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Pulmonary Vein Angiography and Spike Potential Mapping Guided Ultrasound Ablation in Pulmonary Vein Ostium to Treat Focal Atrial Fibrillation

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LU ET AL.: ***Pulmonary Vein Angiography and Spike Potential Mapping Guided Ultrasound Ablation in Pulmonary Vein Ostium to Treat Focal Atrial Fibrillation. Objectives:*** *The purpose is to evaluate the effect of pulmonary vein angiography (PVA) and spike potential (PSP) mapping guided ultrasound ablation in the pulmonary vein ostium (PVO) to treat focal atrial fibrillation (FAf).* ***Methods:*** *The criteria of patient enrollment were: 1) paroxysmal FAf ≥6 months, 2) the FAf was refractory to antiarrhythmic agents, 3) without organic heart disease, 4) frequent P'-on-T atrial premature beat (APB) and 5) its induced FAf on Holter. R1 and L1 Swartz sheaths were positioned at PVOs by transseptal approach. PVA was conducted to direct PSP and APB mapping. Target PVO was: 1) clear and stable PSP, 2) earliest APB orientation, 3) PSP driven or triggered FAf. An ultrasound balloon catheter was inserted to ablate target PVO with the parameters of temperature ≥60°C and time 60~120s. The end points were 1) PSP disappeared or its amplitude decreased more than 80%, 2) complete conduction block from PVO to the left atrium, 3) actual ablation temperature ≥50°C and keeping for ≥60s.* ***Results:*** *Total 24 PVOs (9 left and 9 right superior, 6 left inferior) of 9 patients (M/F 8/1, 57.6±8.3 years old) were ablated. Each PVO was ablated 4.3±1.5 times with actual temperature of 57.2±3.6°C and duration of 96.8±12.5s. The PSP of 8 PVOs (33.3%) disappeared and the amplitude of others was decreased more than 80%. All patients had chest pain during ablation and seven of them were injected opium. There were no complications. All patients had FAf recurred within 48.3±11.7 hours after ablation and previous anti-arrhythmic drugs were then started. During follow-up of 11.8±7.5 month, the frequency of FAf decreased from 5.7±3.9 times per week before ablation to 2.4±0.7 times per week after ablation in 7 patients (77.8%, P<0.05). Another two patients had no FAf recurrence (22.2%).* ***Conclusions:*** *1) The end points of APB and PSP disappearance, actual temperature ≥50°C cannot predict immediate and long-term ablation effect of focal FAf. 2) Late remodeling effect of ablated PVO may be one factor to reduce FAf attack. 3) The method of PVA and PSP mapping guided ultrasound ablation in PVO may not be a radical cure to focal FAf. (J HK Coll Cardiol 2003;11:39-45)*

Focal atrial fibrillation, Interventional therapy

摘要

目的：探討肺靜脈造影和標測電位指導超聲球囊導管消融肺靜脈口治療局灶性房顫的近遠期療效。方法：選擇具有如下特點的陣發性房顫病人進行肺靜脈超聲消融：1）房顫陣發性發作 6 個月以上，2）抗心律失常藥物（胺碘酮、心律平、異搏定或索他洛爾等）防治效果不好，3）不合併器質性心臟病，4）Holter 檢查頻發 P'-on-T 房早，5）房顫可由房早誘發。常規穿刺房間隔 2 次，置入 Swartz R1 和 L1 長鞘，在 7F 大頭導管指引下分別進入左、右肺靜脈進行肺靜脈造影，並標測肺靜脈電位和房早最早起源點，具備以下特點者為消融靶肺靜脈：1 ）能記錄到清楚穩定的肺靜脈電位，2）房早最早起源點，3）異常肺靜脈電位觸發或驅動房顫。更換 9F 超聲球囊導管專用鞘管，在肺靜脈造影指導下對靶肺靜脈進行超聲消融，溫度設置60°C，時間 60~120s。有效指標為：1）肺靜脈電位消失或振幅降低 80%

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以上，2）房早消失，3）實際溫度達到 50°*C* 以上並持續至少 60s。隨訪 6 個月以上。結果：共治療 9 例病人，男 8 例女 1 例，年齡 57.6±8.3 歲。確定 24 條靶肺靜脈，即左、右上肺靜脈各 9 條，左下肺靜脈 6 條。每條肺靜脈消融 4.3±1.5 次，實際溫度 57.2±3.6°*C*，每次平均消融 96.8±12.5s。8 條肺靜脈的電位完全消失（33.3%），其餘肺靜脈的電位振幅降低 80% 以上。9 例病人均有胸痛，7 例需靜注杜冷丁緩解。無併發症。9 例病人術後 48.3±11.7 小時復發房顫，均開始服用術前抗心律失常藥物。隨訪 11.8±7.5 月，2 例病人（22.2%）房顫不再發作，7 例病人（77.8%）房顫發作從術前 5.7±3.9 次/周減少到 2.4±0.7 次/周（P<0.05）。結論：1）以房早消失、肺靜脈電位振幅降低和實際消融溫度不能預測即刻消融效果。2）晚期肺靜脈口重構效應能減少局灶性房顫的遠期發作。3）以肺靜脈造影和標測電位指導的靶肺靜脈超聲球囊導管消融不能根治局灶性房顫。

關鍵詞：局灶性房顫　介入治療

Focal atrial fibrillation (FAf) is triggered or driven by abnormal focus orientated from myocardial sleeve structures such as pulmonary vein or vena cava ostium. The patients with FAf usually have not organic heart disease or purely have slight atrial enlargement.[1-3] Some investigating Intervention therapies could be used to cure the disease by ablating the abnormal focus or isolating its conduction from the sleeve structure to the atria.[4-6] The purpose of the study is to evaluate the effect of pulmonary vein angiography (PVA) and spike potential (PSP) mapping guided ultrasound ablation in the pulmonary vein ostium (PVO) to treat focal atrial fibrillation (FAf).

Material and Methods

Clinical Cases

Patients with following characters were enrolled into the study: 1) more than 6 months of paroxysmal atrial fibrillation; 2) refractory to prophylactic antiarrhythmic agents such as amiodarone, propafenone, verapamil or sotalol; 3) without organic heart disease, 4) frequent P' on T atrial premature beats (APB) on Holter monitoring (Figure 1A), 5) FAf induced by APB was recorded on surface electrocardiogram (ECG).

Electrophysiological Study

Informed consent was written before electrophysiological study and ultrasound balloon catheter ablation. Both procedures were conducted at one time in catheterization laboratory. Patient was lying on X-ray bed and slight sedation was given. One quadrapolar electrode catheter (6F, USCI) was inserted into coronary sinus through left subclavicular vein. Two quadrapolar electrode catheters (6F, USCI) were inserted to record His potential and stimulate right ventricular apex through right femoral vein. One steerable A-focus electrode catheter (5F, IBI) was sent into the interested pulmonary veins by transseptal approach to record the target APB and map induced or spontaneous FAf. Pulmonary vein was determined by retrograde contrast angiography through transseptal sheath (Figure 1B). Regular programming electrode stimuli (UHS20, Biotronik) was conducted to exclude the accessory pathway or other supraventricular tachycardia. Repeat atrial program or non-program stimuli were tried to induce FAf. Five thousands unit common heparin was injected after transseptal Swartz sheath (8F, L1, Swartz) was in position and another thousand unit was added in one hour. Fluoroscopy machine was Digital INNOVA2000 (GE Medical).

The pulmonary vein with more than two items of the following characters was considered as target vein: 1) clear and stable pulmonary spike potential (PSP) could be recorded, 2) PSP was disintegrate or block, 3) earliest APB was recorded, 4) FAf triggered or driven by the pulmonary APB was recorded.

Ultrasound Balloon Catheter Ablation

A special transseptal sheath was inserted into left artium by second transseptal access (11F, IBI). It was further positioned into the target pulmonary vein ostium under the guidance of a 7F steerable large tip electrode catheter (Webster/Mansfield).

Through the IBI transseptal sheath, a steerable ultrasound balloon catheter was inserted into the target pulmonary vein ostium (10F, IBI). This catheter has three main functions. Firstly, it could be used as a steerable mapping and radiofrequency ablation catheter. Secondly, its tip inflatable balloon could contact tightly with the vascular inner wall and make precious position for the ultrasound core mounted in the central staff of the balloon. Thirdly, when the tip balloon was inflated,

it stops the blood flush from the lung to the ablated area so as to ensure the heat ablation efficacy. The structure of the ultrasound ablation catheter in detail refers to Figure 2A. The size of the tip balloon could be adjusted preciously by injected normal saline mixture with contrast. The temperature of the balloon saline could be sensed and adjusted preciously by an ultrasound ablation generator IBI-2000 (Figure 2B).

After the target pulmonary vein was determined, the diameter of its ostium was measured by angiography. The ultrasound balloon was then preciously located at 1 cm inner the ostium and inflated to the ostium diameter under fluoroscopy and angiography (Figure 3). Ablation temperature was preset at 60°C. Actual temperature was continuously monitored. If patient feel chest pain, a small dose of morphine agent was injected intravenously. Each ablation persisted 60~120s. After 2 to 3 times of ablation, the electrophysiology of the ablated target pulmonary vein ostium was repeated. Any three of the following parameters were used to be ablation end point: 1) PSP was disappearance, disintegrate or decreased 80% in its amplitude (Figure 4); 2) PSP or stimulus was blocked between pulmonary vein and left atrium.

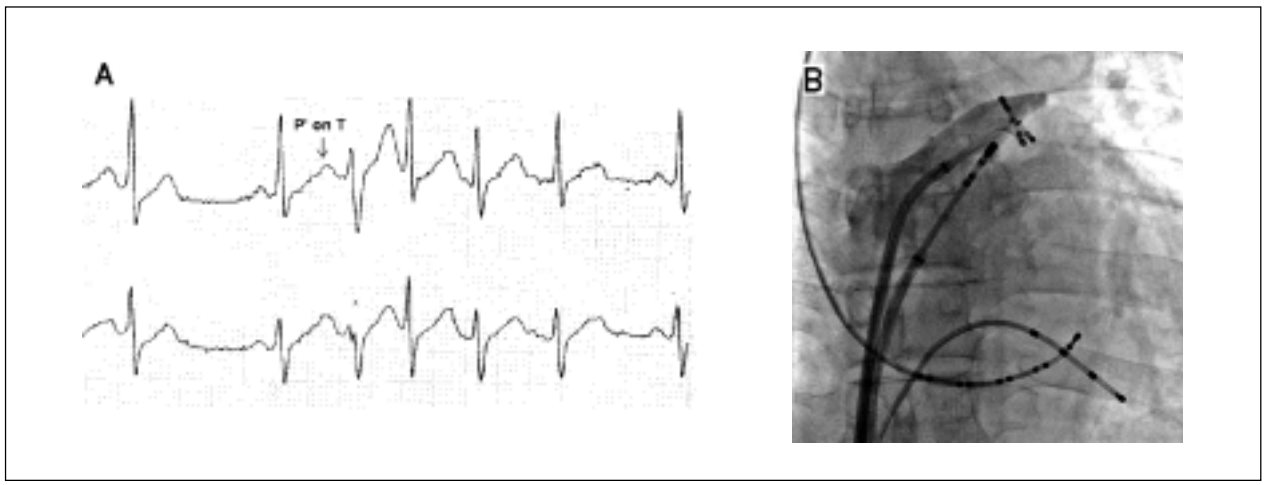

Figure 1. *(A) Frequent atrial premature beat of P' on T triggered burst atrial fibrillation on Holter monitoring. (B) Left superior pulmonary vein was determined by retrograde angiography at 30° right anterior oblique projection through the transseptal sheath.*

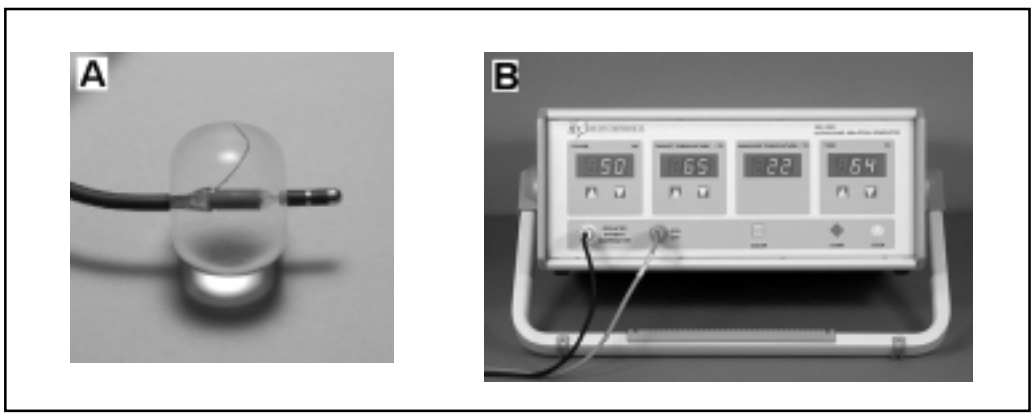

Figure 2. *Configuration of a ultrasound balloon catheter (A) and an ultrasound ablation generator (B). They were manufactured by IBI Co. Ltd.*

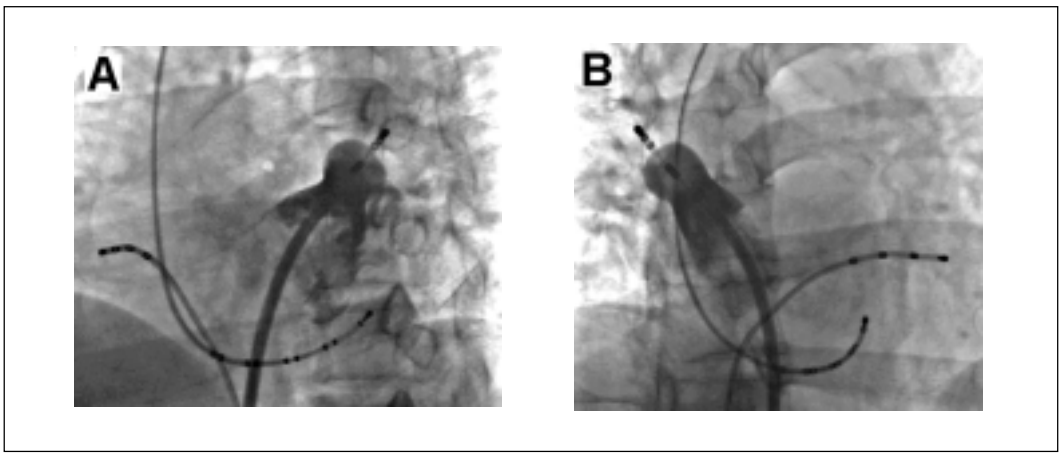

Figure 3. *Ultrasound balloon location under the guidance of target pulmonary vein ostium angiography. (A) Left superior pulmonary vein ostium ablation under 45° left anterior oblique projection. (B) Right superior pulmonary vein ostium under 60° left anterior oblique projection.*

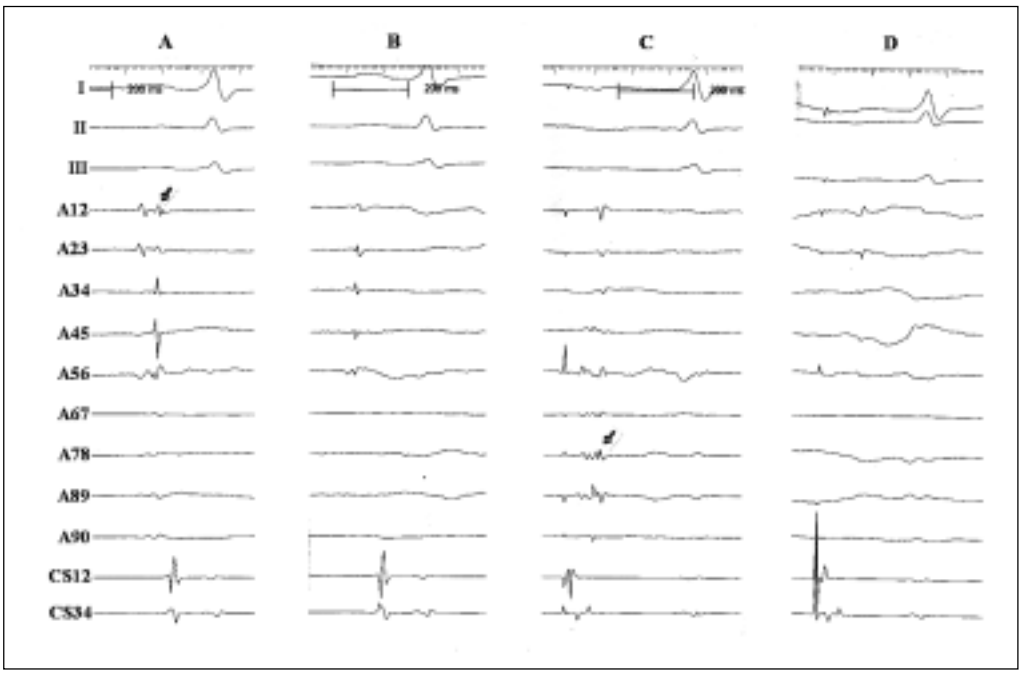

Figure 4. *One of the end points of ultrasound balloon ablation: pulmonary spike potential was disappearance, disintegrate or decreased 80% in its amplitude. From top to bottom, the electrocardiograms were surface lead I, II, III, A-focus electrogram 1 to 5 leads, coronary sinus 1-2 leads and ablation catheter electrogram. (A) Spike potential (arrow) of right superior pulmonary vein ostium was recorded in sinus rhythm before ablation. (B) The spike potential in A was disappeared after two times of ablation. (C) Spike potential (arrow) of left superior pulmonary vein ostium was recorded during coronary sinus pacing before ablation. (D) The spike potential in C was disappeared after three times of ablation.*

3) The earliest APB was cleared away; 4) Monitored actual ablation temperature was higher than 50°C and persisted at least 60 seconds; 5) FAf was stopped by ablation and could not be induced by programmable stimulus as well as drug provocation.

Follow Up

The patients were followed up clinically in 6 months. FAf frequency and persist time, the effect of antiarrhythmic agents and chest film were compared before and after ablation. For patient suspected of secondary pulmonary vein stenosis clinically, selective pulmonary vein angiogram was conducted.

Statistics

The material was presented in mean±standard error. Student t test was used to compare the difference between two groups and $P \leq 0.05$ was considered significant difference.

Results

Nine patients were enrolled into the study. There were eight males and one female with mean age of 57.6±8.3 years old. Altogether 24 target pulmonary veins were determined. They were nine left superior pulmonary veins, nine right superior pulmonary veins and six left inferior pulmonary veins. Mean 4.3±1.5 times of ablation were conducted to each target pulmonary vein ostium. Actual ablation temperature per delivery was 57.2±3.6°C. The total ablation time per case was 378.6±41.3s.

The PSPs of eight target pulmonary veins were completely disappeared (33.3%). The amplitude of other sixteen target pulmonary veins (66.7%) decreased in more than 80%. Nine patients felt obvious chest pain and seven of them needed morphine agent injection. There were no micro or minor complications.

Nine patients recurred FAf in 48.3±11.7 h after ablation procedure (100%). During the follow up of 11.8±7.5 months, the frequency of FAf decreased from 5.7±3.9 times per week before ablation to 2.4±0.7 times per week after ablation in 7 patients (77.8%, $P<0.05$). Another two patients had no FAf recurrence (22.2%). There were no mortality and procedure related complications. The chest X-ray films were not different between before and after ablations. No selective pulmonary vein angiography was needed because no patient was suspected of secondary pulmonary vein stenosis clinically.

Discussion

The Mechanism of Focal Atrial Fibrillation

In clinical, atrial fibrillation could be categorized into three main types: paroxysmal, persistent and permanent. The first one is usually developed in relatively normal heart. Majority FAfs are included into this category. But the later two are often complicated with organic heart disease and atrial enlargement. In electrophysiology, atrial fibrillation is divided into focus and randomized reentrant according to its mechanism. Focal atrial fibrillation (FAf) is triggered or driven by critical atrial premature beats or irregular exciting focus orientated from some atrial myocardial sleeve structures. Randomized reentry atrial fibrillation is dependent on multiple randomized micro-reentry circuses moving in the atria.[7-12] Common atrial myocardial sleeve structures are pulmonary vein ostium, vena cava ostium, coronary sinus ostium and atrial appendages. Among them, left pulmonary vein ostium is the most interested area. It is related to more than 85% of clinical FAf cases.[7-9,13] Therefore, therapies such as electrophysiological ablation or isolation to pulmonary vein are very important theoretically to the cure of FAf.

The Electrophysiology of Pulmonary Vein Ostium

In anatomy, there are more or less atrial myocardium in the conjunction part between left atrium and pulmonary vein. We usually call this part transition area or atrial myocardial sleeve. It could be deep into the pulmonary vein in more than 5 centimeters.[7-9,14,15] In normal heart, the myocardium within the sleeve is excited by impulse orientated from left atrial wall and produces special pulmonary spike potential (PSP). PSP is usually a high frequency and low amplitude potential after atrial wave.[7,13,14] When an atrial premature beat or FAf within the sleeve occurs, PSP transfers to the front of the atrial wave. By mapping with multiple electrodes catheter, PSPs in the sleeve have different conduction type and/or time. So some investigators believe FAf is in nature an irregular atrial tachycardia.[7,14,16]

By programmable stimulus delivered in both sleeve and left atrium, it is found PSP has decreased conduction characteristics of slow response fibers. There is one or more slow conduction parts existed in the sleeve. Ablating abnormal electrical focus itself or just blocking the conduction of the key parts within the sleeve could cure FAf provoked by this mechanism.[9-11]

Interventional Therapy for FAf

According to the research results on the mechanism of FAf, the interventional therapies used in clinic at present are mainly:[9-11] 1) radiofrequency or ultrasound energy ablation to the electrical focus and/or its conduction guided by the guidance of pulmonary vein angiography and precious electrical mapping to the sleeve structure (spot ablation); 2) radiofrequency energy isolation to the sleeve within or outside its ostium guided by noncontact electroanatomical mapping or endoscopy (cirlus ablation); 3) dual atrial pacemaker implantation. These techniques are under investigation and their effects on FAf are still controversy.[7-9]

The Effect of Ultrasound Balloon Catheter Ablation to FAf

When the ultrasound balloon is positioned in the target pulmonary vein ostium, critical amount of normal saline mixture with contrast is used to inflate the balloon. After the ultrasound generator started, the saline within the balloon is heated. The heat is conducted and makes injury to the sleeve wall. The ablation course could be controlled by adjustment to the temperature of saline and the time of ultrasound energy delivered.[17] The advantages of this intervention are: 1) simpler procedure; 2) less dependent to complex electrophysiological study; 3) oven injury to the sleeve wall, 4) minor stenosis of target pulmonary vein. Its disadvantages include: 1) poor portion selection; 2) more serious injury than spot ablation, 3) poor contact between the irregular morphology of the sleeve and regular balloon morphology. In our study, unsatisfied immediate ablation effect may be due to above disadvantages of the intervention. The long-term prophylactic effect would be related to the remodeling of the ablated sleeve structures.

Limitation of the Study

Followings are the major limitations of the study: 1) Due to the shortage of determined ablation end points during the interventional procedure, its long-term effect could not be accurately forecasted; 2) Because the small case group, selective bias could not be avoided; 3) Pulmonary vein stenosis could not excluded completely for pulmonary vein angiography is not a necessary follow up item; 4) Not being a randomized and controlled trial, the natural variation of FAf and observer bias may be participated in the long-term prophylactic effect of the therapy. Therefore, further investigations are needed to confirm the long-term efficacy.

Conclusions

1) Atrial premature beat disappearance, PSP amplitude decrease, and actual ablation temperature might not be reliable end points during the procedure of ultrasound balloon catheter ablation to FAf; 2) The remodeling of the target pulmonary vein ostium may be one of the factors to the prophylactic effect of the therapy; 3) The immediate reocurring of FAf after ultrasound balloon catheter ablation does not completely represent its long-term effect.

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