Activation Patterns and Conduction Velocity in Posterolateral Right Atrium During Typical Atrial Flutter Using an Electroanatomic Mapping System

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Background To investigate the activation patterns and conduction velocity (CV) in the posterolateral right atrial (RA) wall during typical counterclockwise atrial flutter (AFL) using an electroanatomic mapping system.

Methods and Results During typical AFL in 25 patients, the transverse conduction pattern and CV were classified and calculated. The line blocking transverse conduction was defined by the conduction pattern and double potentials recorded during mapping. There were 3 types (including 2 subtypes) of transverse conduction pattern based on the conduction blocks across the posterolateral RA in a line between the superior and inferior venae cavae. Trans-cristal conduction activation in a horizontal direction was seen in all but 4 patients. The CV in the gap area was 0.59±0.21 m/s.

Conclusions Three types of transverse conduction pattern were observed during trans-cristal conduction and the trans-cristal CV was relatively slower than that in other parts of the RA, except for the isthmus. (Circ J 2008; 72: 384–391)

Key Words: Atrial flutter; Catheter ablation; Conduction velocity; Crista terminalis; Electroanatomic mapping system

Atrial flutter (AFL) has been traditionally defined as a tachycardia greater than 240 beats/min with a continuously waving baseline; however, electrophysiological studies have demonstrated that current classifications of AFL based only on the ECG pattern are inadequate.1 Typical AFL activation occurs in a virtual ring of muscle bounded anteriorly by the tricuspid annulus (TA), posteriorly by the orifices of the superior vena cava (SVC) and inferior vena cava (IVC), and by a line of functional block linked by the crista terminalis (CT) in the posterior wall of the right atrium (RA).2 The cavotricuspid isthmus is an essential part of the typical AFL circuit and has been identified as the area of slow conduction.3,4 To date, it has been assumed that activation of typical AFL rotates around the TA, and it is considered that an electrical barrier to transverse conduction exists throughout the posterolateral area of the RA, from the SVC to the IVC5,6. However, it has been shown recently that blocking does not occur in that entire region.7,8 Thus, there may be the complication of another loop reentry, together with typical AFL rotation around the TA. Furthermore, the other loop reentry would travel across the line between the SVC and IVC in the posterolateral wall of the RA, and this has been confirmed by conventional electrophysiological methods9 and, recently, by noncontact mapping.7,8 The pattern of propagation across the posterolateral RA has been studied using virtual electrograms10 but the conduction patterns and conduction velocity (CV) across the CT during typical AFL, as seen on actual electrograms, are not completely understood.

In the present study, we evaluated not only the conduction pattern but also the CV in the lateral RA area during typical counterclockwise (CCW) AFL using a high-resolution electroanatomic mapping system.

Methods

Patient Characteristics The study group consisted of 25 symptomatic patients (22 men, 3 women, mean age 64±12 years) who had undergone successful catheter ablation of typical AFL (Table 1). Of them, 19 had a history of paroxysmal atrial fibrillation and 17 had cardiovascular diseases, comprising 9 with hypertension, 4 with valvular disease, 2 with coronary disease and 2 with dilated cardiomyopathy (Table 1). Eighteen patients with atrial fibrillation had mainly AFL in the clinical setting; their atrial fibrillation was either incidentally documented as a few episodes that terminated in less than several hours, or was documented only in the perioperative phase. In this study, all patients had AFL that was documented by ECG when they were not given anti-arrhythmic drugs.

Electrophysiological Study (EPS) Informed written consent was given by all patients before participating in the EPS. As described previously, all anti-
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Circulation Journal Vol.72, March 2008

Arrhythmia drugs were discontinued for at least 5 half-lives before the study. None of the patients was given amiodarone or bepridil. In all patients a 7-Fr, 20-pole, deflectable halo catheter with 10-mm paired spacing (Biosense-Webster, Johnson & Johnson, NJ, USA) was positioned around the TA to simultaneously record RA activation in the high septal wall, roof, lateral wall and cavotricuspid isthmus. A 5-Fr, 10-pole catheter with 2-mm interelectrode distance and 5-mm spacing between each electrode pair was also inserted into the coronary sinus (CS) via the subclavian vein.

Table 1 Clinical Characteristics of the Patients

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<th>Sex</th>
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<th>LVEF (%)</th>
<th>LAD (mm)</th>
<th>LVEDd (mm)</th>
<th>AFLCL (mm)</th>
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Mean ± SD 64 ± 12  60 ± 14  40 ± 7  50 ± 5  248 ± 31

AF, atrial fibrillation; HT, hypertension; LVEF, left ventricular ejection fraction; LAD, left atrial dimension; LVEDd, left ventricular end-diastolic dimension; AFLCL, atrial flutter cycle length; VD, valvular disease; OP, postoperative state; DCM, dilated cardiomyopathy; TCM, tachycardia induced cardiomyopathy; IHD, ischemic heart disease; ASD, atrial septal defect; AVB, atrioventricular block; PM, permanent pacemaker implantation.

Table 2 Cycle Length of Atrial Flutter, CV, Area of Block, Conduction Pattern, and % of Gap

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<th>Case no.</th>
<th>No. of points</th>
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<th>Gap pattern</th>
<th>%</th>
<th>CV (m/s)</th>
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Mean ± SD 108 ± 14  51 ± 19  0.59 ± 0.21

CV, conduction velocity; ND, calculation of CV was not done.
The proximal electrode pair was positioned at the ostium of
the CS, and 5-Fr multipolar catheters were placed at the
high RA, the bundle of His and the right ventricular apex.
An 8-Fr sheath (Preface, Biosense-Webster, Johnson &
Johnson) placed in the right femoral vein was used to intro-
duce the electroanatomic mapping catheter. A 7-Fr, 4-mm tip
electrode mapping/ablation catheter (Navi-Star, Biosense-
Webster, Johnson & Johnson) was advanced into the RA.
If spontaneous AFL was found at the onset of the study, we
performed halo catheter mapping and electroanatomic
mapping to investigate the reentrant circuit. Typical AFL
was present during the study, and mapping was performed
during the arrhythmia. If sinus rhythm was present at base-
line, low RA or CS pacing was performed until 2:1 atrial
capture, in order to induce AFL, and then mapping was per-
formed. All stimuli were delivered through an external stim-
ulator at a 2-ms pulse width at twice the diastolic threshold.
Rapid atrial pacing for concealed entrainment was done in
all patients in the area of the cavotricuspid isthmus during
AFL for confirmation of cavotricuspid-isthmus-related
AFL, and in the posterolateral RA in 8 patients who had a
CT gap in that area.

Electroanatomic Mapping System
The CARTO™ nonfluoroscopic electroanatomic map-
ning and navigation system (Biosense-Webster, Johnson &
Johnson) has been described elsewhere. A 4-mm tip cathe-
ter (Navi-Star) is used for mapping and ablation. Because
of its positional and morphological stability, the electro-
gram recorded by the CS catheter is considered as the refer-
ence for local activation time. The 3-dimensional geometry
of the chamber is reconstructed in real time from the elec-
trophysiological information, which is colour-coded and
superimposed on the anatomic map. The RA is plotted by
dragging the mapping catheter over the endocardium and
mapping is complete when all lesions of the RA have been
systematically sampled. The maximum negative dV/dt of
the unipolar electrogram is selected as the local activation
time. In the present study, CARTO mapping of the RA was
performed during AFL in all 25 patients. Furthermore,
mapping was performed during atrial pacing at a cycle
length (CL) of 600 ms from the CS during sinus rhythm in
10 patients after completion of a linear block on the cavo-
tricuspid isthmus using radiofrequency catheter ablation.
The voltage maps produced in all patients during typical
episodes of AFL in the RA posterolateral wall were also
evaluated. The voltages of atrial electrograms arbitrarily
selected from 3 sites in the block area and 3 sites in the
propagation area were calculated using the AFL voltage
map. When a double potential was recorded in the block
area, the higher voltage was selected as 1 of the sites. In the
study of the voltage of the atrial electrograms, the block area
was defined as the area close to the block line (<10 mm)
estimated from both the activation and propagation maps.
In 21 patients (cases 5–25 in Table 2), the non-block area
was defined as the area where conduction was observed in
the posterolateral area.

Radiofrequency Catheter Ablation
After concordance of the post-pacing interval at the cav-
otricuspid isthmus with the CL of AFL was confirmed, radio-
frequency catheter ablation of the cavotricuspid isthmus
was performed with a 4-mm tip catheter (Navi-Star) during
AFL and by pacing from the proximal CS during sinus
rhythm.

The preset temperature was 50–60°C and the preset dura-
tion of each radiofrequency application was 60 s. The aim
was to create linear lesions on the cavitricuspid isthmus.
Pacing at up to 300 beats/min from the RA lateral wall and
CS was performed after achieving bidirectional isthmus
block, which was defined as successful ablation.

Measurement and Calculation of CV
Based on the anatomic mapping, the RA was viewed
from the right posterolateral view. Double potentials were
often seen in the posterolateral area, at the sinus venosa or
CT, during typical AFL. The activation pattern in this view
was evaluated on the propagation and activation maps, and
based on them and the location of the double potentials, a
virtual straight line was drawn from the SVC to the IVC
(Fig 1 Left).

In this study, CV was calculated by the method of
Kojodjojo et al12 for accurate measurement (Fig 1). Three
adjoining points were selected on either side of the virtual

Fig1. Methods used to determine the conduc-
tion velocity of the main activation wavefront.
(Left panel) Isochronal map of counterclockwise
typical atrial flutter (isochronal step: 10 ms). See
text for details. Pink dots indicate where double
potentials were recorded. The dotted line from the
superior vena cava (SVC) and the inferior vena
cava (IVC) indicates the virtual straight line and
shows where the virtual straight line is exceeded
and conduction spreads from the posterior side to
the lateral side. The insert shows the 3 endocardial
points marked O, A and B used for calculation of
the conduction velocity and the Right Upper panel
is a schematic representation of them. Two points
are set in front of the virtual straight line and 1 be-
hind the line. The point at the shortest distance
from point O is named point A (OA < OB). A
triangle is formed from these 3 points, and the
conduction velocity is calculated. Colour bar indi-
cates the time range within the isochronal map.
CS, coronary sinus.
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straight line and on each side adjacent points with a distance of less than 20 mm were selected. One (eg, O in Fig 1) was set on the posterior side of the virtual straight line, and the remaining 2 (Figs 1A,B) were set on the anterior side of the line (Fig 1 Right). In this method, the 3 points define a triangle in a single plane and the distance between any 2 points in 3-dimensional space can be calculated using the formula:

\[
OA = \sqrt{(Xa-Xo)^2 + (Ya-Yo)^2 + (Za-Zo)^2}
\]

if O and A have the coordinates (Xo, Yo, Zo) and (Xa, Ya, Za), respectively.

\(tOA\) is the difference in local activation time between O and A, respectively.

Therefore, the wavefront propagation CV is given as:

\[
CV = \frac{OA}{tOA} \cos \theta.
\]

In this model, conduction within each triad is assumed to be uniform and chamber curvature is not considered; however, by limiting the distance between the 2 furthest points of the triad to less than 20 mm, with a mean distance of 13.2±4.3 mm between O and A, these potential causes of errors are minimized.

In the present study when 2 or more block lines were seen in the posterolateral area, we used the calculated CV of the anterior block line.

The distance from the SVC to the IVC was based on the virtual straight line. In addition, we measured the length of the block line from the IVC and the end of the block line was based on the pivot point determined from the activation and propagation mapping. The end of the block line from the SVC was selected using the same method. However, we did not draw the block line from the SVC, and no pivot point was seen because a collision between the activation wavefront traveling in a CCW direction from the TA and that from the posterior wall occurred in the upper area. Furthermore, the CV was not calculated when we observed a complete block line from the SVC and IVC in the posterolateral area.

In addition, we considered that in the human atrium the calculated CV in the area of a conduction block determines the relationship between CV and the appearance of conduction block.

Definitions

Typical AFL was defined as a macro-reentrant atrial tachycardia circulating around the TA and cavotricuspid isthmus, as demonstrated by concealed entrainment performed at the cavotricuspid isthmus. CCW typical AFL was defined as typical AFL with a descending activation sequence in the free wall and an ascending sequence in the septal wall. Clockwise typical AFL was defined as typical AFL with a descending activation sequence in the septal wall and an ascending sequence in the free wall. A scar area was defined from an electrophysiological standpoint as an electrically silent area with an electrogram amplitude <0.04 mV and which displayed no distinguishable or repetitive patterns.

The block line was defined by both the presence of double potentials and from observations derived from propagation and activation mapping during CCW AFL. Thus, the conduction block line appeared and the activation wavefront turned at the pivot points, as previously reported.

Statistical Analysis

Continuous values are expressed as mean±standard deviation. SPSS 11.0 for Windows was used for the statistical analysis (Chicago, IL, USA) and the unpaired Student’s t-test was used for comparing 2 groups. A p-value of 0.05 or less was considered significant.

Results

Electroanatomic Mapping During Typical CCW AFL

Complete electroanatomic maps were obtained for typical instances of AFL (mean CL=248±31 ms, range 210–330 ms; Table 2). All patients had CCW activation of the RA limited anteriorly by the TA. In addition, pacing from the cavotricuspid isthmus during AFL showed concealed entrainment, with the post-pacing interval equal to the AFL CL in all patients.

Global atrial mapping from 108±34 points showed complete circuit activation around the TA in the RA. During CCW AFL, the leading edge of the activation wavefront emerged from the low posteroseptal region, traveled up the septal and posterior walls, reached the roof, spread down the anterolateral wall and entered the cavotricuspid isthmus. Moreover, the activation wavefront circulated CCW around the TA, merged with the activation wavefront and traveled through the posterior area in the anterior lateral area of the RA (9–11 o’clock positions in Fig 1). In all patients the direction of the activation wavefront demonstrated by the electroanatomic mapping system was consistent with the activation sequence recorded by the halo catheter.

Activation and Propagation Patterns During Typical AFL in the RA Posterolateral Wall

Conduction in the transverse direction of the right posterior wall was from the septal wall to the free wall. With some exceptions, conduction of excitation in 2 directions united at the lateral wall and descended the free wall. A block line was seen on the posterolateral RA wall in the activation and propagation maps of the 25 patients during typical AFL and was confirmed by the presence of double potentials in the electrograms recorded along the line. The pattern of conduction over the CT during typical AFL was divided into 3 types.

1) Type A (single complete block, n=4). The block line was seen on the posterolateral wall in 4 patients with CCW AFL. Electrograms along the line of block demonstrated widely separated double potentials from the SVC side to the IVC side, and the line of block extended from the IVC to the SVC. Because conduction in this area was very slow and the excitation that had turned from behind was cut off, it was confirmed that it did not unite with the excitation conduction that had rotated around the TA (Fig 2A).

2) Type B (single incomplete line of block, n=19). A single incomplete block was seen on the posterolateral wall in 19 patients with CCW AFL. Electrograms along the line of block demonstrated double potentials. In 4 patients propagation across the lateral wall of the RA was seen only in the mid portion of the line (subtype I; Fig 2B). The block line was observed in the lower area; it did not extend to the upper area in 15 patients (subtype II; Fig 2C).

3) Type C (double incomplete line of block, n=2). Two block lines were seen on the posterolateral wall in 2 patients with CCW AFL. In both patients, double poten-
tials were scattered in 2 areas on the lower posterolateral wall. The 2 block lines extended from the IVC to the mid posterolateral RA, but did not reach the SVC (Fig 2D).

In all 25 cases, trans-cristal conduction in the horizontal direction did not occur in the area close to the IVC.

Fig 2. Representative cases of the conduction patterns according to the crista terminalis and isochronal maps (step: 10 ms) and voltage maps of typical counterclockwise atrial flutter (CCW AFL). The arrows indicate the direction of conduction. The white dotted line indicates the virtual straight line. The blue dots on the isochronal maps for types A, B1 and B2 (A–C Right panels) indicate double potentials. (A) Type A conduction pattern (Left panel) and voltage map (Right panel) during typical CCW AFL (case no. 4). The excitement that conducts from the back of the right atrium (RA) is cut off at the virtual straight line. The excitement in front of the virtual straight line comes only from around the tricuspid annulus. On the voltage map, low voltage potentials spread over the area corresponding to the conduction block area, shown as a dashed line in the Left panel. (B) Type B (subtype I) conduction pattern (Left panel) and voltage map (Right panel) during typical CCW AFL (case no. 7). The excitement from the back of the RA is not completely cut off at the virtual straight line, and is partly conducted. The block exists in 2 places: the upper block touches the superior vena cava (SVC) and the lower block touches the inferior vena cava (IVC). The excitement that passed over the virtual straight line midway unites with the excitement from around the tricuspid annulus. On the voltage map, low voltage potentials spread over the area corresponding to the conduction block area, shown as a dotted line in the Left panel. (C) Type B (subtype II) conduction pattern during typical CCW AFL (case no. 20). The excitement from the back of RA is not completely cut off at the virtual straight line, and is partly conducted. The block exists in only 1 place near the IVC and does not reach the SVC. The excitement that passed over the virtual straight line unites with that from around the tricuspid annulus. On the voltage map, low voltage potentials spread over the area corresponding to the conduction block area close to the IVC, shown as a dotted line in the Left panel. Note that the voltage in the non-block area (gap conduction) is relatively higher that in the block area. (D) Type C conduction pattern during typical CCW AFL (case no. 25). The excitement from the back of RA is not completely cut off at virtual straight line, and part conducts. The block part exists at 2 places. These 2 exist almost in parallel, and each of them is an incomplete block. These block lines, which are placed at the IVC, cannot reach to the SVC. The excitement that passed over these virtual straight lines unites with the excitement around the tricuspid annulus. The pink dot in the isochronal map is a double potential. On the voltage map, low voltage potentials spread over the area corresponding to the conduction block area, shown as a dotted line in the Left panel.

Voltage Maps Recorded During Typical AFL in the RA Posterolateral Wall

In the voltage maps recorded during AFL, the areas close to the SVC, IVC and tricuspid valve showed low voltage (<0.1 mV) and the posterolateral area also had a relatively low voltage compared with other areas (Figs 2A–D Right
panels). Note that the voltage of the area of block was significantly lower than that of the non-block area (0.47±0.40 mV vs 0.83±0.56 mV, p<0.01).

**Activation Patterns During CCW AFL and CS Os Pacing**

We compared the isochronal maps obtained in 10 patients during typical AFL and rapid atrial pacing at a CL of 600 ms. During AFL, the conduction block was observed in the area close to the IVC (Fig 3 Left panel); however, propagation of the activation wave was observed during rapid atrial pacing (Fig 3 Right panel) after successful ablation. In case no. 16 (Fig 3), the post-pacing interval in the middle portion, where propagation of the activation wave was observed, was the same as the CL of AFL. However, the post-pacing interval close to the IVC, where conduction was blocked, was longer by 40 ms than the CL of AFL. The post-pacing interval was concordant with the CL of AFL in 6 of 8 patients in whom concealed entrainment was performed at the area of CT gap.

**Analysis of Regional Conduction Gap and CV**

The mean distance of the virtual straight line from the SVC to the IVC was 76±17 mm in all patients, and the gap constituted 51±19% of the virtual straight line, excluding patients with the type A conduction pattern. The presence of a transverse conduction gap in the CT was observed frequently in 16 of 19 patients with atrial fibrillation; however, there was a history of atrial fibrillation in 3 of 4 patients with single complete blocks (Tables 1,2).

In all patients, we attempted to measure the CV of the main propagation of the activation wavefront, based on the activation and propagation maps (Table 2), and the mean CV of the main activation wavefront traveling across the CT was 0.59±0.21 m/s.

In all patients, the CV in the lower area close to the IVC was less than 0.2 m/s, and conduction in this area was regarded as having a blocked pattern, based on the electroanatomic mapping. Furthermore, if slow conduction occurred in the blocked lower area, the calculated CV was 0.13±0.04 m/s (0.09–0.20 m/s).

**Discussion**

**Global Electroanatomic Mapping During Typical CCW AFL**

Conventional and electroanatomic mapping has contributed substantially to the understanding of typical AFL. The general pattern of RA activation during typical CCW AFL is circular, going up the atrial septum and down the RA anterior wall7 and in studies using the entrainment mapping technique the CT and the Eustachian ridge were the anterior barrier of the reentrant circuit5,6. The broad band of pericricuspid activation narrows as it enters the cavotricuspid isthmus, slows in the medial portion, ascends the septum and crosses the roof in front of the SVC or, more rarely fusing around it15. In the present study, electroanatomic mapping demonstrated that the activation pattern of typical CCW AFL is consistent with that described previously7.

**Conduction Patterns in Characteristic Posterolateral Block During Typical CCW AFL**

The CT is reportedly the posterior barrier and a central line of block in typical AFL8. Conduction disturbance around the CT has been ascribed to anisotropic conduction, discontinuity of effective axial resistance or anatomic disarrangement17. The highly anisotropic arrangement of the intercellular connections in the CT contributes to the large, directional, conduction difference characteristic of this tissue.

Recently, it was shown that the limited transverse conduction ability of the CT may contribute to the development of typical AFL18,19. Localization of the block line, the posterior barrier of the AFL circuit, has been reported to exclude the CT. A functional block has been seen in the sinus venosa area during CCW and CW AFL20. We demonstrated 3 types of conduction block in the posterolateral RA. A single complete block line (type A) was seen in 16% of the patients (4/25), a single incomplete block line (type B) was seen in 76% (19/25), and a double block line (type C) was seen in 8% (2/25). Three block lines have been reported at the CT or sinus venosa during typical AFL using a noncontact mapping system8. In the present study, more than half of the patients had transverse conduction at the CT. Moreover, we showed simultaneous block lines at the CT and sinus venosa. Single complete conduction and double incomplete conduction of the block between the
SVC and IVC were rarely seen when comparing the frequency of an incomplete block line. Our results obtained by electroanatomic mapping are consistent with those of the previous study using a noncontact mapping system. When there was 1 block line, we assumed that it was located in front of the CT. When there were 2 block lines, we considered that the anterior line corresponded to the CT and the posterior one to the sinus venosa, based on previous studies.

It has been reported that a transverse conduction gap in the CT occurs particularly in patients with atrial fibrillation and in the present study a transverse conduction gap in the CT was observed in 16 of 19 patients with atrial fibrillation. However, there was also a history of atrial fibrillation in 3 of 4 patients with a single complete block. These 3 patients had either cardiomyopathy or postoperative valvular disease, so although the organic heart disease might be related to the occurrence of atrial fibrillation, the relationship between the presence of atrial fibrillation and complete transverse conduction block in the CT remains unclear.

**Comparison of Activation Patterns During CCW AFL and CS Pacing**

In the comparison of the isochronal maps obtained during typical AFL and rapid atrial pacing at a CL of 600 ms, a conduction block close to the IVC was not seen during rapid atrial pacing. We emphasize that in the present study, the pattern of conduction in the lower area close to the IVC was regarded as a conduction block in all patients, based on electroanatomic mapping, although this area of block was functional in some of the patients. Several investigators have already reported on this matter.

**CV in Characteristic Posterolateral Block During Typical CCW AFL**

The electroanatomic mapping system enables distance and the time difference to be measured, from which the CV can be calculated. In general, CV depends on the distance, conduction time and the angle between the 2 points selected for measurement of the CV of the main activation wavefront. We used the method of Kojodjojo et al to improve the accuracy of calculating the CV. Furthermore, we selected 2 points anterior and posterior of the virtual straight line when the distance between the 2 points was less than 20 mm, in order to minimize the error caused by endocardial curvature and the long distance between the points.

Many investigators have reported on the CV in the atrium, especially in the TA. In the present study, using 3-dimensional mapping in patients with typical CCW AFL, the mean CVs in the cavotricuspid isthmus (0.81±0.23 m/s) and septum (0.93±0.18 m/s) were significantly slower than those in the lateral free wall (1.16±0.23 m/s) and superior free wall (1.10±0.20 m/s) in 4 segments around the TA and the CV in the cavotricuspid isthmus was significantly slower than that in the septum (p<0.05).

The measured transverse CV across the CT was 0.73±0.30 m/s during upper loop reentry, and the CT gap width was 15.7±6.8 mm. To date, there are no data regarding the CV across the CT using the CARTO mapping system. In our study, the trans-cristal CV was 0.59±0.21 m/s, which is similar to the value found in another study that used a noncontact mapping system (0.73±0.30 m/s, p=0.10) but was relatively slower than the CV in the other part of the reentry limb, except in the isthmus area. Furthermore, to the best of our knowledge this is the first report that the voltage of the block area in CT is significantly lower than that of the propagation area.

The CT gap as a percentage (51±19%) of the distance between the SVC and IVC (76±17 mm) was larger than that in another study using a noncontact mapping system (15.7±6.8 mm in gap width). The difference may be related to the method of determining the pivot points (ie, from the double potentials and propagation mapping in the CARTO mapping system vs from the animation of the isopotential map using the filter setting of 2 Hz). In the noncontact mapping system the counter lines of voltage converged and turned as they passed the edge of the CT gap.

The post-pacing interval was concordant with the CL of AFL in 6 of 8 patients in whom concealed entrainment was performed in the area of the CT gap. Therefore, in our study dual loop reentry was established in the majority of cases of typical AFL with a CT gap, but no upper loop reentry was seen after successful catheter ablation. Thus, we consider that upper loop reentry occurs rarely after ablation, even the dual loop reentry of typical AFL. However, pacing at up to 300 beats/min from the RA lateral wall and CS was only performed after achieving bidirectional isthmus block, because that was defined as successful ablation in this study. A more aggressive pacing protocol might induce dual loop reentry.

**Study Limitations**

For the CV distance, measurements were calculated using a series of short straight-line distances that approximated the true curved surface of the RA, and are therefore subject to error. The closer the distance between 2 points on a sphere, the lesser is the error introduced in calculating the distance between them, given that a line is the asymptotic measure of 2 points with closest proximity on a curved surface. Neither the direction in which the wave side travels or the set direction of these 2 points correspond completely. Therefore, we tried to decrease the error margin further by using the method. The distance from the SVC to the IVC was based on the CARTO mapping because of the difficulty in judging the border between the SVC and the atrium, even when using fluoroscopy or right atrigraphy. In this study, we defined a block occurring at the CT when there was a single block line at the posterolateral RA; however, we did not determine the accurate location of the block line, CT or sinus venosa, because we did not use intracardiac echocardiography. Furthermore, we mapped the posterolateral RA wall in the threshold of 2.0 cm, which might introduce the course mapping. High-density mapping in the threshold of less than 2.0 cm may provide us with more information about transverse conduction across the CT.

**Conclusion**

In the present study there were 3 types of transverse conduction patterns across the line of the posterolateral RA between the SVC and IVC during typical CCW AFL. The trans-cristal CV was relatively slower than that in other parts of the RA, except for the isthmus area. Furthermore, the voltage of the block area in the posterolateral RA was significantly lower than that in the transverse conduction area. The trans-cristal CV measured by the CARTO mapping system was similar to that measured by a noncontact mapping system. In all patients, the conduction pattern in the lower area close to the IVC was regarded as complete block. Thus, (functional) block in this area is essential for
the establishment of typical CCW AFL.

References


