* FUMIO SUZUKI, M.D.,† KAZUTAKA AONUMA, M.D.,‡ and HIROAKI SHIMOKAWA, M.D.*

From the *Department of Cardiovascular Medicine, Tohoku University Graduate School of Medicine, Sendai; †Division of Cardiology, Fukujuji Hospital, Tokyo; and ‡Department of Cardiology, University of Tsukuba Graduate School of Comprehensive Human Sciences, Ibaragi, Japan

Atrial Tachycardia from the Left Atrial Septum. We report a rare case of atrial tachycardia (AT) originating from the upper left atrial septum. Electroanatomic mapping of both atria demonstrated that the earliest atrial activation during AT occurred at the upper left atrial septum 26 msec before the onset of the P wave, followed by the mid-right atrial septum (10 msec before the onset of the P wave) and then the upper right atrial septum just adjacent to the left septal AT site (1 msec before the onset of the P wave), indicating detour pathway conduction from the upper left to the upper right atrium. Embryologically, it was suggested that the superior components of the secondary atrial septum are made by the infolded atrial walls and could develop a transseptal detour pathway involving the left-side atrial septal musculature, the superior rim of the oval fossa and the right-side atrial septal musculature. A single radiofrequency application targeting the upper left atrial septum successfully abolished the AT. *(J Cardiovasc Electrophysiol, Vol. 17, pp. 907-911, August 2006)*

atrial tachycardia, left atrial septum, interatrial conduction, infolded atrial walls

Introduction

We report a rare case of atrial tachycardia (AT) originating from the upper left atrial septum. In this case, discordant atrial activation over the right septal versus left septal endocardial surfaces was observed during AT. This finding may well be explained by the assumption that the septal musculatures are composed of two (not a single) muscular layers divided by an intervening adipose tissue.

Case Report

A 71-year-old woman was referred to the Department of Cardiovascular Medicine at Tohoku University Hospital for the treatment of incessant supraventricular tachycardia. She had been suffering from recurrent episodes of palpitations almost every day for one year. The tachycardia was refractory to several antiarrhythmic drugs, including disopyramide, cibenzoline, and metoprolol. On Holter ECG monitoring, nonsustained and incessant supraventricular tachycardia at a rate of 160 beats per minute, usually lasting for 10–30 beats, was recorded throughout the day. There was no evidence of organic heart disease, including coronary artery disease, or myocardial or valvular heart disease.

An electrophysiological (EP) study was performed using conventional catheter activation mapping and three-dimensional electroanatomic mapping (CARTO, Biosense/Webster, Inc., Diamond Bar, CA, USA) [1] after all antiarrhythmic drugs were discontinued at a minimum of five half-lives. Informed written consent was obtained from the patient before the EP study. Incessant supraventricular tachycardia with narrow QRS morphology continued throughout the EP study. Overdrive suppression of tachycardia was induced by atrial burst pacing, suggesting that the tachycardia mechanism was due to atrial automaticity. Ventricular burst pacing during tachycardia demonstrated atrioventricular (AV) dissociation, thus excluding AV reciprocating tachycardia using an accessory AV pathway. A bolus injection of 20 mg of adenosine triphosphate induced AV block during tachycardia, thereby excluding AV nodal reentry as a mechanism of tachycardia. These findings strongly suggested that the tachycardia was ectopic AT due to atrial automaticity.

AT Localization and Catheter Ablation

To determine the AT origin, CARTO mapping was performed first in the right atrium. The CARTO mapping (Fig. 1A) demonstrated that the earliest endocardial activation in the right atrium occurred at the mid-atrial septum 10 msec before the onset of the surface P wave, from which site the wavefronts spread radially in all directions over the right atrial endocardial surface (Fig. 1B). Several applications of radiofrequency (RF) current targeting the mid-atrial septum failed to abolish the AT. Then, electroanatomic mapping of the left atrium was attempted via a transseptal approach. The CARTO mapping of the left atrium demonstrated that the "true" earliest atrial activation occurred at the upper left atrial septum 26 msec before the onset of the surface P wave (Fig. 1A). It is intriguing to note, from the biatrial CARTO map, that the earliest breakthrough in the right atrium was not located at the upper right atrial septum (activation time: 1 msec before the onset of the P wave) just adjacent to the left septal AT site, but was located at the mid-atrial septum some distance away from the AT site (activation time: 10 msec before the onset of the P wave), indicating discordant septal activation between the left versus right atrium (Fig. 1B). The discordant septal activation strongly suggested that the transseptal conduction of the AT impulse was not using direct muscle-to-muscle connections between the upper left and right atrial septum. Rather, the wavefront from the left septal AT site

Address for correspondence: Koji Kumagai, M.D., Department of Cardiovascular Medicine, Tohoku University Graduate School of Medicine, 1-1 Seiryo-machi, Sendai, Japan 980-8574. Fax: +81-22-717-7156; E-mail: kkumagai@cardio.med.tohoku.ac.jp

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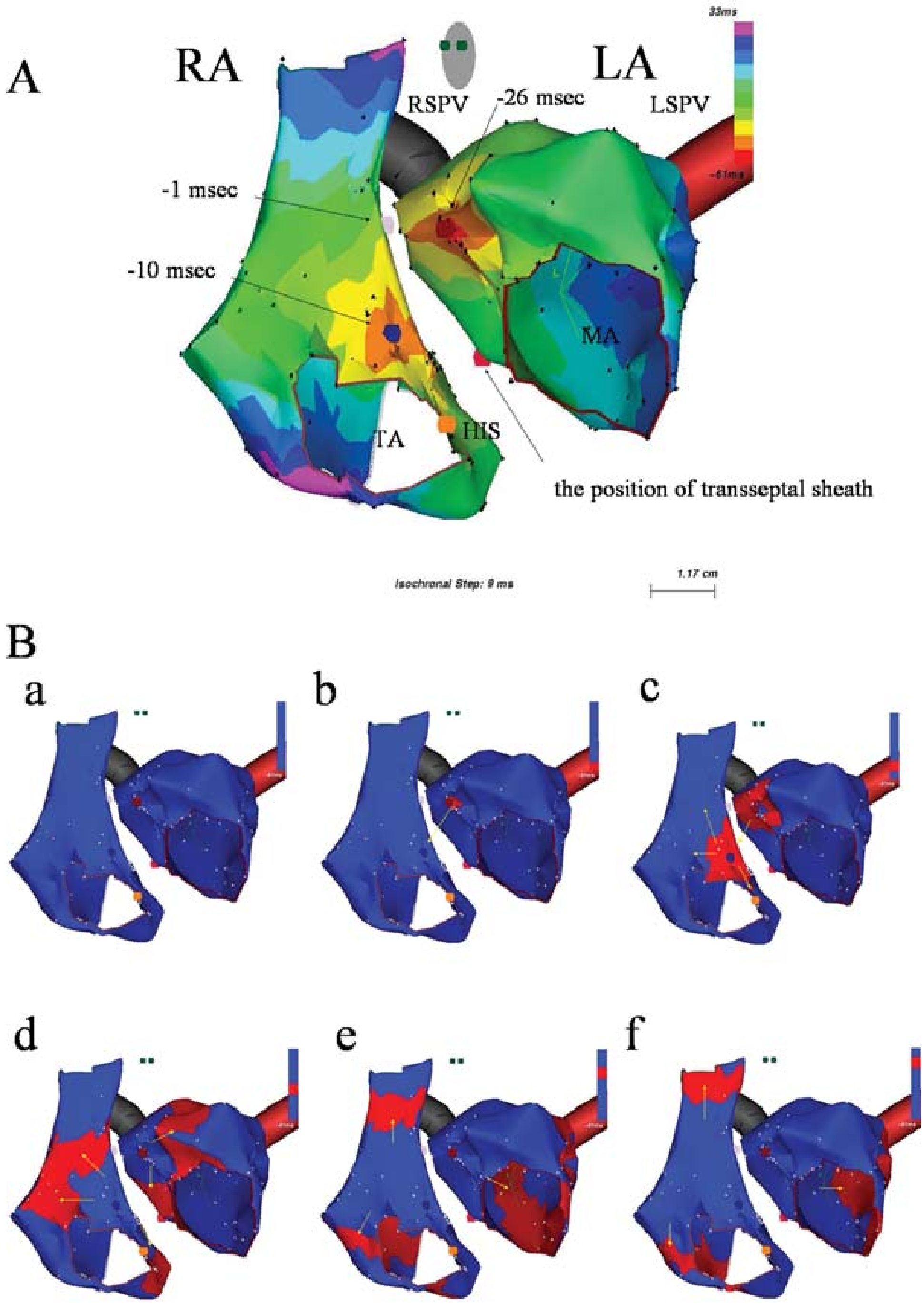

Figure 1. *A: Biatrial activation map during AT in the left anterior oblique view (60°). The color-coded activation sequence is shown in red to purple, demonstrating the earliest to the latest excitation site. A single area showing the earliest activation (red) is located at the upper left atrial septum. Furthermore, another area with the earliest activation (blue) in the right atrium (RA) is identified at the mid-atrial septum (presumably, the rim of the oval fossa). Excitation at the upper right atrial septum just opposite to the left septal AT site is delayed and follows that of the mid-right atrial septum. The pink and orange tags indicate the point where the transseptal sheath was placed at the oval fossa and the site of the HIS, respectively. Note that the earliest activation site at the upper left atrial septum (red) is about 3 cm above the position of the transseptal sheath, whereas the area with the earliest activation in the RA (blue) is positioned only a little above the level of the transseptal sheath (HIS = His bundle region; LA = left atrium; LSPV = left superior pulmonary vein; MA = mitral annulus; RSPV = right superior pulmonary vein; TA = tricuspid annulus). B: Biatrial propagation maps (a through f) during AT in the left anterior oblique view (60°). The wavefronts from the AT site spread radially over the left atrial endocardial surface; part of the AT wavefronts is transmitted to the mid-right atrial septum, and then spread radially from that site over the right atrial endocardial surface.*

seemed to reach the superior rim of the oval fossa first via the left-side musculature of the atrial septum, and then from that site propagated upward toward the upper right atrial septum by way of the right-side septal musculature (detour pathway conduction). A single RF application (tip temperature 50°C, 60 seconds energy delivery) targeting the upper left atrial septum successfully abolished the AT (Fig. 2). The patient was free from symptoms during a follow-up period of 13 months.

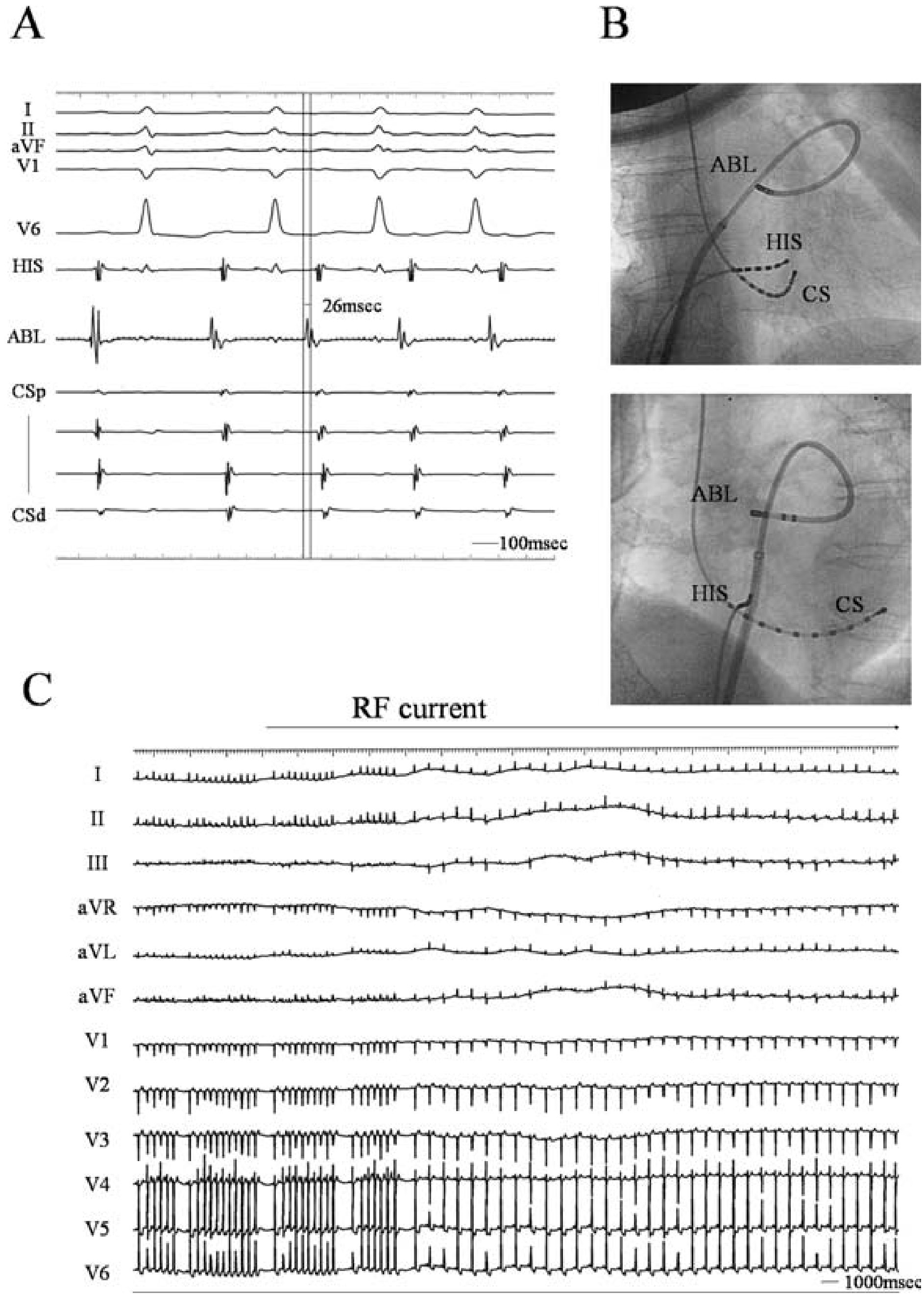

Figure 2. *ECG tracings and successful ablation. A: The earliest activation on the ablation catheter preceded the onset of the surface P wave by 26 msec during AT. B: Catheter position at the successful ablation site in the antero-posterior view (top) and 60° left anterior oblique view (bottom). Successful ablation site was located about 3 cm above the position of the transseptal sheath at the oval fossa. C: Incessant AT was terminated 6.5 seconds after the beginning of radiofrequency (RF) current application (ABL = ablation catheter; CSp and CSd = proximal and distal sites of the coronary sinus; HIS = His bundle region).*

Discussion

To the best of our knowledge, this is the first case report of left septal AT originating from the upper left atrial septum during which interatrial electrical conduction from the left to right atrium was shown, with biatrial CARTO mapping, to occur transseptally by way of the left-side atrial septal musculature, the superior rim of the oval fossa, and eventually the right-side atrial septal musculature. Hoffmann et al. reported that among the 12 patients with left ectopic AT, ectopic foci were found to be located at the inferior area near the mitral annulus, ostium of the left atrial appendage, and the ostia of the pulmonary veins, and that there was no left septal AT originating from the left atrial septum.[2] Marrouche et al. indicated that among the five patients with left septal AT, the sites of tachycardia origin were located at the left inferoposterior atrial septum in three patients and the mid-atrial septum in two patients and that there was no left septal AT originating from the upper left atrial septum.[3] Dong et al. also demonstrated that among the 16 left atrial focal tachycardias, two ATs originated from the mid-atrial septum and there was no AT originating from the upper left atrial septum.[4]

Two-Layered Musculatures Within the Septum Secundum

Embryologically, the atrial septum originates from two different anatomic and histological regions of the sinus venosus and is supposed to be formed by the adhesion of the septum primum and secundum. The superior components of the so-called septum secundum are made by the infolding of atrial walls between the superior caval and right pulmonary veins and therefore do not constitute a true septum separating the right and left atrial chambers.[5,6] Histologically, it has been postulated that due to the infolding of atrial walls, the structure of the upper atrial septum above the level of the oval foramen is composed of three-layered tissues—the right- and left-sided atrial musculatures and the (embryologically, epicardial) fibrofatty tissue separating those two muscular layers.[5,6] However, presence or absence of two-layered musculatures within the septum secundum has long been ignored in the study of interatrial transseptal conduction between the right and the left atrium.

Transseptal Conduction: Straight Pathway versus Detour Pathway

Most clinical cardiac electrophysiologists would probably suppose, in the absence of proper understanding of the development and anatomy of the atrial septum, that the primary and secondary atrial septums grow into the common atrium like overlapping muscular sheets.[5] When a single-layered muscular sheet is presumed to constitute the superior component of secondary atrial septum, transseptal conduction of the AT impulse from the upper left to right atrial septum may use direct muscle-to-muscle communications (straight pathway conduction). This straight pathway conduction, however, was excluded because the biatrial CARTO map showed that the earliest breakthrough in the right atrium was not located at the upper right atrial septum just adjacent to the left septal AT site, but was located at the mid-atrial septum some distance away from the AT site (Fig. 1). Thus, the biatrial CARTO map from this patient strongly suggests the presence of transseptal detour pathway employing the superior rim of the oval fossa. Embryologically, it is suggested that the superior components of the so-called septum secundum are made by the infolding of atrial walls between the superior caval and right pulmonary veins.[5,6] This anatomical arrangement would likely form the detour pathway from the upper left atrial septum (= AT origin) to the upper right atrial septum.

In addition to the detour pathway through infolded atrial walls, it would also be conceivable that discordant septal activation may be attributable, in part, to the anisotropic conduction related to the myocardial architecture[7] near the AT site.

Sites of Interatrial Connections

The two atrial chambers are generally assumed to be connected to each other both anatomically and electrically at the level of Bachmann's bundle,[8] the coronary sinus (CS) musculature[9] and the region of the oval fossa.[5,6,10] Roithinger et al. performed right atrial CARTO mapping during pacing from the distal CS or the posterior wall of the left atrium in humans and identified three sites of transseptal breakthrough (i.e., the region of the CS orifice, putative insertion site of Bachmann's bundle, and the region of the oval fossa).[10] By contrast, Lemery et al. performed right and left atrial noncontact mapping during pacing from the left atrial appendage, the proximal, and the distal CS and identified transseptal breakthrough only at the level of Bachmann's bundle and the CS orifice in the majority of patients.[8] In their study, interatrial electrical conduction through the region of the oval fossa was generally not identified.[8] In our case report, biatrial CARTO mapping during left septal AT showed that the transseptal electrical conduction from the left to the right atrium occurred only through the region of the oval fossa (Fig. 1). This may be related to the site of AT origin,[8] and may be due to the geometric characteristics that the AT focus (upper left atrial septum) was more closely located to the site of the oval fossa than to the left atrial insertion site of Bachmann's bundle or to the region of the CS musculature. In this regard, Sakamoto et al. described in their canine pacing study that the distance from the pacing site to each of the insertion sites of interatrial muscular connections in the ipsilateral atrium was the primary determinant in the selection of preferred conduction pathway.[11]

It is possible that the AT origin of this patient, in fact, may have been the anterior aspect of the antrum of the right superior or right middle lobe pulmonary vein, which was adjacent to the upper left atrial septum. It is sometimes difficult to appreciate where the pulmonary veins start and where the junction with the left atrium is. Integration of the CARTO map with a CT or MR imaging may have been helpful in differentiating AT from pulmonary vein tachycardia, but such integration was not performed in this patient.

Limitations

Although in the present case, we consider that the superior components of the so-called septum secundum are made by the infolding of atrial walls between the superior caval and right pulmonary veins,[5,6] the actual prevalence of septum secundum formed by the infolded atrial walls in the human atrium remains unknown. Lemery et al.[8] described that interatrial electrical conduction through the region of the oval fossa was found in only one patient (5%) when distal CS pacing was performed. This seems to suggest that the actual prevalence of septum secundum formed by the infolded atrial walls may be low in the adult humans.

We have shown using biatrial CARTO mapping that during left septal AT the right atrial endocardial activation started from the mid-right atrial septum (Fig. 1), suggesting that the transseptal conduction from the left to the right atrium occurred through the region of the oval fossa. This finding does not necessarily denote that the interatrial conduction over the Bachmann's bundle was structurally interrupted. Rather, it is likely that when pacing was performed from the putative left atrial insertion site of Bachmann's bundle near the left atrial appendage, right atrial breakthrough over the Bachmann's bundle would be identified. However, left atrial pacing was not attempted in this patient.

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