Relation Between Transverse Conduction Capability and the Anatomy of the Crista Terminalis in Patients With Atrial Flutter and Atrial Fibrillation
—— Analysis by Intracardiac Echocardiography ——

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Although crista terminalis (CT) has been identified as the barrier to transverse conduction during typical atrial flutter (AFL), the relation between transverse conduction capabilities and anatomy of the CT remains unclear. The aim of the study was to evaluate that relation using intracardiac echocardiography (ICE). Ten patients with typical AFL (group AFL), 7 patients with paroxysmal atrial fibrillation (PAF) (group AF) and 8 patients without PAF or AFL (group N) underwent electrophysiologic testing. Using ICE images, the maximum diameter of the short axis of the CT (dCT) was measured and mapping and pacing catheters were positioned precisely. From extrastimulation delivered 1–2 cm anteriorly (free wall) or posteriorly (posterior wall) to the CT, the effective refractory period (CT-ERP) was determined as the longest coupling interval that resulted in split potentials at the mapping catheter positioned along the CT, a finding consistent with a transverse conduction block at the CT. The dCT was greater in group AFL than in groups AF and N (5.0±0.8 vs 4.3±0.7, p<0.05 and 4.2±0.4 mm, p<0.01, respectively). The CT-ERP was longer during pacing from the posterior wall than from the free wall (307±68 vs 266±29 ms, p<0.05) as a whole group. The CT-ERP for the posterior wall pacing was longer in group AFL than in group N (339±80 vs 255±13, p<0.05). CT-ERP did not correlate with dCT; however, dCT was greater in patients with split potentials at the CT than in patients without them (4.9±0.8 vs 4.1±0.5 mm, p<0.05). Therefore, the transverse conduction block of CT was more likely to occur in a thick CT. A limited transverse conduction capability of the CT is related to its thickness and might contribute to the development of typical AFL. (Circ J 2002; 66: 1113–1118)

Key Words: Atrial fibrillation; Atrial flutter; Crista terminalis; Intracardiac echocardiography

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typical atrial flutter (AFL) is a macroreentrant rhythm localized to the right atrium (RA)1–4 and the crista terminalis (CT) is a barrier to transverse conduction during the arrhythmia.5–12 Although it is considered to be anatomically fixed5–12 mapping studies in animal models have shown that the CT barrier is functional,10 and recent studies have suggested there is a rate-dependent transverse conduction block at the CT in patients with typical AFL.7,8 However, the relation between transverse conduction capability and the anatomy of the CT has not been elucidated thoroughly.

Intracardiac echocardiography (ICE) is a technique to visualize various intra-atrial structures that are not visible on fluoroscopy and allow precise localization of intracardiac catheters relative to anatomic structures (eg, CT, the fossa ovalis, eustachian ridge, coronary sinus, and vena cava).9,13–16 Using ICE, some investigators found that the posterolateral boundary of the AFL circuit was located at the CT.7,17

The present study was therefore designed to determine the relationship between transverse conduction capability and the anatomy of the CT in patients with atrial flutter or fibrillation and to clarify the role of CT in the development of these arrhythmias using ICE.

Methods

Study Population

The study group included 25 patients (7 women, 18 men; mean age, 60±12 years; range, 28–81 years) who were referred for electrophysiologic study (EPS) or radiofrequency catheter ablation. None had organic heart disease evaluated by physical examination, 12-lead ECG, chest X-ray, echocardiography and exercise test. None of the patients had evidence of intracardiac thrombus formation as assessed with transesophageal echocardiography. These patients were divided into the 3 groups: 10 patients with typical AFL (group AFL), 7 patients with paroxysmal atrial fibrillation (group AF) and 8 patients who had neither PAF nor AFL (group N: 3 patients with atrioventricular reentrant tachycardia, 2 with idiopathic ventricular tachycardia and 3 with atrioventricular nodal reentrant tachycardia). The study protocol was approved by the institutional review board and written informed consent was obtained for all patients before participation.

ICE Imaging and Data Acquisition

At the start of the study, 22 patients were in sinus rhythm
and 3 were in typical AFL that was converted into sinus rhythm by atrial overdrive pacing. ICE was performed using a 9-MHz rotating ultrasound transducer, mounted at the distal end of a 9F, 110-cm catheter (Boston Scientific/EP Technology Co, San Jose, CA, USA). Images were acquired using an ultrasound imaging system (CVIS INSIGHT, Boston Scientific Co, Sunnyvale, CA, USA). The transducer provides circular images at a rate of up to 30 frames/s. The maximal radial imaging depth is up to 10 cm and the maximal axial resolution is approximately 0.2–0.3 mm.

The imaging catheter was advanced to the superior vena cava (SVC) via a femoral venous approach using a 9F long sheath (Goodman Co, Nagoya, Japan). The imaging catheter was then gradually withdrawn through the body of the right atrium and placed immediately below the junction of the RA and inferior vena cava (IVC) in order to fully characterize the anatomic location and extent of the CT and other RA anatomic structures. All ICE images from throughout the study were recorded on super VHS videotape for subsequent review.

ICE allowed clear visualization of the CT in its full extent from where it crossed anterior and medial to the SVC at the SVC-RA junction to its inferior end where it became continuous with the eustachian valve, anterior to the IVC in most subjects. However, in some patients, the CT became progressively less prominent from its superior to inferior end and its inferior one-third was indiscernible. Therefore, the maximum diameter of the short axis of the CT (dCT) at end-systole was measured at both the level of the SVC-RA junction (high RA) and that of the fossa ovalis (mid RA) during sinus rhythm, and was not measured in its inferior part (Fig 1). The mean value of dCT at the high and mid RA was calculated for each patient by 2 observers and the mean values of those observations were determined to represent each subject.

**Electrophysiologic Study**

During sinus rhythm, the transverse conduction capability of the CT could be determined in all patients. The EPS was performed in a fasting state after withdrawal of all antiarrhythmic drugs at least 5 half-lives beforehand. Two steerable 6F decapolar catheters with an interelectrode spacing of 2 mm (Biosense Webster, Inc, Diamond Bar, CA, USA) were advanced into the RA via the right femoral vein (Fig 2). Under fluoroscopic and ICE guidance, one of these catheters was positioned along the CT for determination of conduction across the CT. The other rove catheter was positioned for pacing 1–2 cm anteriorly or posteriorly to the CT under ICE guidance. Endocardial bipolar electrograms were recorded with a filter bandwidth of 30–500 Hz simultaneously with 12-lead ECG and stored digitally on a Cardiolab System (Prucka Engineering, Inc, Sugar Land, Texas, USA). During normal sinus rhythm, programmed RA stimulation was performed with rectangular pulses of 1 ms duration at twice the diastolic threshold. The effective refractory period for transverse conduction of the CT (CT-ERP) was measured by an extrastimulus technique. The coupling interval of the extrastimulus (S2) was shortened in stepwise by 10 ms after every 8 basic stimuli (S1) at a cycle length of 600 ms.

**Definitions**

CT-ERP was defined as the longest S1–S2 coupling interval that resulted in a complete transverse conduction
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For this purpose, the atrial electrogram was recorded from the middle bipole (5/6) of the decapolar catheter positioned at the CT and pacing was performed from the corresponding bipole of the pacing catheter placed on the opposite side of the CT. A complete transverse conduction block at the CT was defined by the appearance of split potentials at the CT mapping catheter with a marked alteration of the activation sequence of the second component of the split potentials during extrastimulation. Split potentials were defined as 2 discrete deflections per beat separated by an isoelectric interval.

Statistical Analysis

The values are presented as mean±standard deviation. The nonparametric Mann-Whitney's U test was used for statistical comparison between 2 groups. An analysis of variance was used to determine the difference among 3 groups. Multiple comparisons were made using Scheffe's test. Linear regression analysis was used to evaluate the correlation between CT-ERP and dCT. A p<0.05 was taken as statistically significant.

Results

Diameter of the CT (Fig 4)

The mean value of dCT in group AFL was significantly greater than in groups AF and N (5.0±0.8 vs 4.3±0.7, p<0.05 and 4.2±0.4 mm, p<0.01, respectively). The dCT did not differ between groups AF and N. It did not relate to either the age or gender of the patients.

Transverse Conduction Block at the CT

The CT-ERP could be determined during pacing from both the RA free wall and the posterior wall in 7 patients in group AFL, 4 patients in group AF and 4 patients in group N. In these patients, CT-ERP was significantly longer during pacing from the posterior wall (posterior to the CT) than from the free wall (anterior to the CT) (307±68 vs 267±29 ms, p<0.05, Fig 5), which indicates that the transverse conduction block at the CT was achieved more easily with extrastimulation from the posterior wall.

The CT-ERP for the posterior wall pacing was significantly longer in group AFL (339±80 ms) than in group N (255±13 ms, p<0.01). It tended to be longer in group AFL than in group AF (290±42), but the difference did not reach the statistical significance. The CT-ERP for the free wall pacing was also significantly longer in group AFL (328±114 ms) and group AF (321±131 ms) than in group N (243±21 ms, p<0.05), but there was no significant difference in the CT-ERP for the free wall pacing between groups AFL and group AF.
Relationship Between Diameter and Transverse Conduction Capability of the CT

The relationship between the dCT and CT-ERP for the posterior wall pacing was determined in 15 patients in whom the CT-ERP could be determined before the RA became refractory. There was no correlation (Fig 6), but the dCT was greater in patients with split potentials at the mapping catheter positioned along the CT than in patients without split potentials (Fig 7). The RA-ERP for the posterior wall pacing did not differ significantly between patients with a split potential (243±15 ms) and those without it (259±38 ms). Therefore, a transverse conduction block was more likely to occur in patients with a thicker CT.

Discussion

Major Findings

We believe this is the first study to measure the size of CT and relate it to atrial arrhythmias. Our major findings are summarized.

1. The diameter of the CT was significantly greater in patients with typical AFL than in patients with AF or in those who had neither AFL nor AF.

2. The CT-ERP was longer during pacing from the posterior wall than from the free wall.

3. The CT-ERP for the posterior wall pacing was longer in group AFL than in either AF or N.

4. Although the CT-ERP did not correlate significantly with the dCT, the dCT was greater in patients with split potentials occurring at the CT mapping catheter during programmed stimulation. Therefore, a transverse conduction block was more likely to occur in a thicker CT.

Relationship Between the Diameter of the CT and AFL

We found that the diameter of the CT was significantly greater in patients with typical AFL than in patients with only AF and those with neither AFL nor AF. However, we could not be fully elucidate why patients with typical AFL had a thicker CT. It has been well established that fibration induces electrical and anatomical remodeling of the atria, the extent of the enlargement of the left and right atrium enlarged according to the duration of AF. AFL might also cause electrical and anatomical remodeling of the atrium and so the thicker CT in patients with AFL might be caused by anatomical changes from the tachycardia-induced cardiomyopathy. However, it was not clear whether anatomical remodeling of the atrium would alter the diameter of the CT. A thicker CT might be an essential anatomical characteristic for the development of typical AFL rather than a sequel to it.

Transverse Conduction Block of the CT

In patients with typical AFL, split potentials indicating a line of complete conduction block have been documented at the CT. Although the barrier at the CT is considered anatomically fixed, mapping studies in animal models have shown transverse conduction across the CT in the normal heart. Recent studies suggest there is a rate-dependent transverse conduction block at the CT in patients with typical AFL. We evaluated the transverse conduction capability of the CT by RA extrastimulation from both a septal site and an anterior free wall site that were posterior anterior, respectively, to the CT. As demonstrated in the present study, extrastimulation with shorter coupling intervals resulted in split potentials and a marked alteration of the activation sequence, suggestive of a functional conduction block.

The mechanism of the conduction block is very likely to be anisotropy rather than specific differences in local refractoriness. Anisotropy at the CT with a high conduction velocity in the longitudinal direction and a low conduction velocity in the transverse direction because of a high gap junction density at the end-to-end connections and a low density at the side-to-side connections is well known. Yamashita et al found that the local effective refractory periods did not show any specific pattern at the CT, whereas a marked anisotropic conduction was found at the inter- caval region. High rate stimulation resulted in a functional conduction block at the lateral edge of the CT as well as at the border zone between CT and the pectinate muscle.

In the present study, the CT-ERP was longer during pacing from the posterior wall than from the free wall; that is, the conduction block in the CT was achieved at a longer coupling interval during extrastimulation from the posterior wall than from the free wall, which is consistent with the observation by Arenal et al that a transverse conduction block at the CT appears at a longer pacing cycle length with posterior wall pacing than with lateral wall pacing in patients with typical AFL. The mechanism of the differences in rate-dependent transverse conduction block between pacing from the posterior wall and lateral (free) wall has not been fully elucidated. Arenal et al suggested that differences in cellular arrangement between the smooth and trabeculated atrial walls might produce different input in the CT and consequently a different rate-dependent conduction block. According to these transverse conduction characteristics of the CT, AFL would be induced more easily by atrial arrhythmias arising in the posterior wall or the left atrium than by those arising from the high and lateral RA, and spontaneous AFL could therefore more likely rotate in a counterclockwise direction. It should be noted that in the present study the transverse conduction characteristics of the CT were observed not only in patients with typical AFL, but also in those without it. Therefore, the transverse conduction capability of the CT may be present irrespective of the presence and type of atrial arrhythmia.

Differences in Transverse Conduction Capability of the CT Between Patients With and Without Typical AFL

A functional conduction block of the CT occurred at longer coupling intervals in patients with typical AFL, as compared with patients without AFL, which is consistent with the observation of Schumacher et al. They additionally demonstrated that the length of the line of block at the CT in patients with AFL exceeded that in those with AF and the occurrence of an extended functional conduction block at the CT may be one of the electrophysiologic conditions that primes the development of AFL. It has been shown that the CT may have limited transverse conduction capabilities in patients with typical AFL, depending on the pacing cycle length.

Relationship Between Diameter and the Transverse Conduction Capability of the CT

In the present study, the diameter of the CT was significantly greater and a functional conduction block at the CT occurred at a longer coupling interval in patients with typical AFL than in those without AFL. Although the CT-ERP did not correlate with the dCT, the diameter was greater in patients with split potentials at the mapping catheter posi-

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tioned along the CT than in patients without them, a finding of transverse conduction block at the CT occurring before the RA became refractory. It is possible that these findings only indicate that the CT-ERP was longer than the ERP of the adjacent atrial tissue. In other wards, the RA-ERP might be shorter in patients with a split potential than those without it. However, the RA-ERP for posterior wall pacing did not differ between patients with a split potential and those without it. Therefore, a transverse conduction block of CT was more likely to occur in patients with a thicker CT.

We cannot clearly explain why the transverse conduction block of the CT is related to its diameter. It may be partly associated with anisotropic conduction of the CT caused by a characteristic distribution of the gap junction; however, there are other mechanisms. Unidirectional conduction block in the heart can occur at the site where the impulse is transmitted from a small to a large tissue volume; that is, the occurrence of a conduction block at an abrupt geometrical transition can be explained by both the impedance mismatch at the transition site and the critical curvature beyond the transition. Taking that into account, it is likely that a thicker CT would more readily cause a transverse conduction block. There is the possibility that pathologic changes in the CT are related, at least in part, to the development of a transverse conduction block of CT. An increase in the diameter of CT may accelerate longitudinal conduction, but we did not measure the longitudinal conduction velocity in the CT.

Study Limitations

First, in order to determine the anatomy of the CT, we measured the maximum diameter of the short axis of the CT in end-systole at the level of the SVC-RA junction (high RA) and the fossa ovalis (mid RA), which may have encompassed the entire morphology of the CT. More sophisticated technology, such as 3-dimensional ICE is required to accurately determine the anatomy of the CT. Secondly, the density of atrial mapping in humans is too low for detailed evaluation of the conduction capabilities of the CT. Split potentials associated with an alteration of the activation sequence of the second component strongly suggest conduction block, but a marked conduction delay can not be excluded definitively. However, findings from experimental studies with high density epicardial mapping support our interpretation.

Thirdly, we could determine the CT-ERP in only 15 patients, because the other 10 patients had a longer RA-ERP than CT-ERP, which would explain why the CT-ERP did not correlate with the dCT (Fig 6). Finally, 3 patients with AFL did not develop a split potential. Friedman et al found the posterior line of the crista terminalis in patients with atrial flutter and fibrillation. Atrium Cardiol 1999; 34: 363 – 373.


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Conclusions

Although limited, the present study clearly indicated that the thickness of the CT could limit its transverse conduction capabilities and consequently lead to the development of typical AFL.

References

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