3-D mapping of Left Atrial Conduction Pattern

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The purpose of this study is to examine a normal conduction pathway of the left atrium. During pulmonary vein isolation using a three-dimensional mapping system, we observed the characteristics of the conduction pattern. Subjects consisted of 15 patients with paroxysmal atrial fibrillation (mean age, 62.8 ± 8.4 years). Left atrial activation conduction begins in the interatrial septum, and moves toward the peak of the ridge between the left atrial appendage and left pulmonary vein. In coronary sinus or appendage pacing, conduction was in the opposite direction at the same location. The mean conduction velocity in this area was 2.03 ± 0.43 m/s. Features of decrement conduction were not present. Anatomical position of the appendage differed greatly between patients. A detailed observation using the inner-cavity view of a three-dimensional mapping system also showed that the peak of the ridge reached the center of the roof.

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Introduction

The trigger for about ninety percent of paroxysmal atrial fibrillation is reported to originate from the pulmonary vein (PV).1) A percutaneous isolation procedure in which the ostial PV and left atrium are electrically isolated using radiofrequency catheter ablation2) is being used with increasing frequency in recent years. Various other ablation methods have also been reported recently.3–5) On the other hand, cases of persistent atrial fibrillation are reported to be alleviated by ablation for the complex fractionated atrial electrogram.6) However, there are few reports about the normal conduction pattern around the left atrium and related electrophysiological features. The purpose of this study is to clarify our understanding of the normal conduction pathway of the left atrium using a noncontact electroanatomical mapping system (NCM).

Methods

Radiofrequency catheter ablation was performed in 15 consecutive consenting patients with paroxysmal atrial fibrillation (13 men, 2 women: mean age, 62.8 ± 8.4 years). Patient details are summarized in Table 1. The mean left atrial dimension, from long-axis view by echocardiography, was 38.4 ± 7.9 mm, and the mean left atrial volume obtained with a four-chamber cross-sectional view was 1988.0 ± 769.6 mm³. All antiarrhythmic drugs were stopped at least three half-lives before the study. PV and posterior wall isolation with a single large circular lesion was performed according to a method pre-
Previously described, during radiofrequency ablation, sequential mapping of the left atrium was performed using EnSite (St. Jude Medical, MN, USA) as the NCM system. We observed the features of the normal conduction pattern of the left atrium. The multiple-electrode array of NCM was placed on the left atrial appendage (LAA). CARTO-merge (Biosense Webster, CA, USA) was also used to accurately assess the anatomical distribution relationship in patients enrolled in this study. A three-dimensional rendering of the left atrium was created from a multi-detector computed tomography image. The pattern of activation conduction in the left atrium was investigated using the NCM. The track of the earliest activation was depicted using tracking virtual (TV), a program that comes with the NCM and shows the largest negative site on a virtual unipolar electrogram. We used TV to determine the process and features of the pathway. Overdrive pacing (1:1 atrial capture or until 180 ms) in the right atrium, distal coronary sinus, and LAA was performed. The purpose of this study was to assess the conduction pattern. To establish measurement of conduction velocity, we defined the area extending directly from the right and left edges of the mitral valve annulus to the atrial roof as the two edges of the anterior wall (Figure 1). One major advantage of the NCM is that a virtual electrogram can be obtained in any location. In addition, conduction velocity in the chosen sites can be calculated by obtaining the distance. The velocity passing through the area defined as the anterior wall was obtained for each case.

**Results**

During sinus rhythm and pacing in right atrium, TV was observed to move laterally between the roof and mitral valve annulus on the anterior wall. In all cases, this activation conduction was shown to begin from the interatrial septum and progress toward peak of the ridge in the antero-lateral margin separating the PV from the LAA (Figure 2). In the area beyond the peak of the PV–LAA ridge, the activation conduction moved towards the anterioris. In three of fifty cases (20%), the direction of activation conduction was changed by pacing from the peak of the PV–LAA ridge to the posterior wall. TV was confirmed to move in the opposite direction at the same location in the anterior wall in cases with pacing in the coronary sinus or LAA. The mean conduction velocity in this area was $2.03 \pm 0.43$ m/s. After the study of conduction velocity, we analyze the features via this specific site using an overdrive pacing method. The pacing rate changed from 600 to 180 ms, and with pacing in each site, no significant change in velocity was observed (Figure 3). Decrement conduction was not present. There was no significant difference between atrial dimension (Figure 4) and conduction velocity (Figure 5) obtained with left atrium.

### Table 1 Patient characteristics (left atrium)

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<th>velocity (m/s)</th>
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Bi-direction of conduction pattern by RA pace: cases 5, 9, 10.

![Figure 1](image1.png)

**Figure 1**

Left anterior oblique view shows the left atrium. The “dot-line” shows the distance and location that we establish as the anterior wall in this study.

![Table 1](image2.png)
Discussion

The area of earliest activation conduction in the left atrium in response to sinus rhythm and pacing followed nearly the same route anatomically. Recent anatomical investigations of the anterior wall of the left atrium have identified the existence of a location called the transverse myocardial bundle (TMB). This is a muscle bundle seen on the epicardial side that begins superior to the fossa ovalis and ends at the peak of the PV–LAA ridge. The earliest activation conduction we observed in the anterior wall was in the same location reported for the TMB. This suggests that the TMB is associated with a conduction route in the left atrium. We are also investigating the relationship between this location and Bachmann’s bundle, which connects both atria, but at the present the relationship remains unclear. With regard to the direction of conduction in this area, the possibility that a functional block line exists in the atrial roof cannot be ruled out, but a detailed investigation of the anatomical positional relationship using CARTO-merge confirmed that conduction in the anterior wall always detours at the peak of the PV–LAA ridge. In addition, no significant velocity changes such as the property of decrement conduction were observed in response to burst pacing from both directions. In this study, we were not able to establish the property in this area. A possible reason is the short measurement distance (mean distance 28.6 ± 6.8 mm). This study used NCM and chose only the anterior wall which was a smooth aspect of the left atrium intentionally because of the limitation of this system. In addition, the structure of the left atrium is complicated. It is estimated that various other factors are associated with decrement conduction. Various methods have been reported for ablation procedures to treat atrial fibrillation. However, the same ablation site at the PV anterior wall is used in most methods. Ablation passed up the peak of the PV–LAA ridge. Some have suggested the peak of the PV–LAA ridge as important and
Ablation of this point is often required. In addition, the existence of one of the cardiac ganglionated plexi near this area has also been reported. Activation conduction from the interatrial septum is separated in this area, an important area anatomically and electrophysiologically. We suggest that these findings resemble the crista terminalis of the right atrium. In this study, another important point was observed about the feature of the peak of the PV–LAA ridge. Close observation of the ridge position using the intra-cavity view of CARTO-merge revealed that the peak of the PV–LAA ridge reaches the center part of the left atrial roof (Figure 6). The position of the LAA is protean in a way by each

Figure 3
Pacing in the right atrium shows antero-posterior view (upper section) and cranial view (lower section). In figure (a), a red dot shows the earliest unipolar electrogram of tracking virtual (TV). The earliest activity begins at the interatrial septum. Figure (b) shows that the TV goes through the anterior wall toward the peak of the ridge. Figure (c) shows the point in which TV moved down during LAA and LSPV. Figure (d) shows the TV path advancing from the peak of the ridge to the posterior wall.

RSPV: right superior pulmonary vein, RIPV: right inferior pulmonary vein, LSPV: left superior pulmonary vein, LIPV: left inferior pulmonary vein, LAA: left atrial appendage.

Figure 4
This graph shows the relationship between conduction velocity (m/s) and left atrial dimension (mm2) during pacing from right atrium. There was no significant correlation present among both parameters. However, in the case with a patient who had an enlarged left atrium, there is a tendency towards a decrease in conduction velocity was observed.
case. Also, the position of the peak of the PV–LAA ridge is prescribed by the left atrium. Therefore, it was thought that we should have evaluated the position of the ridge when we ablated it. In particular, for the cases for which PV isolation is difficult, it is desirable to set an ablation line in the dorsum from the peak of the PV–LAA ridge. In the TBM region, wall-thickness is thicker than at other

Figure 5
The figure shows a graph which compared conduction velocity (m/s) of the left atrium with a pacing rate (bpm).

Figure 6
Intra-cavity view shows left atrium and left side of pulmonary vein (PV) and left atrial appendage (LAA) using the CARTO-merge system. The arrow demonstrates the peak of the PV-LAA ridge. Figure 6-1 shows a case in which LAA is located in the left lateral portion. In these cases, the peak of the PV-LAA ridge is confined to be situated on the left side. On the other hand, if the appendage is located more anteriorly, the peak of the PV-LAA ridge does a shift to central part of the left atrium (Figure 6-2). In this way, the position of the ridge is influenced by the position of the LAA.
site. This is the anatomical features that we should consider when recognizing the gaps in the line of ablation.

**Conclusion**

An active conduction pathway in the left atrium was observed using NCM. Regularity along the TMB in the anterior wall was observed in conduction at the left atrium during sinus rhythm, which ended at the peak of the PV–LAA ridge. In this study, conduction velocity did not change with pacing rate, and the feature of decrement conduction property was not observed. Anatomical position of the LAA differs greatly between patients. Our observation showed the peak of the ridge extending to the center of the left atrial roof. Further study of the electrophysiological problems of the peak of the PV–LAA ridge is expected.

**References**