Shortening of Conduction Time Over Arborized Atrioventricular Accessory Pathway With Mahaim Fibers Physiology Just Before Interruption During Radiofrequency Ablation

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A 21-year-old woman had paroxysmal wide QRS tachycardia with a left bundle branch block configuration and a retrograde conducted P wave just behind the QRS complex. An electrophysiological study revealed antidromic atrioventricular tachycardia involving an atrioventricular connection with decremental conduction as the anterograde limb and normal atrioventricular node as the retrograde limb. During constant pacing from the high right atrium (HRA) at the cycle length (CL) of 600 ms, the QRS configurations were not identical to those during the wide QRS tachycardia or constant pacing at the CL of less than 500 ms. The process by which this arborized atrioventricular accessory pathway with the Mahaim fibers physiology was interrupted by radiofrequency catheter ablation is described. Radiofrequency energy was delivered to the site recording a Mahaim potential at the tricuspid annulus during constant pacing from the HRA at the CL of 429 ms. The stimulus-QRS interval gradually shortened as it reached the power plateau without changing the preexcited QRS configuration. Shortening of the conduction time over the Mahaim pathway might have resulted in changing of the propagation from a slow to fast conduction zone or acceleration in response to thermal effect in a node-like structure on the atrial insertion site. (Jpn Circ J 2000; 64: 151–155)

Key Words: Atrioventricular accessory pathway; Junctional rhythm; Longitudinal dissociation; Mahaim fibers physiology; Radiofrequency catheter ablation

An antidromic atrioventricular reciprocating tachycardia via an atrioventricular or atrofascicular accessory pathway with Mahaim fibers physiology (Mahaim pathway) is a rare form of supraventricular tachycardia.1,2 The Mahaim pathway exhibits conduction only in the anterograde direction, with long conduction times and decremental conduction properties.3 The atrial insertion site of the Mahaim pathway is usually located at the lateral or posterior region of the tricuspid annulus and has been anatomically described as a node-like structure.3,4 It was recently reported that radiofrequency catheter ablation (RF-CA) guided by the Mahaim potential along the tricuspid annulus effectively eliminates the conduction of Mahaim pathways.5,9,10 Here, we describe the process of interruption with shortening of the conduction time over the arborized Mahaim pathway without changing the preexcitation pattern during radiofrequency energy delivery. This observation is very important with regard to the anatomical structure of the Mahaim pathway.

Case Report

A 21-year-old woman had, for 3 years, recurrent episodes of paroxysmal wide QRS complex tachycardia resistant to pharmacological therapy. During the episodic palpitations, the QRS complex showed a left bundle branch block configuration, a retrograde conducted P wave just behind the QRS complex, and a relatively long PR interval (Fig 1A). After bolus intravenous injection of 20 mg adenosine triphosphate, the wide QRS complex tachycardia terminated suddenly. Recovered sinus rhythm had a long PR interval and a QRS configuration identical to that observed during the tachycardia. The patient was referred for electrophysiologic study (EPS) and RF-CA.

The baseline ECG on admission was normal with the exception of slight ventricular pre-excitation. Physical examination, chest X-ray, and transthoracic echocardiography revealed normal findings. After obtaining informed consent, a standard diagnostic EPS was performed in conjunction with the RF-CA. Four 5-Fr quadrupolar electrode catheters were introduced percutaneously into the femoral and subclavian veins and positioned at the high right atrium (HRA), His-bundle recording region (HBE), right ventricular apex (RVA), and coronary sinus. Intracardiac bipolar electrograms were filtered at 30–400 Hz and were recorded on an optical disk by an EP Lab System (Quinton Electrophysiology Corp., Toronto, Canada). Pacing was performed at twice the diastolic threshold with a programmable stimulator (Nihon Koden, Tokyo, Japan) using stimuli 2 ms in duration.

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Fig 1. Comparison of 12-lead ECG. (A) During the antidromic atrioventricular reciprocating tachycardia, the QRS configuration reveals left bundle branch block and left axis deviation. A long P-R interval (235 ms) and short R-P (160 ms) are observed. (B) During high right atrium constant pacing at a cycle length of 600 ms, the QRS configuration reveals left bundle branch block and normal axis, not identical to the QRS configuration of the antidromic atrioventricular reciprocating tachycardia. Different ventricular preexcitation is demonstrated. (C) During radiofrequency energy delivery immediately before eliminating the Mahaim pathway, the QRS configuration is identical to that of the antidromic atrioventricular reciprocating tachycardia. Note that the St-QRS interval is short (48 ms) compared with the P-R interval (235 ms) during antidromic atrioventricular reciprocating tachycardia.

Fig 2. Various ventricular pre-excitation and decremental conduction recording during sinus rhythm and constant pacing from the high right atrium at cycle lengths of 600, 500, 429, and 375 ms. Shown are surface leads II, aVF, V1 and intracardiac recordings from the high right atrium (HRA), His-bundle recording region (HBE), coronary sinus (CS), and right ventricular apex (RVA). A, distal; P, proximal. (A) During sinus rhythm, a small ventricular pre-excitation is observed in II and aVF. AH interval was 90 ms and HV interval was 46 ms. (B) The atrioventricular interval at the HBE is clearly shortening to 119 ms. Note that the ventricular electrogram of the HBE precedes QRS onset (long vertical line) by 27 ms, suggesting that ventricular insertion is close to the HBE. (C) to (E) The St-QRS interval is 207 ms during pacing at the cycle length (PCL) of 500 ms, 235 ms (PCL of 429 ms) and 290 ms (PCL of 375 ms), respectively, showing decremental conduction properties and fully pre-excited QRS configuration.
Fig. 3. Tracings of Mahaim potential during sinus rhythm (left panel) (A) and constant pacing (PCL of 429 ms) from the HRA (right panel) (B). During HRA pacing, the dull shaped Mahaim potential (M, arrow) was distinctly recorded at the site shown in (B). The AM interval was 68 ms, MV interval 45 ms and AV ratio 6.6, respectively, during sinus rhythm. The interval from a stimulus to A recorded by the ablation catheter was 40 ms at the time of the HRA constant pacing at a cycle length of 429 ms. Abl. indicates the ablation catheter. Other abbreviation as in Fig. 2. Radiographs in the right anterior oblique (C) and left anterior oblique (D) projections indicating catheter position during successful ablation procedure. The ablation catheter (arrow) is positioned at the lateral region of the tricuspid annulus.

Fig. 4. Tracings during successful catheter ablation of the Mahaim pathway. Radiofrequency current was delivered during HRA constant pacing (PCL of 429 ms). Note that 207 ms St-QRS interval before ablation gradually shortened to 48 ms immediately before eliminating Mahaim conduction without change in the pre-excited QRS configuration (see Fig. 1). Mahaim pathway conduction block (loss of pre-excitation, *) occurred with 4.4 s after onset of radiofrequency energy delivery (RF on, arrow). Bottom tracing represents the output (WATT) from the radiofrequency generator. Abbreviations as in Fig. 2.

Incremental pacing from the HRA at the cycle length of less than 500 ms showed decremental properties of atrioventricular conduction, with a relatively long stimulus-QRS (St-QRS) interval. The pre-excited QRS configurations were gradually changed to that during the wide QRS complex tachycardia. However, during constant pacing at the cycle length of 600 ms, the atrioventricular interval at the HBE was 60 ms, which was clearly shorter than that during sinus rhythm or constant pacing at shorter cycle length. Moreover, the QRS configurations were not identical to those during the wide QRS complex tachycardia or constant pacing at the cycle length of less than 500 ms (Figs 1B, 2). Furthermore, this conduction was unstable and the slight differences in each QRS configuration were demonstrated during constant pacing at the cycle length of 600 ms. During the HRA extrastimulus at the basic drive
cycle length of 600 ms, the St-QRS interval revealed decremen-
tal conduction with a smooth conduction curve.

The wide QRS complex tachycardia was repeatedly
induced by rapid pacing or extrastimulus from the HRA or
RV A. The His bundle deflections were buried within the
ventricular electrogamms, and the ventricular electrogram at
the HBE preceded the onset of the QRS complex by 27 ms.
Ventricular activation at the RVA was late compared with
ventricular activation at the HBE. The earliest retrograde
atrial activation was recorded at the HBE. During the
tachycardia, ventricular extrastimuli delivered slightly
before His bundle deflection advanced the retrograde atrial
activation identical to that observed during the tachycardia.

In addition late right atrial extrastimuli advanced ventricu-
lar activation without changing the pre-excited QRS
configuration and did not advance the timing of atrial acti-
vation in the HBE. These findings were compatible with
antidromic atrioventricular tachycardia involving an atrio-
ventricular connection as the anterograde limb and normal
atrioventricular node as the retrograde limb.

Meticulous mapping along the tricuspid annulus was
performed using a steerable ablation catheter with a 4-mm
distal electrode. Dull Mahaim potentials were recorded
during sinus rhythm or constant pacing at the cycle length
of 429 ms from the HRA when the ablation catheter was
positioned at the lateral region along the tricuspid annulus
(Fig 3). Radiofrequency energy was delivered by a temper-
ature-controlled at 60°C. Before the radiofrequency energy
delivery, the St-QRS interval was 207 ms. Interestingly, the
St-QRS interval gradually shortened as the power plateau
was reached, and the pre-excitation conduction over the
Mahaim pathway was eliminated after 4.4 s (Fig 4). Until
the interruption, the pre-excited QRS configurations were
unchanged and identical to those before the delivery of the
radiofrequency energy (Fig 1C). The radiofrequency
energy continued to be delivered for 60 s.

Thereafter, programmed stimulation could not induce
antidromic tachycardia during either baseline conditions or
isoproterenol infusion. There were no complications during
these procedures. The patient was not treated with antiar-
rhythmic medications, and there has been no recurrence of
tachycardia during the 14-month follow-up period.

Discussion

In the present case, we demonstrated the interruption of
the Mahaim pathway, which displayed shortening conduction
times during radiofrequency energy delivery without a
change in the pre-excitation pattern. No previous reports have
described such Mahaim pathway conduction short-
ened by RF-CA. In addition, pacing from the HRA at the
cycle length of 600 ms showed another pre-excited QRS
configuration over poor conduction of the Mahaim
pathway. All of the pre-excitations were eliminated by a
single application of radiofrequency energy. After the
successful ablation, neither pre-excitation during constant
pacing nor extrastimulus from the HRA was observed.

With regard to shortening of the Mahaim pathway
conduction during RF-CA, there are 2 hypotheses. First, it
might have resulted from changing of the propagation from
a slow to fast conduction zone in a node-like structure on
the atrial insertion site. Mahaim pathways demonstrate
electrophysiologic properties such as gap phenomenon
and functional longitudinal dissociation, in addition to
decremental conduction. Histologically, it has been demon-
strated that the Mahaim pathway is specialized, originating
in a node-like structure on the atrial musculature, inserting
either into or in close proximity to the right bundle
branch. Therefore, it seems that these electrophysiologic
features and anatomic structures of the Mahaim pathway
bear a striking resemblance to those of the atrioventricular
node and atrioventricular conduction. It would be
expected that the Mahaim pathway also consists of cells
that show different conduction properties. In the present
case, the 207-ms St-QRS interval before radiofrequency
energy delivery gradually shortened to 48 ms immediately
before elimination of the Mahaim conduction. However, the
St-QRS interval of 48 ms just before interruption was
too short because the conduction time from the stimulus to
the A recorded at the ablation catheter was 40 ms. The atrio-
ventricular conduction via the Mahaim pathway seems
unlikely.

Second, it might have resulted from accelerated Mahaim
pathway conduction due to a thermal effect. Accelerated
junctional rhythm (AJR) is frequently observed during
slow pathway ablation in patients with atrioventricular
node reentrant tachycardia. There are several reports about
the origin and characteristics of AJR during RF-CA for
slow pathway. Using in vitro animal models, it has been
reported that the underlying mechanism of heat-
induced AJR is most likely heat-induced acceleration of
normal automaticity caused by an increase in the slope of
phase 4 depolarization and a shortening of the action poten-
tial duration in atrioventricular nodal cells very close to
the compact atrioventricular node. Okishige et al found a
sustained monomorphic ventricular tachycardia originating
from the Mahaim fibere; Negami et al described atrial
tachycardia originating in the accessory atrioventricular
node (Mahaim fiber) without ventricular conduction; and
Dean et al reported wide complex tachycardia due to auto-
maticity in an accessory pathway. These reports suggest
that the node-like structure on the atrial insertion site of
the Mahaim pathway might have automaticity and consist of
atrioventricular nodal-like cells that respond to the thermal
effect.

According to several reports, the optimal site to elimi-
nate the Mahaim pathway is at the atrial insertion site along
the tricuspid annulus where the Mahaim potential is
recorded. On the other hand, Haissaguerre et al performed
radiofrequency energy delivery at the distal Mahaim path-
way insertion site in their first 11 patients. In 9 of them the
ablation was unsuccessful, but a change in the pre-excitation
pattern was produced in 4 patients. Cappato et al likewise
reported that the radiofrequency energy applied to the presumtive
ventricular insertion site of the Mahaim pathway failed! These reports strongly suggest that the distal insertion site of the Mahaim pathway is
arborized widely. In the short atrioventricular interval-QRS
complex during only constant pacing from the HRA at a
cycle length of 600 ms in the present case, the ventricular
electrogram at the HBE was earliest activation site, and it
preceded the onset of the QRS complex by 27 ms. The QRS
configuration of the surface ECG indicated pre-excitation
at the right ventricular anterior septum. We speculate that
this Mahaim pathway might have had poor conduction
arborized to the right ventricular anterior septum. In addi-


tion, it originated in the atrial insertion site of the Mahaim
pathway because the pre-excitation was simultaneously
eliminated by a single application of radiofrequency energy
along the tricuspid annuls.
Finally, in addition to advances in EPS and mapping techniques, RF-CA has provided valuable information about the reentrant circuits and mechanisms in several arrhythmias. We think that our observations are very important with regard to the nonuniform anisotropic structure and conduction of the Mahaim pathway.

References


