Comparison of clinical outcomes and safety of catheter ablation for atrial fibrillation supported by data from CT scan or three-dimensional rotational angiogram of left atrium and pulmonary veins

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Background. Catheter ablation in the left atrium has become a common therapeutic strategy in the management of atrial fibrillation (AF). The high degree of success and safety profile of this procedure is dependent on precise knowledge of the true anatomy in the chamber. This information is imported mostly from cardiac computed tomography. A novel method for imaging the left atrial anatomy is three-dimensional rotational angiography (3DRA).

Methods. The aim of our study was to the compare clinical outcome and safety of catheter ablation for atrial fibrillation guided by 3DRA vs. conventional CT scan. One hundred and twenty-five patients referred for AF catheter ablation at St. Anne's University Hospital Brno were included in the retrospective analysis of clinical outcome within the first year after the procedure.

Results. There was a close correlation in overall procedural parameters between the groups. The frequency of recurrent episodes of AF (24% in CT-guided group vs. 27% in 3DRA-guided group, P=0.721) as well as the onset of atypical atrial flutter after the procedure (10% vs. 8%, respectively, P=0.731) were similar in both groups. No difference in the number of patients necessitating repeat ablation (5% vs. 5%, P=0.984) was found. Procedural complications of ablations guided by 3DRA were comparable with those guided by CT (2% vs. 3%, respectively, P=0.568).

Conclusion. 3DRA has proven to be a safe and simple method for imaging the left atrium and guiding catheter ablation for AF. This approach is anticipated to become a new standard in 3D reconstruction of the left atrium.

Keywords: atrial fibrillation, catheter ablation, electrophysiology, three dimensional rotational atriography, computed tomography, imaging, left atrium

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INTRODUCTION

Catheter ablation for atrial fibrillation is a technically challenging but highly effective left atrial procedure¹. Given the variability of the left atrium and pulmonary vein ostia, precise knowledge of true anatomy is the key to a successful and safe intervention². Therefore, preprocedural computer tomography (CT) or magnetic resonance (MR) is frequently used as anatomical guidance for catheter ablation³⁻⁵. A novel method allowing reconstruction of the left atrium is three-dimensional rotational angiogram (3DRA), which is carried out intra-procedurally right in the EP lab^{6,7}. The acquired 3D volume is then used as a template for non-fluoroscopic 3D electroanatomic mapping in the systems Carto (Biosense Webster, Diamond Bar, CA, USA) or Velocity (St. Jude Medical, St. Paul, MN, USA) (ref. 8,9). Three-dimensional rotational angiogram also enables merging the resulting 3D image with live fluoroscopy, which is a great help for orientation in the left atrium during the map acquisition (Fig. 1). Moreover, the anatomical data obtained from 3D rotational angiogram of left atrium has proven to be comparable with the information from conventional CT scan and radiation exposure is lower by using 3DRA (ref. 10,11). Another advantage is the possibility of integrating the 3D image from the rotational angiography into the electroanatomical mapping system, which facilitates the execution of AF ablation and reduces the total procedural time and radiation exposure while providing similar clinical outcomes¹². Previous studies have proven that the fusion of CT or MR image of the left atrium with the electroanatomical map in the Carto-Merge system is beneficial for the clinical outcome of the AF ablation and reduction in fluoroscopic guidance^{4,13,14}. The range of 3D rotational angiography application is even wider. There are reports of registration of 3D volume obtained from 3DRA with intracardiac echocardiography (ICE) allowing for electroanatomical mapping of the left atrium. This was the first ever image integration of two left atrial reconstructions by means of two different intraprocedural methods of noninvasive cardiac imaging - 3D rotational angiography and ICE-based image registration in electroanatomical mapping system¹⁵.

Three-dimensional rotational angiogram is performed

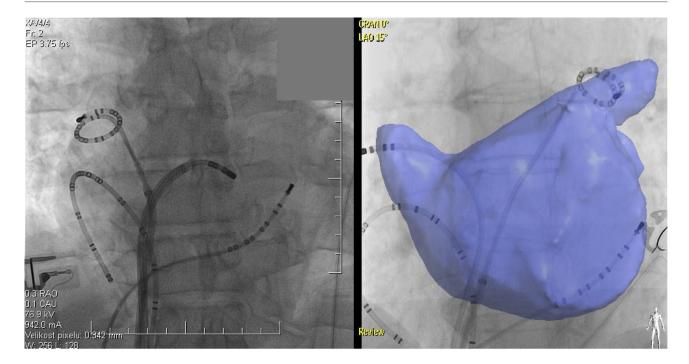


Fig. 1. On the left, there is a skiascopic view of catheter ablation of atrial fibrillation without using three-dimensional rotational angiography. On the right, there is a fused image of the skiascopic view and the 3D image of the left atrium obtained from three dimensional angiography. This fused image is great guidance for catheter ablation of atrial fibrillation.

using cardiac X-ray system with custom software for 3D image post-processing. Following the initial intracardial contrast injection, a fixed C-arm rotates around the patient and acquires a series of x-ray images immediately reconstructed by a software algorithm into the 3D volume representing the left atrium and pulmonary vein ostia. The contrast medium can be injected either directly into the left atrium with subsequent rapid ventricular pacing or intravenous administration of adenosine to induce shortterm asystoly and allow for homogenous contrast opacification, or indirectly in the right atrium with a delay of 9 s preceding the initiation of rotational run to permit the transit of contrast medium through the lungs into the left atrium^{16,17}. Advanced angiography systems equipped with 3DRA (e.g. EP Navigator - Philips, DynaCT Cardiac -Siemens, Innova - GE Healthcare) are currently available to enhance and support electrophysiological intervention.

From 2010 to June 2013, our center performed more than 408 left atrial and 33 right or left ventricular angiograms. To the best of our knowledge, there are no data available on the clinical outcome of catheter ablation for atrial fibrillation guided by 3D rotational angiogram of left atrium. The aim of our study was to compare clinical outcome and safety of the catheter ablation for atrial fibrillation guided by 3D rotational angiography vs. conventional CT scan.

METHODS

One hundred and twenty-five patients referred for AF catheter ablation at St. Anne's University Hospital in Brno were included in the retrospective analysis of clinical out-

come within the first year after the procedure. Data from January 2011 to August 2011 reported only CT-guided ablations while the majority of the procedures between September 2011 and August 2012 have already used the 3D rotational angiography with left atrial injection and those were involved in the study. Had there been a history of iodine allergy or renal insufficiency indicated by a decline in glomerular filtration rate of less than 45 mL/min, no 3DRA or CT were performed.

Patient preparation

All patients underwent a full clinical assessment in an outpatient service for cardiac arrhythmia and were submitted to catheter ablation for drug refractory paroxysmal or persistent atrial fibrillation. Transthoracic echocardiography was performed preoperatively in all of them. If considered necessary, anticoagulant therapy followed CHA2DS2-VASc score guidelines and was discontinued five days prior to the scheduled procedure 18. Patients were supplemented with subcutaneous low molecular heparin adjusted according to their weight until the day of the procedure to compensate for ineffective levels of INR. Those treated from January 2011 to August 2011 underwent preprocedural cardiac CT. Before the procedure, transesophageal echocardiography was performed to exclude the presence of intracardiac thrombus.

Computed tomography

Patients underwent a CT scan within seven to 14 days preceding the procedure using 64 Slice CT Scanner (GE Lightspeed VCT, General Electric, Fairfield, USA) with configuration 120 KV, 800 mAs, a collimation width of 63 x 0.625 mm, and a spiral pitch factor of 0.98. The

images were then reconstructed in a resolution of 512 x 512 pixels. Contrast medium injection (100-150 mL of Ultravist 370, Bayer Pharma AG, Berlin, Germany or Iomeron 400, PNG Gerolymatos A.E.B.E., Kryoneri – Athens, Greece) was administered via the peripheral vein. During the acquisition, patients remained lying down with both arms raised and breath-holding. The obtained x-ray images were then transferred to a data CD. At the time of the procedure, 3D representation of the left atrium was reconstructed in the 3D electroanatomical mapping system (EnSite Velocity, St. Jude Medical, St. Paul, MN, USA) based on the anatomic shell imported from CT.

Three-dimensional rotation angiography

Rotational angiography was performed using a C-arm angiography system Philips Allura Xper FD 10 with a 10-inch flat detector (Philips Healthcare, Best, The Netherlands). After injecting the contrast medium into the left atrium, C-arm was rotated from 120° right anterior oblique (RAO) to 120° left anterior oblique position (LAO) over 4.1 s. Images acquired at a rate of 30 frames per minute were then transferred to a working station and reconstructed into a 3D volume using the specialized software for automated segmentation (EP Navigator 3.0, Philips Healthcare, Best, The Netherlands). For a contrast injection, a pigtail catheter (Cordis, Miami, FL, USA) advanced to the left atrium was used and a bolus of 60 mL contrast medium (Ultravist 370 I/mL, Bayer Pharma AG, Berlin, Germany) was administered at a speed of 15 mL/s via power injector (Mark-V ProVis, Medrad, Inc., Indianola, PA, USA). Patients were lying down with the hands along the body and were asked for shallow breathing. Prior to contrast application, a quadrupolar steerable catheter (Irvine Biomedicals, Irvine, CA, USA) was positioned into the right atrial apex and rapid ventricular pacing of 220 beats per min was performed with a substantial decrease in blood pressure detected by the absence of oxygen saturation curve on the pulse oximetry monitor screen (Philips IntelliVue MP-20, Philips, Eindhoven, The Netherlands) (ref. 19). Finally, the contrast medium was injected and C-arm rotation initiated with a 2 s delay. Along with the left atrial rotational angiography, all patients underwent a 3D rotational esophagography to visualize the position of the esophagus and its relation to other cardiac structures 20. Opacification was achieved by swallowing 30-50 mL of barium sulfate esophageal cream (Micropaque – Guerbet, Roissy, France) five seconds before the initiation of rotational run.

Catheter ablation

All patients underwent the ablation procedure under a standard protocol using Philips Allura Xper FD10 system (Philips Healthcare, Best, The Netherlands). Sheaths and electrophysiological catheters were inserted via both femoral veins under local anaesthesia. The 8F sheath was introduced through the left femoral vein and used for advancement of a decapolar catheter into the coronary sinus. Double transseptal puncture was performed via right femoral venous access with the guidance of fluoroscopy, local injection of an iodinated contrast medium with an invasive blood pressure monitoring system on a needle tip, and intracardial ultrasound. Then, both an 8.5F Agilis steerable introducer and an 8F SL1 sheath (St. Jude Medical, St. Paul, MN, USA) were positioned into the left atrium and a bolus of intravenous heparin with continuous infusion adjusted according to the ACT (target levels of 350 to 300 s) was administered. An irrigatedtip ablation catheter (CelsiusTM Thermo-cool, Biosense Webster, Diamond Bar, CA, USA) was inserted over the Agilis steerable sheath and placed into the left atrium as well as a duodecapolar spiral catheter (ReflexionSpiral Variable Radius CatheterTM, St. Jude Medical, St. Paul, MN, USA) advanced over the SL1 transseptal sheath. An electroanatomical map of the left atrium and left pulmonary veins was made based on a 3D anatomic shell from either CT or 3DRA in the EnSite NavX system

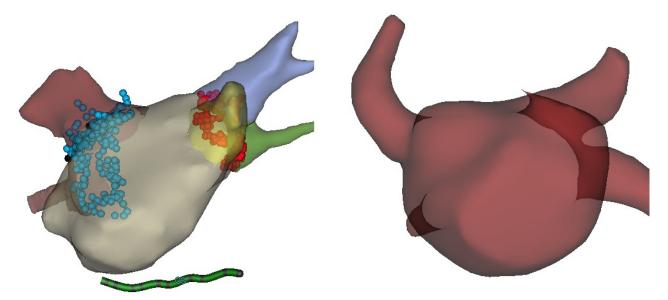


Fig. 2. On the right, there is a 3D image of the left atrium obtained from CT scan. On the left, there is shown an electroanatomical map of the left atrium based on the image obtained from CT (the red and blue points mark location of RF ablations).

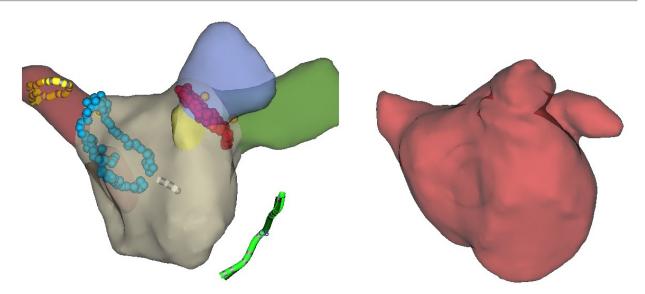


Fig. 3. On the right, there is a 3D image of the left atrium obtained from three-dimensional rotational angiography. On the left, there is shown an electroanatomical map of the left atrium based on the image obtained from CT (the red and blue points mark location of RF ablations).

(St. Jude Medical, St. Paul, MN, USA) (Fig. 2 and 3). Radio-frequency energy was delivered creating circular ablation lesions to isolate pulmonary vein ostia. The successful isolation was defined by achieving the entrance and/or exit block. In patients with persistent atrial fibrillation, adjacent lines of ablation at the left atrial roof, mitral isthmus and distal coronary sinus were performed. During the procedure, patients remained under mild sedation with midazolam and fentanyl. Femoral sheaths were removed within three hours post procedure upon a decrease of intravenously administered heparin and groin compressions were applied. Patients were discharged the day after the ablation.

Follow up

Patients were followed during regular visits at one, six and 12 month(s) after the index procedure in the outpatient service for cardiac arrhythmias. Evaluation of prior 24-h holter monitoring, 12-lead ECG recordings, and arrhythmia episodes were documented. If considered necessary, patients were provided with an episodic ECG portable heart scan (Omron Healthcare Co. Ltd., Kyoto, Japan) for a period of 14 days and the results were analyzed in an extra visit. All data were entered into the hospital information system, which served as source documentation for our analysis.

Radiation dose assessment

A total radiation dose was calculated for both the ablation procedure and the left atrial imaging (3DRA or CT). Regarding the different use of units, we compared the effective radiation dose (mSv). The amount of radiation during cardiac CT scan was expressed as "dose length product" (mGy cm¹) and was adjusted using a conversion coefficient 0,017 mSV mGy¹cm¹ (ref.²¹). Radiation exposure for 3D rotational angiography was measured as "dose area product" (mGy cm²) and the ef-

fective dose was calculated using a conversion coefficient 0,18 mSVmGy¹cm² (ref.²²).

Statistical analysis

Patient characteristics and the clinical outcome of both groups were described using descriptive statistics. Continuous variables are expressed as a mean \pm standard deviation (SD) and categorical variables as absolute values and percentages. All parameters were compared according to the imaging method used. Categorical data were analyzed using chi-squared test or Fisher's exact test. Continuous data were evaluated using unpaired Student's t-test or nonparametric Mann-Whitney when dealing with non-normal distribution. Results were deemed statistically significant for a P value > 0.5 since all analyses were performed at the 5% significance level.

RESULTS

The study sample involved 125 patients with paroxysmal or persistent atrial fibrillation who received therapeutic catheter ablation at the Arrhythmology Department of St. Anne's University Hospital in Brno between January 2011 and August 2012. The ablation procedure was guided either by preoperational CT scan (62 patients) or periprocedural 3D rotational angiography (63 patients). There was no difference in age, gender, BMI, left atrium diameter, left ventricular ejection fraction, concomitant diseases or proportion of paroxysmal to persistent AF between both groups. The overall characteristics are presented in Table 1.

For rotational angiography, only direct (left atrial) contrast injection approach was applied with a success rate of 98.5%. The 3D reconstruction was unsuccessful in one patient due to large LA diameter and poor isocentering associated with incomplete resulting image (pulmo-

Table 1. Patients' characteristics.

	CT (N=62) DRA (N=63)			
Parameter	N (%)	N (%)	<i>P</i> *	
Gender (male)	44 (71%)	48 (76%)	0.508	
Hypertension	43 (69%)	42 (67%)	0.747	
Diabetes mellitus	14 (23%)	9 (14%)	0.231	
Hyperlipoproteinemia	32 (52%)	29 (46%)	0.533	
Ischemic heart disease	11 (18%)	6 (10%)	0.180	
Stroke	4 (6%)	2 (3%)	0.392	
Type of atrial fibrillation:			0.480	
Paroxysmal	44 (71%)	41 (65%)		
Persistent	18 (29%)	22 (35%)		
	Mean (SD)	Mean (SD)		
Age (years)	60.3 (10.28)	58.3 (9.61)	0.215	
Left atrial diameter (mm)	43.2 (6.51)	45.5 (6.27)	0.082	
Left ventricular ejection	56.5 (9.55)	57.2 (7.02)	0.888	
fraction (%)				
BMI	29.5 (5.1)	29.3 (4.0)	0.728	

nary vein ostia were not depicted). Conversely, the CT scan yielded 100% success profile.

There was a close correlation in overall procedural parameters between both groups. No difference was observed in procedural time (231 \pm 38 vs. 249 \pm 57 min, P=0.094), fluoroscopic time (24.6 \pm 8 vs. 24 \pm 7.5 min, P=0.702) or number of RF applications (78.21 vs. 84 \pm 23,

Table 2. Procedure results.

	CT	3DRA	
	(N=62)	(N=63)	
Parameters	Mean	Mean	P*
of procedure	(SD)	(SD)	Ρ"
Procedural time	231.6	249.5	0.094
(minutes)	(38.64)	(57.68)	
Fluoroscopic time	24.6	24.0	0.702
(minutes)	(7.99)	(7.46)	
Number of RF	78.6	84.2	0.174
applications	(21.23)	(22.77)	
Ablation time	2732.2	3105.2	0.014
(seconds)	(748.29)	(850.13)	
Radiation exposure	17.66	5.99	< 0.01
(mSv)	(2.32)	(2.68)	

P=0.174). However, ablation time (2732 ± 748 vs. 3105 ± 850, P=0.014) and radiation exposure (17.66 ± 2.32 vs. 5.99 ± 2.68 mGycm², P<0.01) were significantly lower for 3DRA-guided procedures (Table 2). The mean follow-up period was 13.8 ± 3.5 months. The frequency of recurrent episodes of AF (24% in CT-guided group vs. 27% in 3DRA-guided group, P=0.721) as well as the onset of atypical atrial flutter after the index procedure (10% vs. 8%, respectively, P=0.731) were similar in both groups (Table 3). No difference in the number of patients necessitating repeat ablation (5% vs. 5%, P=0.984) was observed. During the follow-up period, both groups showed

a corresponding proportion of prescribed antiarrhythmic drugs (55% vs. 49%, *P*=0.529) and present anticoagulation therapy (42% vs. 46%, *P*=0.777). Procedural complications of ablations guided by 3DRA were comparable with

Table 3. Clinical results.

	CT (N=62)	3DRA (N=63)	
One-year follow-up	N (%)	N (%)	<i>P</i> *
Recurrent of atrial	15 (24%)	17 (27%)	0.721
fibrillation Onset of atypical atrial	6 (10%)	5 (8%)	0.731
flutter	0 (1070)	3 (070)	0.751
Antiarrhythmic drugs	34 (55%)	31 (49%)	0.529
Anticoagulation therapy	26 (42%)	28 (44%)	0.777
Repeat ablation	3 (5%)	3 (5%)	0.984
Procedural complications	1 (2%)	3 (5%)	0.568
(hemodynamically			
insignificant pericardial			
effusions)			

those guided by CT (2% vs. 3%, respectively, *P*=0.568). Only hemodynamically insignificant pericardial effusions not requiring any intervention were reported. No other complications were encountered.

DISCUSSION

Prior studies have already shown that 3DRA reconstruction of left atrium is a feasible, simple and safe method with a high rate of success. The main benefit of the approach is online image acquisition during the electrophysiological procedure at the cath lab and the ability to overlay resulting 3D shell onto the live fluoroscopic screen.

The 3DRA data has proven equal to a cardiac CT scan with no difference in terms of left atrial parameters, such as PV ostia or LA volume measurements. Additionally, patients are subjected to a lower dose of radiation and contrast medium compared to CT. More recently, studies investigating the utility of 3DRA for imaging the right or left ventricle as guidance for catheter ablation of ventricular arrhythmias have been published²³.

To the best of our knowledge, there are only limited research data available assessing clinical outcome of AF ablation guided by 3DRA vs. CT. A study conducted by Knecht et al. is one of the few examples addressing the topic²⁴. In a randomized trial, they compared clinical outcome of catheter ablation for atrial fibrillation supported by conventional electroanatomical mapping using the CARTO system with procedures guided by 3D rotational angiography. Between 2007 and 2008, they assigned 91 patients with paroxysmal (63%) and persistent (37%) atrial fibrillation referred for ablation in Boston and Bordeaux. Those patients were randomized to either CARTO-guided (47 patients) or 3DRA-guided (44 patients) ablation. The data showed close correlation in procedural time (232 ± 65 vs. 218 ± 67 min, *P*=0.335), fluoroscopy time (75 ±

28 vs. 67 ± 26 min, P=0.151), or radiation dose (71810 \pm 42954 vs. 68009 ± 38345 mGycm², P=0.719) between the groups. Patients were followed for a mean period of 10 \pm 4 months and no difference in AF recurrence (20% vs. 15%, P=0.555) or any episodes of recurrent arrhythmia (34% vs. 38%, P=0.668) were observed.

Our results are in concordance with these findings. Only procedural and ablation time were non-significantly longer in the 3DRA-guided group and could be explained by extra time needed for the performance of LA rotational angiography which has been a more aggressive approach in the management of atrial fibrillation at our center during the last two years associated with longer duration of RF delivery. We also found a statistically significant reduction in radiation exposure in those procedures supported by 3DRA compared to CT. Based on our experience, a merger of 3DRA with live fluoroscopy enables us to apply a lower x-ray dose in order to produce the same image sequence which can potentially decrease the radiation exposure in procedures while reaching the same fluoroscopic time. The frequency of AF recurrence was 24% in 3DRA-guided and 27% in the CT-guided group (*P*=0.721) and recurrent arrhythmia in general was 34% vs. 35%, P=0.902. The proportion of arrhythmia-free patients in our sample was slightly lower than Knecht et al., but the mean follow-up period was on average four months longer $(13.8 \pm 3.5 \text{ to } 10 \pm 4 \text{ months})$, possibly leading to a higher occurrence of arrhythmia episodes. The high safety profile of 3D rotational angiography was achieved in both study samples (ours vs. Knecht) with no difference in procedural risks compared to conventional procedures.

Another study investigating clinical outcomes of procedures employing 3D rotational angiography was performed by Carpen et al.¹². This retrospective analysis confirmed that fusion of 3DRA with the electroanatomical mapping system results in reduction of total procedural time and radiation exposure with similar clinical outcome during the follow-up (10±3 months vs. 11.9±5.3 months) compared to procedures without the fusion. Despite the small sample size (36 patients), this conclusion supports the application of 3DRA to guide ablations for atrial fibrillation.

These findings imply a clinical benefit of 3D rotational angiography employed in routine practice. Knecht et al. used 3DRA as a stand-alone imaging method while we dispute 3DRA as an adequate substitute for the conventional electroanatomical mapping since specific functionalities, such as voltage and activation mapping, are not supported and can be useful in patients converting from AF into another atrial arrhythmia (e. g. atypical atrial flutter) during the procedure. Interventions guided only by 3DRA could also be challenging for less experienced physicians.

However, retrospective analysis and a shorter followup period are the main limitations of our study. Another limitation is consecutive inclusion of patients and potential bias of results with the growing experience of operators performing the AF ablation. In contrast, our ablation technique was constant during this period. The sample size in our study was larger than both the retrospective and prospective trials reporting on clinical outcomes of AF ablation using 3DRA (ref. ^{12,24}). Further confirmation of the retrospective data with a prospective, randomized study is required, but is not ethically justified due to the superiority of 3DRA in reducing radiation exposure documented in a number of studies ^{6,7,10}. On the other hand, a new state-of-the-art cardiac CT often subjects patients to a lower dose of radiation with values close to the 3D rotational angiography²⁵.

Based on the literature, no prior study has compared the clinical outcomes of ablation procedures using 3D rotational angiography as a substitute to cardiac CT. Both Tang et al. and Kriatselis et al. reported a reduction in the dose of radiation and contrast medium for patients undergoing 3DRA in comparison to CT. Our clinical results demonstrate the utility of 3D rotation angiography as an adequate alternative to a commonly performed CT scan^{6,7}.

CONCLUSION

Three-dimensional rotational angiography has proven to be a safe and simple method for imaging the left atrium and guiding catheter ablation for atrial fibrillation. Our clinical experience suggests that 3DRA is comparable to a conventional CT scan. Given the low radiation exposure and use of contrast medium in comparison to CT, this approach could be a useful alternative technique in 3D reconstruction of the left atrium as a support for AF ablation.

ABBREVIATIONS

3D, three dimensional; 3DRA, three-dimensional rotational angiogram; AF, atrial fibrillation; CT, computed tomography; MRI, magnetic resonance imaging.

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