Radiofrequency Catheter Ablation of Paroxysmal Atrial Fibrillation; Guidance by Intracardiac Echocardiography and Integration with other Imaging Techniques

M. R. M. Jongbloed¹, J. J. Bax¹, N. M. S. de Groot¹, M. S. Dirksen², H. J. Lamb², A. de Roos², E. E. van der Wall¹ and M. J. Schalij¹

¹Department of Cardiology and ²Radiology, Leiden University Medical Center, The Netherlands

Introduction

Atrial fibrillation is the most common arrhythmia, with an increasing prevalence at higher age[1]. Besides symptoms that affect quality of life, there is a significant risk of thromboembolic complications, heart failure and death. Different therapeutic options are proposed. Results of pharmacological treatment are often disappointing. Adverse side effects of antiarrhythmic medication are considerable and pro-arrhythmic effects may occur[2]. Over the recent years, interest in non-pharmacological therapies for atrial fibrillation has increased. Besides the development of techniques focusing on rate-control, such as His bundle ablation, surgical techniques aiming at restoration of sinus rhythm have been developed[3]. In addition, intra-operative application of radiofrequency current has been proposed and several catheter-based techniques have been developed. The observation that ectopic foci originating in the pulmonary veins can initiate atrial fibrillation[4], has stimulated the development of percutaneous ablation strategies aiming at ablation at the site of the pulmonary veins. Results are promising, but at the cost of long procedure times and serious procedure-related complications[5]. These issues are (in part) related to the fact that the ablation targets, namely the veno-atrial junctions and the pulmonary veins or their ostia, are not easily visualized using fluoroscopy alone. Furthermore, fluoroscopy does not allow identification of anatomical intra-cardiac structures accurately and cannot be used to verify adequate catheter-tissue contact. Accurate catheter positioning is therefore difficult. These problems can partly be overcome by the use of three-dimensional electro-anatomic mapping systems and intracardiac echocardiography during the ablation procedure; in addition, non-invasive imaging of the pulmonary veins using magnetic resonance techniques or multi-slice computed tomography will allow planning of the ablation strategy prior to the ablation procedure.

The aim of this case report is to describe the integrated use of different imaging modalities in the treatment of atrial fibrillation by radiofrequency catheter ablation. We have performed multi-slice computed tomography prior to radiofrequency catheter ablation to obtain information on the number/location of the pulmonary veins, their ostia and eventual anomalies. During the radiofrequency catheter ablation procedure, intra-cardiac echocardiography was used to determine catheter position in relation to the anatomic structures, assessment of catheter-tissue contact and evaluation of potential complications. A non-fluoroscopic mapping and navigation system provided electrophysiologic information, during the procedure and constructed a three-dimensional model in which ablation lesions could be marked.
Case Presentation

A 30-year-old male was referred to our hospital because of symptomatic paroxysmal atrial fibrillation. The patient had a 3-year history of paroxysmal atrial fibrillation, with daily episodes varying from 10 min to several hours. The episodes were preceded by chest discomfort in combination with palpitations, extreme fatigue and (occasionally) dizziness. Different antiarrhythmic drug combinations did not result in a reduction of the number of episodes. On physical examination, blood pressure was 140/90 mmHg with a heart rate of 85 bpm. No abnormalities indicative of heart failure were observed. The ECG showed sinus rhythm without abnormalities. All laboratory tests were normal. Transthoracic echocardiography was normal except a slightly enlarged left atrium (45 mm). During electrophysiologic examination atrial fibrillation was repetitively inducible. Accordingly, the patient was referred for radiofrequency catheter ablation, aimed at electrical isolation of the pulmonary veins. Prior to the ablation procedure, multi-slice computed tomography was performed, showing normal pulmonary vein anatomy (Fig. 1). Additional pulmonary veins or common ostia were not observed. Radiofrequency catheter ablation of pulmonary veins was performed guided by a three-dimensional non-fluoroscopic electro-anatomic mapping system (CARTO®, Biosense Webster) and intra-cardiac echocardiography (AcuNav, Acuson Corporation, Mountain view, CA). Two 6 F quadripolar reference catheters and one 7 F 4 mm tip mapping and ablation catheter were introduced via the right femoral vein, while the 10 F ultrasound catheter was inserted in the left femoral vein. Heparin (7500 IU) was administered intravenously at initiation of the procedure. During the procedure activated clotting time was maintained at 2.5 to three times the baseline value (controlled hourly).

Intra-cardiac Echocardiography

The AcuNav diagnostic ultrasound catheter (10 Fr) consists of a 64-element miniaturized, multi-frequency (5 MHz–10 MHz) phased-array transducer that scans in the longitudinal plane, providing a 90° sector image with tissue penetration of 12 cm. Unique features of the catheter include the manoeuvrability inside the cardiac chambers and the options of colour and pulse Doppler measurements.

Imaging of the left atrium and its anatomical structures was achieved with the ultrasound catheter positioned in the right atrium. After exclusion of an intra-cardiac thrombus, transseptal puncture was performed guided by intra-cardiac echocardiography. Intra-cardiac echocardiography provided a clear vision of the interatrial septum, distinguishing the central fossa ovalis from the fatty limbus (Fig. 2). On advancing the puncture needle, tenting of the septum could be seen before puncture of the septum was achieved. After transseptal puncture the ablation catheter was positioned in the left atrium. Intra-cardiac echocardiography was then directed at imaging of the pulmonary veins. Figure 3 illustrates the left superior pulmonary vein; Colour Doppler can be used to evaluate flow in the pulmonary veins (Fig. 4). Figure 5 displays the right pulmonary veins. Figure 6 shows the ablation catheter positioned at the ostium of the left inferior pulmonary vein. Pulsed Doppler recordings (Fig. 7) allow evaluation of potential stenosis of the pulmonary veins after ablation.

Radiofrequency Catheter Ablation

Radiofrequency catheter ablation was aimed at electrical isolation of the pulmonary veins by creating circumfer-
Catheter position in relation to the pulmonary vein ostia was determined using direct visual information obtained from intra-cardiac echocardiography. On each ablation point, RF-current was applied for 30 s. Successful ablation was defined as a disappearance or decrease in local electrogram amplitude >80% at the site of the ablation lesion. A total of 93 ablation points were made around three pulmonary vein ostia. The right inferior pulmonary vein ostium was not targeted, as catheter manoeuvrability is difficult at this site and pulmonary vein ectopy is relatively less frequent.\textsuperscript{4} Intra-cardiac echocardiography was used to exclude migration of the catheter. Electrophysiologic information was obtained by the CARTO-system, which provided a three-dimensional reconstruction of the left atrium and the pulmonary veins, using information about the number of PV provided by multi-slice computed tomography. Furthermore, the CARTO-system was used to mark ablation sites. During radiofrequency catheter ablation, these marks were used to determine the next ablation site. Once the target site was determined, intra-cardiac echocardiography was used to identify the pulmonary vein ostium en catheter position. CARTO supported the anatomic localization of the ablation catheter. Catheter–tissue contact was confirmed with intra-cardiac echocardiography (perpendicular catheter contact). Thus, imaging techniques were integrated to perform successful radiofrequency catheter ablation. Figure 8 demonstrates a CARTO image after ablation of the left superior pulmonary vein ostia. After ablation the patient was electrically converted to sinus rhythm and no ectopic atrial activity could be detected any more. Continuity of conduction block was confirmed by pacing from the left
atrium and from the pulmonary veins. Arrhythmia induction (burst pacing up to a cycle length of 400 ms and three extra stimuli) could not induce atrial fibrillation. Intra-cardiac echocardiography excluded acute pulmonary vein stenosis after ablation. The procedure time was 155 min and fluoroscopy time was 35 min.

After the procedure, 7 days telemetric rhythm observation showed no recurrence of atrial fibrillation. Three months after radiofrequency catheter ablation of the pulmonary veins, no recurrence of atrial fibrillation had occurred.

Discussion

Radiofrequency catheter ablation is an approach to curative treatment of pharmacological refractory atrial fibrillation. In 1998, Haïssaguerre et al. described the initiation of atrial fibrillation by ectopic foci originating in the pulmonary veins. Radiofrequency catheter ablation has been directed at ablating arrhythmogenic foci after identification of pulmonary vein potentials using mapping techniques. In 62–73% of patients with paroxysmal AF sinus rhythm can be restored without the need for antiarrhythmic medication, but after multiple ablation sessions in 41–69% of patients. Pappone et al. have described an anatomical approach, aimed at electric isolation of all pulmonary veins by circumferential ablation around pulmonary vein ostia. Success rates in patients with paroxysmal AF are promising (62–65% without antiarrhythmic drugs, up to 85% of patients with formerly ineffective drugs), but procedure times and fluoroscopy times are still extensive, related to inadequate visualization of intra-cardiac structures and difficulty in catheter manoeuvrability. Pulmonary vein stenosis has been described following ablation procedures in the pulmonary veins. To facilitate these complex ablation procedures we described in the current report the use and integration of different imaging techniques.

First, multi-slice computed tomography was used to evaluate the exact anatomy of the pulmonary veins. The capacity of pulmonary veins to initiate atrial fibrillation has been attributed to sleeves of atrial myocardium extending in the pulmonary veins. Variations in numbers of pulmonary veins and distances between their orifices are known to occur in humans. Information, available before radiofrequency catheter ablation, would facilitate the procedure and for this reason multi-slice computed tomography is performed. Multi-slice computed tomography allows the creation of complex three-dimensional reconstructions, without image disturbance due to cardiac motion. Detailed reconstructions can be made of the heart and cardiac vessels.

The use of a three-dimensional electro-anatomic mapping system has been described in guiding radiofrequency catheter ablation procedures. In this case report, the CARTO system was used to provide a three-dimensional reconstruction of the pulmonary veins and the left atrium in which position of the ablation catheter and ablation sites were depicted. Furthermore, the CARTO system was used for activation mapping and measurements of voltages of electrocardiograms recorded at the site of ablation, in order to evaluate continuity of line of block.

Intra-cardiac echocardiography can be used to guide transseptal puncture. During the radiofrequency catheter ablation, intra-cardiac echocardiography can be used to direct the ablation catheter in relation to intra-cardiac structures. Exact localization of the catheter in relation to the pulmonary veins can be obtained easily with intra-cardiac echocardiography, which is not feasible using fluoroscopy. Moreover, procedure and fluoroscopy times can be shortened significantly with the use of intra-cardiac echocardiography. In addition, intra-cardiac echocardiography confirms adequate catheter–tissue contact, which is difficult with fluoroscopy. Markers of catheter–tissue contact include perpendicular contact, the lack of lateral sliding and of microbubble formation. Finally, intra-cardiac echocardiography, using pulsed Doppler recordings, can be used to detect/exclude complications of the procedure such as pulmonary vein stenosis.

In summary, in this case report we have described our initial experience in the integration of different imaging modalities to optimize/guide radiofrequency catheter ablation of pulmonary veins in a patient with paroxysmal atrial fibrillation. In particular the use of intra-cardiac echocardiography may significantly facilitate the safe performance of these complex procedures. At this moment we are exploring the feasibility of this integrated approach before implementation in routine practice. It remains to be determined whether this integrated approach will result in further reduction of recurrence of AF. Therefore, the issue of cost-efficacy has to be carefully considered.
References


