Three-dimensional computed tomography overlay for pulmonary vein antrum isolation: Follow-up and clinical outcomes

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Abstract

Background To facilitate the creation of circumferential lines in pulmonary vein (PV) antrum isolation, three-dimensional (3D) navigation systems are used widely. Alternatively, 3D reconstructions of the left atrium (LA) can be superimposed directly on fluoroscopy to guide ablation catheters and to mark ablation sites.

Methods In 71 atrial fibrillation patients circumferential PV ablation was performed. 3D reconstructions of the LA were derived from contrast cardiac-computed tomography and circumferential PV isolation was performed. In subsequent ablation procedures, veins were re-isolated, and defragmentation or linear lesions were performed if necessary.

Results Adequate 3D reconstructions were formed and registered to fluoroscopy in all patients. All veins, except 2 in one single patient, could be isolated, resulting in freedom of AF in 45 patients (63 %). In 19 patients a second procedure was performed, in which 2.7 ± 1.1 PV per patient were re-isolated; in 3 patients a third procedure was performed. After follow-up of 15 ± 8 months, 51 (91 %) of patients with paroxysmal and 10 (67 %) with persistent AF were free of AF.

Conclusions The results of 3D overlay for circumferential PV isolation are good, although the reconnection rate and need for subsequent ablations remains high, and the outcomes of this technique appear to be equivalent to other mapping techniques.

Keywords Atrial fibrillation · Catheter ablation · Image integration · Electro-anatomic mapping

Introduction

To facilitate the creation of continuous circumferential lesions around pulmonary vein antra, electro-anatomical mapping systems are used widely [1]. After the initial concept of fluoroscopy-guided segmental isolation of separate pulmonary veins (PVs) [2], atrial fibrillation (AF) ablation shifted from PV ostial ablation to wide circumferential or antrum isolation [1, 3], aiming to isolate both ipsilateral veins by one single circular ablation line remote from the PV ostia, resulting in better outcomes [4, 5] and less PV stenosis [6].

The use of electro-anatomical mapping has been demonstrated to improve outcome after ablation [5, 7] and to reduce radiation burden [8, 9]. However, use of electro-anatomical mapping systems may increase procedural duration and overheads, and may limit the choice of ablation catheters. In recent years, a technique of superimposition of a 3D reconstruction of the left atrium over fluoroscopy has been developed [6, 10–13]. We have described the feasibility of this computed tomography (CT) overlay for pulmonary vein antrum isolation and its equivalence to established electro-anatomical mapping [14].

In the present registry, we describe the clinical results of our initial experience with 3D overlay for AF ablation.

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Methods

Study population and initial procedure

Between May 2007 and April 2010, 76 patients with drug refractory paroxysmal ($n=56$) or persistent ($n=15$) atrial fibrillation were ablated using the 3D-overlay technique. Thirty-eight patients had been included in a prior randomised study [14], while the remaining patients of this registry were scheduled for this ablation technique randomly. Prior to ablation all patients underwent trans-thoracic echocardiography; trans-oesophageal echocardiography was performed according to the guidelines [1]. All patients gave informed consent for the procedure.

For all procedures, oral anticoagulation was continued at INR levels between 2.5 and 3.5, while antiarrhythmic drugs were stopped for at least 3 days, except amiodarone. Catheter ablation was performed in patients in a fasting state, using local anaesthetics and conscious sedation. Transseptal access was obtained by two separate punctures via the right femoral vein for introduction of SL0 8.5 Fr sheaths (St. Jude Medical, USA), continuously flushed with heparinised saline. After transseptal access systemic heparinisation was started and titrated to an activated clotting time >300 s.

For catheter ablation an irrigated 3.5 or 4.0 mm RF-ablation catheter was used, at a maximum power of 30–35 Watts and an irrigation rate of 20 ml/min. PV isolation was performed by wide circumferential ablation, aiming to isolate both ipsilateral PVs simultaneously. Isolation of a PV was defined as complete disappearance of PV potentials, demonstrated by a multipolar circular diagnostic catheter.

3D imaging

3D reconstructions were constructed from contrast cardiac CT acquisitions. This technique has been described before [14]. In short, CT was performed using a 64-slice initially, and later a 256-slice CT scanner, with 85 ml of intravenous contrast. Based on slices of 0.7–1.0 mm, image reconstruction was performed at 40 % or 75 % of the RR interval to acquire images at end-systole or mid-diastole, respectively.

Segmentation and reconstruction of the left atria were performed by the EP navigator system (Philips Healthcare, Best, the Netherlands). This computer-derived segmentation was checked manually and corrected if necessary.

Overlay registration and position tagging

The EP navigator system allowed superimposition of a segmented 3D CT image of the left atrium and proximal PVs on the X-ray image (*CT overlay*). The technique of registration of the 3D image to the fluoroscopy has been described in detail before [14]. Registration of the 3D CT image to the X-ray

image was achieved using a standard method: Initially, a simultaneous contrast injection in both superior veins was used to position the 3D image in the frontal plane, followed by a contrast injection in the left superior PV in lateral projection to adjust table height. Finally, spatial orientation was confirmed by selective contrast injections in both inferior veins. After registration and locking, the 3D CT image was continuously orientated in the same angle as the fluoroscopy. In addition, the 3D image could be clipped manually, allowing internal views.

Ablation location tags were placed on the surface of the 3D image by mouse-clicking on the ablation tip in the fluoroscopic image. In case of ambiguity between the posterior or anterior position, the C-arm was rotated about 30° in left anterior oblique or right anterior oblique direction to resolve the proper location of the catheter. Examples of a registered 3D fluoroscopy overlay and ablation tagging are shown in Fig. 1.

Re-do procedures

Outcome was based on symptoms and subsequent electrocardiographical confirmation of atrial fibrillation or tachycardia. In case of recurrence of symptomatic tachyarrhythmias after 2 months, a subsequent ablation procedure was proposed to the patient. The principal aim of a second procedure was to re-isolate veins with reconnection. This was performed using fluoroscopy and a multipolar catheter only, without use of overlay or other mapping techniques. If, after re-isolation, AF, atrial tachycardia or atrial flutter persisted, an electro-anatomical mapping system was used to map tachycardia and to explore sites of fractionated electrograms. In case of macroreentrant tachycardia, an anatomical linear lesion was created to stop the flutter; focal or microreentrant tachycardias were ablated locally. If AF persisted after re-isolation of the PVs, fractionated electrograms were targeted, until fibrillation terminated or AF cycle length increased [15].

Follow-up

Initial follow-up was scheduled at 2 to 3 months after each ablation, at 6 months, and for every 6 months subsequently. At each visit, patients were questioned about symptoms and a 12-lead ECG was performed. In case of symptoms suspected for atrial arrhythmia, either a 24-hour ambulant ECG or a 2–4 week event recorder was performed.

Statistics

Quantitative data are expressed as mean $\pm$ SD. For comparison of continuous data, a two-sided Student's *t*-test was used. Comparisons of categorical data were performed using Fisher's exact or Chi square test. Survival curves were generated using the Kaplan-Meier method. *P* values <0.05 were considered to be statistically significant.

Fig. 1 **a**, Registration of the left atrium to the fluoroscopy after simultaneous contrast injection in both superior pulmonary veins. **b**, Position of Lasso catheter in right superior vein and ablation catheter in ostium of left superior vein. **c**, Left oblique (45°) image of RF application at inferior border of the right antrum. **d**, Final image after isolation of both PV antra

Results

Patients and initial procedure

Between 2007 and 2010, PV isolation using the CT-overlay technique was performed in 71 patients (mean age 57 ± 10 years, 50 male): 56 with paroxysmal and 15 with persistent AF. Baseline characteristics are shown in Table 1. Follow-up after the initial procedure ranged from 3 to 37 months, mean 18 ± 7 . Contrast CT provided excellent image quality in all patients, and successful registration was achieved in all cases.

Initial ablation procedure was successful in all except 1 patient in whom 2 veins could not be isolated. The procedure was complicated by a femoral pseudoaneurysm in 1, and a septicaemia in 1 patient.

Table 1 Baseline characteristics

Age, years	57 ± 10
Male/female	50/21
Failed AAD	2.5 ± 0.5
AF history, years	5 ± 6
AF classification	
Paroxysmal	56 (79)
Persistent	15 (21)

Data are given as mean $\pm$ SD or numbers (%). AAD antiarrhythmic drugs, AF atrial fibrillation

Clinical outcome after the initial ablation procedure

After a blanking period of 2 months, arrhythmia recurred in 26 patients (37 %) after 181 ± 149 days. Forty-five patients (63 %) remained free of symptoms for a follow-up period of 15 ± 8 months. Recurrent arrhythmia was atrial fibrillation in 20 (77 %) and regular tachycardia in 6 (23 %). Nineteen patients with recurrence (73 %) consented to a second ablation procedure. Of the remaining 7 patients, symptoms of fibrillation disappeared completely in 2, spontaneously in 1 and with oral flecainide in 1; in 2, there was a marked symptomatic improvement, without antiarrhythmic drugs. Three patients had no change in AF symptoms. Arrhythmia-free survival after the initial procedure is shown in Fig. 2.

Re-do procedures

Nineteen patients underwent a second procedure, and in 3 patients a third procedure was performed. The average number of ablation procedures in patients with paroxysmal and persistent AF was 1.2 ± 0.5 and 1.5 ± 0.7 respectively ($p = 0.06$). During the second procedure, recovery of PV conduction was seen in all patients, with an average of 2.7 ± 1.1 conducting veins per patient and all PVs were re-isolated. Regular tachycardia was due to PV reconnection in 5 (83 %); in 1 patient regular tachycardia was due to a roof-dependent macroreentrant flutter, which was successfully

Fig. 2 *Upper panel*, Kaplan-Meier curve showing survival free of atrial tachycardia or fibrillation after the initial ablation procedure. *Lower panel*, arrhythmia-free survival after the last ablation

terminated by a roofline. In 2 patients with persistent AF, ablation of fragmented electrograms was performed. After the second procedure, arrhythmia recurred in 6 patients, 5 with persistent AF and 1 with initial paroxysmal AF, who progressed to persistent. Three of the 6 patients with recurrence after the second chose to undergo a third procedure.

During the 3rd ablation procedure, reconnection was observed in 3 veins in 2 patients. Re-isolation resulted in disappearance of AF in one. The remaining 2 patients in whom a third procedure was performed remained symptomatic, also after extensive ablation of fractionated electrograms.

Finally, after a follow-up of 15 ± 8 months after the last ablation, freedom of AF was observed in 51 (91 %) of paroxysmal and 10 (67 %) of persistent AF patients, while in 2 and 4 patients, respectively, a symptomatic improvement is found (Table 2 and Fig. 2).

Discussion

The present study shows that the use of overlay of a 3D image of the left atrium is feasible for circumferential PV isolation and the clinical outcomes are good and comparable with other techniques, both for paroxysmal and persistent AF.

After initial focal PV ablations [16] and segmental ostial ablations [2], the currently recommended technique of PV isolation is wide circumferential ablation, aiming to isolate both antra of ipsilateral veins [1]. Creation of continuous circular lines around ipsilateral PVs requires adequate anatomical guiding of the ablation catheter by electro-anatomical mapping, either as a sole technique [3, 17] or with integration of cardiac CT [18, 19].

In recent years, the technical feasibility and the procedural success of the CT-overlay technique has been demonstrated by several authors [11, 13, 14, 20]; however, the clinical follow-up is reported in one randomised study only [21], demonstrating its equivalence to a conventional mapping technique. Although we did not perform a direct comparison of CT overlay to electro-anatomical mapping, procedural success, freedom of symptomatic AF and need for subsequent ablations are comparable with other reports [18, 21, 22]. The outcome of a single ablation procedure is fair, but the recurrence rate remains high, due to a high incidence of recovery of conduction from the PVs; however, this recovery rate is similar to standard techniques [23, 24]. In our opinion there is no reason to suspect less transmural of the lesions created using the overlay technique than with electro-anatomical mapping.

A potential drawback for the use of CT overlay instead of electro-anatomical mapping is a concern for increased radiation burden, both for the patient and the operator [25]. However, several randomised studies did not show significant differences in radiation dose [14, 21], even though fluoroscopy time may be prolonged. Limited use of fluoroscopy, low frame rates, minimal radiation beam energy, and

Table 2 Results and outcome after ablation

	Paroxysmal (n=56)	Persistent (n=15)	P-value
Ablation procedures, n	1.2 $\pm$ 0.5	1.5 $\pm$ 0.7	0.06
Final outcome			0.02
Free of AF	51 (91)	10 (67)	
Improvement	2 (4)	4 (27)	
Recurrence	3 (5)	1 (7)	
Antiarrhythmic drugs			0.0003
β -blocker	3	6	
Class I/III	2	2	
None	51	7	
Defragmentation, n	1	2	0.11
2nd procedure, n	12 (21)	7 (47)	0.10
Reconducting veins	2.7 $\pm$ 1.0	2.8 $\pm$ 1.3	0.87
3rd procedure, n	1 (8)	2 (29)	0.76
Reconducting veins	1	1.0 $\pm$ 1.4	—

Data are given as numbers (%), or mean $\pm$ SD

careful diaphragm can limit total radiation burden to an acceptable level [14].

Among the potential advantages of use of a CT-overlay technique is a reduction in procedural costs; use of complex electro-anatomical mapping systems may increase the costs of a procedure, not only for the initial, once-only purchase of the mapping system, but also for the use of exclusive, more expensive catheters, repetitively [25, 26].

Limitations

For a demonstration of equivalence of the current overlay technique to standard electro-anatomical mapping systems a prospective, randomised comparison should be conducted; we believe, however, that our results are comparable with the standard techniques. Preferably, absence of AF should be verified by ambulant ECGs or event recorders; as this is not part of our current practice for patients who are free of symptoms, we can not exclude that some of the asymptomatic patients still may have AF paroxysms.

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