Original Article

Electrophysiological characteristics of AV nodal reentrant tachycardia associated with persistent left superior vena cava

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Received August 24, 2016; Accepted October 31, 2016; Epub March 15, 2017; Published March 30, 2017

Abstract: Background: The course of the AV nodal slow pathway in patients with persistent left superior vena cava (PLSVC) has not been fully elucidated, and its optimal ablation site remains controversial. The present study investigated the electrophysiological characteristics of AV nodal reentrant tachycardias (AVNRTs) associated with PLSVC and the safety and efficacy of their radiofrequency catheter ablation (RFCA). Methods and results: Eight consecutive patients with PLSVC (7 women and 1 man; mean age, 36.3 ± 6.0 years) out of 325 with AVNRT who underwent RFCA at our center between June 2012 and June 2015 were included. After electrophysiological study, ablation was successfully completed at the routine target site in 2 patients, while the other 6 required ablation at the anterior wall of the coronary sinus within 1 cm from the ostium, where effective target potential was a relatively fractionated atrial electrogram followed by a large ventricular electrogram (A/V ratio >1:3) and impedance was approximately 20 Ω higher than at the routine target site. Conclusions: RFCA is feasible and safe for AV nodal modification associated with PLSVC, with the majority of target sites located in the anterior wall of the coronary sinus within 1 cm from the ostium.

Keywords: AV nodal reentrant tachycardia, radiofrequency ablation, persistent left superior vena cava

Introduction

Radiofrequency catheter ablation (RFCA) of the slow pathway of the atrioventricular (AV) node in the Koch’s triangle is effective in treatment of AV nodal reentrant tachycardia (AVNRT) [1, 2]. Left superior vena cava (PLSVC) is one of the most frequent anomalies of the systemic venous return [3], and several case reports documented an association with AVNRT without fully elucidating the course of the AV nodal slow pathway and optimal ablation site [3-6]. This retrospective single center study therefore investigated the electrophysiological characteristics and optimal ablation site of AVNRTs associated with PLSVC.

Methods

Study population

Of the 325 consecutive patients presenting with AVNRT who underwent RFCA ablation at our centers between June 2012 and June 2015, 8 had PLSVC. After localizing the greatly dilated coronary sinus ostium by echocardiography in these 8 patients (Figure 1), a dual-source CT scan (Somatom Definition, Siemens, Forchheim, Germany) was used during sinus rhythm to scan the heart from the middle of the ascending aorta to the diaphragm with intravenous injection of 120 mL of iopromide (Ultravist, Schering, Berlin, Germany) at 4-5 mL/s during a single breath hold. Reformed 3D images obtained by post-processing and reconstructions confirmed the presence of a markedly enlarged coronary sinus.

Electrophysiological study

All antiarrhythmic drug therapy was discontinued for 5 half-lives before the electrophysiological study. Written informed consent was obtained from all patients before the procedure. Under fluoroscopic visualization, 3 quadripolar catheters were advanced to the high
right atrium, His bundle and right ventricular apex through the femoral vein. A multipolar electrode catheter introduced through the left subclavian vein was passed directly into the coronary sinus through the PLSVC draining to the markedly enlarged coronary sinus. An electrophysiological study was performed using programmed and burst pacing from the right atrium or ventricle. If the tachycardia could not be induced, isoproterenol was infused intravenously.

**Catheter ablation technique**

Once the diagnosis of AVNRT was established, 3D anatomical mapping of right atrium and (or) coronary sinus was performed using CARTO systems (Biosense Webster). The 4-mm non-irrigated ablation catheter (Biosense Webster) was positioned using the right femoral vein approach, with a 30° RAO, and a 45° LAO fluoroscopic projection and 3D anatomical mapping. The ablation site was initially selected based on the slow pathway potential recorded along the tricuspid annulus near the coronary sinus ostium. The catheter tip was initially directed against the area around the posterior interventricular septum in front of the coronary sinus ostium at the level of the coronary sinus bottom. If the slow pathway potential could not be found at the low level, the catheter tip was gradually elevated. If the slow pathway potential could not be found in these areas, an atrial/ventricular (A/V) ratio ≈ 1:4 was used as criterion to select the ablation site. RF application was initiated at 35-40 W for a maximum temperature of 55°C. If a non-sustained junctional tachycardia (NSJT) was not observed in 10 s, the catheter was repositioned. When AV dissociation during NSJT was observed, the delivery of RF current was immediately discontinued. If the NSJT could not be observed during ablation at the routine site, the catheter tip was repositioned in the coronary sinus ostium for mapping and ablation. The endpoint for the procedure was the inability to rein-duce AVNRT by an electrophysiological study similar to the baseline study with or without intravenous isoproterenol infusion. Slow pathway potential criteria were derived from the method published by Haissaguerre et al. [1]. Telephonic follow-up was conducted at 1, 6, and 12 months post procedure. Recurrence was

**Figure 1.** Echocardiography images. The diameter of normal coronary sinus (green arrow) is 0.650 cm (A). The diameter of dilated coronary sinus in patients with persistent left superior vena cava (green arrow) is 1.83 cm (B). Ultrasound color flow imaging of persistent left superior vena cava (green arrow) (C).
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Figure 2. Potentials at the successful target site. Potentials in the posteroinferior region of Koch’s triangle were small fractionated atrial electrogram followed by a large ventricular electrogram (A/V ratio ≈ 1:4) in two patients (A, B). Potential in the superior, inferior or posterior walls of coronary sinus was a large atrial electrogram followed by a small ventricular electrogram (A/V ratio ≈ 4:1) (C). Potentials in the anterior wall of the coronary sinus within 1 cm from the ostium were relatively fractionated atrial electrogram followed by a large ventricular electrogram (A/V ratio >1:3) in six patients (D-I). (Magnification ×16).

Figure 3. Ablation in a patient with persistent left superior vena cava. After angiography of the PLSVC under X ray fluoroscopy, the ablation catheter tip at the effective target site was along the tricuspid annulus from the LAO view (A). From the RAO view, the ablation catheter tip crossed the anterior wall (white dotted line) of the coronary sinus and was in the area of Koch’ triangle (B).

Results

Seven of the 8 patients with ANRTs associated with PLSVC were female; mean age was 36.3 ± 6.0 years; all presented with palpitations with a mean heart rate of 166 ± 36, none had any other apparent heart disease. In electrocardiogram, 6 had an R’ wave in lead V1, and 5 had an S’ wave in inferior leads. Three patients with PLSVC previously underwent unsuccessful catheter ablation elsewhere.

Mapping and ablation

After 3D anatomical mapping of the right atrium, the slow pathway was recorded (Figure 2A and 2B) and ablated successfully in the area of Koch’ triangle along the tricuspid annulus in 2 patients (Figure 3), with effective target impedance of 128 and 138 Ω; total procedural time of 58 and 65 minutes; total fluoroscopy time of 5.6 and 6.5 minutes; and RF application time of 160 and 200 seconds, respectively. In the other 6 patients, the slow pathway potential was not recorded at the routine target site, and ablation using an anatomical approach also failed. The ablation catheter than was moved into the markedly dilated coronary sinus ostium. In the first two of these 6 patients, the superior, inferior, anterior and posterior walls of the coronary sinus near the ostium were mapped, and the potential was a large atrial electrogram followed by a small ventricular electrogram (A/V ratio ≈ 4:1) (Figure 2C).

Statistical analysis

Continuous variables are presented as mean ± SD. The impedance of the effective target site

mapping of the right atrium, the slow pathway was recorded (Figure 2A and 2B) and ablated successfully in the area of Koch’ triangle along the tricuspid annulus in 2 patients (Figure 3), with effective target impedance of 128 and 138 Ω; total procedural time of 58 and 65 minutes; total fluoroscopy time of 5.6 and 6.5 minutes; and RF application time of 160 and 200 seconds, respectively. In the other 6 patients, the slow pathway potential was not recorded at the routine target site, and ablation using an anatomical approach also failed. The ablation catheter than was moved into the markedly dilated coronary sinus ostium. In the first two of these 6 patients, the superior, inferior, anterior and posterior walls of the coronary sinus near the ostium were mapped, and the potential was a large atrial electrogram followed by a small ventricular electrogram (A/V ratio ≈ 4:1) (Figure 2C). Ablation

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Ablation defined according to patient’s symptom, and/or arrhythmia documentation.

Statistical analysis

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attempted in these areas was ineffective (Figure 4A and 4B). In the anterior wall of the coronary sinus within 1 cm from the ostium, a relatively fractionated atrial electrogram followed by a large ventricular electrogram was recorded (A/V ratio >1:3) (Figure 2D and 2E). Ablation in this region provoked NSJT and was effective (Figure 4A-D and 4G). Contrast medium injected into the left subclavian vein directly opacified the markedly dilated coronary sinus and showed the position of ablation catheter at the site of the successful target (Figure 4C and 4D). Figure 4A, 4C and 4D showed that the ablation catheter was in the coronary sinus, and Figure 4B and 4D showed that the ablation catheter tip pointed straightly forward to the anterior wall of the coronary sinus without crossing the anterior wall line, which was different from the position of ablation catheter at the routine target site (Figure 3). In these first 2 out of the 6 patients, total procedural time was 96 and 88 minutes; total fluoroscopy time was 8.2 and 7.5 minutes; and RF application time was about 360 and 420 seconds, respectively.

In the remaining four of the 6 patients, after three-dimensional anatomical mapping of right atrium and coronary sinus, ablation was ineffective at the routine target site area (Figure 5A and 5B), and the ablation catheter was directly moved into the anterior wall of the coronary sinus within 1 cm from the ostium for mapping and ablation. A similar relatively fractionated atrial electrogram followed by a large ventricular electrogram was recorded (A/V ratio >1:3) (Figure 2F-I). Ablation at this region (Figure 5A and 5B) also provoked NSJT and was effective. Figure 5A and 5B directly showed that the effective target was in the anterior wall of the coronary sinus within 1 cm from the ostium. Total procedural duration in these four patients was 60 ± 10 minutes; total fluoroscopy time was 7.2 ± 2.5 minutes; and RF application time was 210 ± 80 s seconds, all shorter than in the first 2 patients. In the 6 patients who was ablated successfully in coronary sinus, the impedance at the effective target in the anterior wall of coronary sinus was approximately 20 Ω higher than at the routine target site area (158 ± 20 vs. 132 ± 16 Ω, P < 0.05).

Complications and follow-up
No AV block or early termination events actually occurred. There were no procedure related
Discussion

The major findings in the present study were: (1) relatively young women account for the majority (87.5%) of patients with AVNRT associated with PLSVC; (2) ablation could be completed successfully at routine target site in 25% of patients while the rest required ablation in the anterior wall of the coronary sinus within 1 cm from the ostium; and (3) the potential, impedance, and CARTO and fluoroscopic images of the ablation catheter tip at the target site of the anterior wall of the coronary sinus have special characteristics.

PLSVC is one of the most frequent anomalies of systemic venous return, with an incidence of 0.3-0.5% in the general population [3]. Several studies have shown that some patients with PLSVC suffer from AVNRT [3-6]. Okishige et al. [5] reported 3 cases with PLSVC out of a total of 200 AVNRT cases (1.5%). Katsivas [3] showed that PLSVC was present in 5 of 394 (1.24%) patients who underwent ablation for AVNRT at their department (1.24%). The incidence was higher (2.4%) in the present study because three patients with PLSVC previously underwent unsuccessful catheter ablation elsewhere and were transferred to our department. AVNRT associated with PLSVC presented at a relatively younger age (mean 36.3 years). The dilated coronary sinus ostium due to PLSVC leads to atypical courses for the AV nodal slow pathway fiber which might contribute to the younger onset age and uncertainty on optimal ablation site [3-6]. The area of the coronary sinus ostium [5, 6] and the posterosinerior region of Koch’s triangle [3, 4] have been suggested as sites for successful ablation. Though previous study have showed that the mitral annulus could provide a left atrial input to the human AV node [7], for AVNRT patients with normal heart structure, only few of them need to be ablated in the coronary sinus, such as some left atrioventricular nodal connections in typical or atypical AVNRTs [8, 9].

Although the number of cases was limited, the conclusion was different from previous stu-
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dies in which effective target site was either at the bottom of the “barrel” coronary sinus [6] or the bed of the proximal portion of the markedly enlarged coronary sinus [5] or the conventional ablation target position [3, 4]. The accurate location and characteristics of the target site in coronary sinus ostium were not described in previous studies, in which all mapping and ablation procedures were performed under X ray fluoroscopy without three-dimensional reconstructions and angiography, precluding certainty of the accurate location of the target site because of the markedly enlarged coronary sinus ostium. In the two patients who were ablated successfully in the present study at the routine target site area, the slow pathway potential was recorded, and the A/V ratio was ≈ 1:4, whereas in the other six patients who were ablated successfully in the anterior wall of the coronary sinus within 1 cm from the ostium, a relatively fractionated atrial electrogram followed by a large ventricular electrogram was recorded (A/V ratio >1:3). A/V ratio ≈ 4:1 in other walls of the coronary sinus ostium. The reason may be that the anterior wall is close to the ventricular myocardium, whereas the other three walls are close to the atrial myocardium. The relatively fractionated atrial electrogram may represent the existence of the slow pathway, being totally different from the slow pathway potential recorded in the posteroinferior region of Koch’s triangle. We did not observe the slow pathway potential (A/V ratio ≈ 1:4) at the bed of the proximal portion of the markedly enlarged coronary sinus described by Okishige [5], and X ray fluoroscopy might have missed the definitive ablation catheter tip location. In contrast, in the present study, the ablation catheter tip was located by X ray fluoroscopy, CARTO images and angiography of PLSVC. The ablation catheter tip was located to the left side of the coronary sinus ostium from the LAO angle and in the anterior wall of the coronary sinus within 1 cm from the ostium, and not in the posteroinferior region of Koch’s triangle, from the RAO and LL angles. Beyond imaging, target site impedance also provides important information. A sudden increase in impedance indicated that the position of the ablation catheter tip had shifted from the posteroinferior region of Koch’s triangle to the coronary sinus ostium. Previous studies did not provide the latter information.

In the present study, three patients with PLSVC previously had undergone unsuccessful catheter ablation elsewhere which indicated that ablation in these unusual cases was relatively difficult to perform. Coronary sinus ostium was dilated in patients with AVNRT compared with patients with accessory pathway [10], which indicated that the size of coronary sinus ostium itself was closely related to the AV nodal slow pathway. Several variations might be present in the course of the AV nodal slow pathway in patients with PLSVC. The course of the AV nodal slow pathway might be stretched in the anterior wall of the greatly dilated coronary sinus ostium or covered with the anterior wall of the greatly dilated coronary sinus ostium in patients with PLSVC. If the electrophysiological characteristics could be defined in this kind of patients, total procedural duration, total fluoroscopy time and RF application duration could be greatly shortened. In summary, in cases of AVNRTs associated with PLSVC, ablation in coronary sinus was more common, ablation initiated at 35-40 W for a maximum temperature of 55°C was safe, and did not result in any complications or sudden rise in impedance.

The present study has the inherent limitations imposed by its single center retrospective design with small sample of this relatively population. Moreover, in terms of the study findings on effective ablation site location, there is no direct evidence to prove that the AV nodal slow pathway is located in the anterior wall of the coronary sinus within 1 cm from the ostium and participated in the AVNRT.

Radiofrequency ablation is feasible and safe for AV nodal modification associated with PLSVC, with most target sites located in the anterior wall of the coronary sinus within 1 cm from the ostium.

Acknowledgements

This study was supported by the National Natural Science Foundation of China (Grant No. 81100126) and High Level Health Technical Personnel Training Plan (2015-3-056) of Beijing Health Bureau.

Disclosure of conflict of interest

None.

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