

Pulmonary vein orientation assessment: Is it necessary in patients undergoing contact force sensing guided radiofrequency catheter ablation of atrial fibrillation



Pim Gal^a, Joris F.W. Ooms^a, Jan Paul Ottervanger^a, Jaap Jan J. Smit^a, Ahmet Adiyaman^a, Anand R. Ramdat Misier^a, Peter Paul H.M. Delnoy^a, Piet L. Jager^b, Arif Elvan^{a,*}

^a Department of Cardiology, Isala Hospital, Zwolle, The Netherlands

^b Department of Nuclear Medicine, Isala Hospital, Zwolle, The Netherlands

ARTICLE INFO

Article history:

Received 14 October 2014
Received in revised form 6 November 2014
Accepted 24 March 2015
Available online 17 April 2015

Keywords:

Atrial fibrillation
Pulmonary vein isolation
Radiofrequency catheter ablation
Contact force sensing catheter system
Pulmonary vein orientation

ABSTRACT

Purpose: We hypothesized that pulmonary vein (PV) orientation influences tissue contact of the contact force (CF) sensing radiofrequency ablation catheter (CFC) and therefore atrial fibrillation (AF) free survival after pulmonary vein isolation (PVI). The aim of this study was to determine the association between PV orientation, CF and AF free survival in patients undergoing CFC PVI.

Methods: Sixty consecutive patients undergoing CFC PVI were included. ECG-triggered cardiac CT scans were obtained in all patients before PVI, and the PV orientation was measured at the insertion in the LA for all PVs in both the transverse and frontal plane. PVs were assigned to 1 of 4 orientation groups: ventral–caudal, dorsal–caudal, ventral–cranial and dorsal–cranial.

Results: Mean age was 59 years, 88% had paroxysmal AF. AF free survival off anti-arrhythmic drugs after a median follow-up of 12 months was 58% after a single PVI procedure. No association was found between PV orientation and CF. Furthermore, no association was found between PV orientation and AF free survival. In univariate analysis, the number of lesions with a mean CF of 10 g was associated with AF free survival. However, in multivariate analysis, only the AF duration was significantly associated with AF free survival.

Conclusions: This study shows that in patients undergoing PVI with the CFC ablation system, PV orientation does not affect CF and is not associated with AF free survival. PV orientation assessment does not appear to be necessary in patients undergoing CFC PVI.

© 2015 The Authors. Published by Elsevier Ireland Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Pulmonary vein isolation (PVI) is considered the cornerstone in the ablative treatment of atrial fibrillation (AF) [1,2]. Multiple techniques have been developed to perform PVI [3–5]. Currently, the most widely used technique is point-by-point radiofrequency (RF) ablation guided by a 3D electro-anatomical mapping system. Earlier reports attempting to identify geometrical characteristics of pulmonary veins (PVs) that influence AF free survival in patients undergoing point-by-point PVI yielded conflicting results [6,7]. A recent study showed that PV orientation is associated with AF free survival after laser balloon PVI [8]. We hypothesized that PV orientation influences optimal contact between the ablation catheter and atrial tissue, resulting in less durable lesion sets. The aim of this study was to determine whether PV orientation

influences contact force and AF free survival after PVI with a contact force sensing catheter ablation system (CFC).

2. Methods

Sixty consecutive patients with highly symptomatic, drug-refractory AF who underwent a primo PVI using CFC were included. Exclusion criteria were: previous PVI attempt, severe valvular heart disease and contraindications to post-procedural anti-coagulation. A transesophageal echocardiogram to rule out LA thrombus was performed in all patients directly prior to the PVI.

2.1. CT characteristics

All patients underwent CT scanning of the left atrium to guide the procedure. Cardiac multislice CT (MSCT) angiography was performed by a team of very experienced CT technologists using a 64-slice scanner (Lightspeed VCT XT, GE Healthcare). A bolus of 70 ml of nonionic contrast medium of agent (Optiray 350, Mallinckrodt, The Netherlands)

* Corresponding author at: Isala Hospital, Dept of Cardiology, Dr. Van Heesweg 2, 8025 AB Zwolle, The Netherlands. Tel.: +31 38 4242374; fax: +31 38 4243222.
E-mail address: v.r.c.derks@isala.nl (A. Elvan).

was infused through a large antecubital vein at a rate of 5 ml/s, followed by 50-ml saline solution flush. Automatic detection of the contrast bolus in the left atrium was used to time the start of the scan. Delay times varied significantly because of flow rate differences in patients, but were generally in the range of 5–15 s. Craniocaudal scanning was performed during breath-hold and using retrospective ECG gating (to be able to determine volume changes of the LA, but not used in this study). The collimation was 64×0.5 mm, rotation time 400 ms, and the tube voltage was 120 kV with mA dose modulation variable between 80 and 200 mA. All images were checked for adequacy before the end of the procedure to guarantee adequate image quality in all patients. After acquisition, the raw MSCT data were exported, post-processed, and analyzed on a dedicated workstation (GE Healthcare). The images were reviewed by an independent investigator who was not involved in the CFC guided PVI ablation procedures and was not informed about the PVI outcome in these patients.

2.2. Pulmonary vein orientation measurement

The PV trunk orientation measurement has been described before ([9,10], Association between pulmonary vein orientation and atrial fibrillation free survival in patients undergoing endoscopic laser balloon ablation [8]). The orientation of the PV trunk at the site of insertion into the LA was assessed for all PVs in both the transverse and frontal plane. A line was drawn in the direction of each PV trunk in both the transverse and frontal plane. Thereafter, the angle between the PV trunk direction and the intersection line of the sagittal plane was measured in the transverse and frontal plane (Fig. 1). Median PV trunk angles were calculated in the transverse and frontal plane for all four PV trunks. PVs were assigned to a ventral/dorsal or caudal/cranial orientation depending

on the PV trunk angle as compared to the median angle. So, each PV trunk was assigned to one of four orientation groups: ventral–caudal, dorsal–caudal, ventral–cranial and dorsal–cranial.

2.3. Electrophysiological procedure

All patients underwent CFC guided PVI under general anesthesia supervised by a cardiovascular anesthesiologist. First, a 6F quadripolar catheter was placed in the coronary sinus to obtain a procedural intra-cardiac electrogram. Two transeptal punctures were performed using a Brockenbrough needle under fluoroscopy and pressure guidance. 10,000 IU of unfractionated heparin was administered after the first transeptal puncture. A circular mapping catheter (LASSO®, Biosense Webster Inc., Diamond Bar, CA, USA) was inserted into the LA through an 8.5F sheath (SL-1, St. Jude Medical, Minnetonka, MN, USA) and an 8.5F sheath (SL-1, St. Jude Medical, Minnetonka, MN, USA) was used for PV angiography. Both sheaths were flushed continuously with a saline solution containing 2500 UI heparin per 500 ml saline. The targeted activated clotting time was between 300 and 350 s and additional heparin was administered when necessary. The activated clotting time was assessed every 30 min. The CFC catheter was inserted in the LA through an 8.5F sheath and the CFC sensor in the tip electrode was calibrated after positioning the catheter tip in a free floating position in the LA cavity.

2.4. Contact force sensing radiofrequency ablation

The CFC (Smarttouch™, Biosense Webster Inc., Diamond Bar, CA, USA) [3,11] is an externally irrigated catheter with a 3.5 mm tip electrode. The tip electrode is equipped with a contact force sensor which

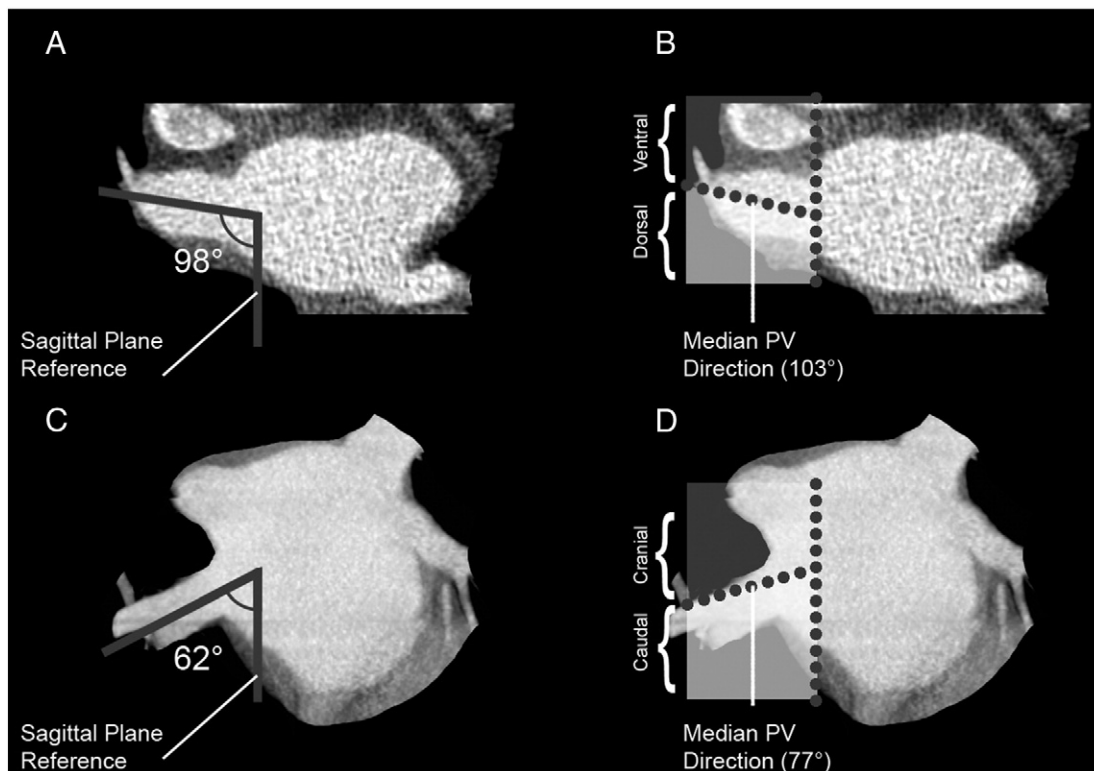


Fig. 1. Example of right upper pulmonary vein orientation measurement in the transverse and frontal planes. This figure displays the PV orientation measurement in the transverse and frontal plane of the RUPV. In panels A and B, the allocation of the RUPV in this patient in the transverse plane is displayed. The angle between the PV direction and the sagittal plane reference is 98° , as is displayed in panel A. The median RUPV direction in the transverse plane is 103° as can be appreciated from table 2, categorizing this RUPV to the dorsal RUPV orientation group. In panels C and D, the allocation of the RUPV of this patient in the frontal plane is displayed. The angle between the PV direction and the sagittal plane reference is 62° , as is displayed in panel C. The median RUPV direction in the frontal plane is 77° , as can be appreciated from table 2, categorizing this RUPV to the caudal RUPV orientation group. Combining the frontal and transverse plane, the RUPV of this patient is categorized to the dorsal–caudal RUPV orientation group. PV: pulmonary vein; RUPV: right upper pulmonary vein.

Table 1
Baseline characteristics.

	Total (n = 60)
Gender female (%)	23%
Age (years)	59.3 (\pm 9.1)
BMI (kg/m ²)	26.9 (\pm 3.5)
AF duration (years)	5.1 (\pm 5.4)
Paroxysmal AF	88%
Failed AADs (range)	1.1 (0–3)
LA dimension in PSLAX (mm)	42.2 (\pm 5.3)
LVEF (%)	58.9 (\pm 3.8)
Hypertension	38%
Previous TIA/stroke	12%
Coronary artery disease	0%
Diabetes	2%

Data are presented as percentages or means \pm their SD or ranges where appropriate; BMI: body mass index; AF: atrial fibrillation; AAD: anti-arrhythmic drugs; LA: left atrium; PSLAX: parasternal long axis view; LVEF: left ventricular ejection fraction. P-values: comparison between AF free and AF recurrence groups.

measures both contact pressure and vector of tip deflection. The catheter system is fully integrated within the 3D electro-anatomical mapping system (CARTO 3™, Biosense Webster Inc., Diamond Bar, CA, USA). PVI was performed by delivering RF energy in a point-by-point fashion to the PV antrum creating contiguous circular ablation lesions. RF energy was applied in a temperature-control mode with a temperature setting of 43 °C. RF energy was applied at 30 W with a flow rate of 15 ml/min or at 40 W with a flow rate of 30 ml/min, depending on site of ablation. The endpoint of the ablation procedure was PV isolation, as documented by entrance and exit block or dissociation of PV potentials.

2.5. Follow-up

A blanking period of 3 months was defined after PVI. Patients visited the outpatient clinic at 3, 6, 12, 18 and 24 months after PVI, including Holter ECG, event recorder monitoring and loop recorder monitoring in selected cases. Patients were immediately referred to the emergency room in case of symptoms. 3 months after PVI, an attempt was made in all patients to cease anti-arrhythmic drugs (AADs).

2.6. Study endpoints

The primary endpoint of our study was AF free survival, defined as patients without AF/atrial flutter/atrial tachycardia recurrence after a blanking period of 3 months. AF recurrence was defined as an ECG showing the characteristics of AF, or on a 30 s telemetry strip, in accordance with European Heart Rhythm Association AF ablation guidelines [1]. Ablation points with a contact force < 10 g were assessed separately, based on a study that showed adequate lesions are applied with a mean contact force > 10 g [12].

Table 2
Pulmonary vein characteristics.

Pulmonary vein	Median angle	Ventral–caudal	Dorsal–caudal	Ventral–cranial	Dorsal–cranial
Left upper	Transverse: 97.1° (\pm 32.0)	28%	24%	22%	26%
	Frontal: 139.0° (\pm 19.7)				
Left lower	Transverse: 62.1° (\pm 17.6)	26%	26%	24%	24%
	Frontal: 86.4° (\pm 19.4)				
Right upper	Transverse: 103.0° (\pm 14.9)	28%	23%	22%	27%
	Frontal: 121.8° (\pm 11.4)				
Right lower	Transverse: 55.5° (\pm 16.2)	20%	32%	30%	18%
	Frontal: 77.1° (\pm 14.8)				

Data are presented as absolute median or percentages, \pm their SD where appropriate.

2.7. Statistical analysis

Continuous variables were expressed as mean with standard deviation in case of normal distribution or median with interquartile range when variables were not normally distributed. Differences in mean contact force among PV orientation configurations was assessed with a Kruskal–Wallis test in case of continuous data and a Chi-square test in case of categorical data. A univariate and multivariate Cox proportional hazard model was used to determine predictors of AF free survival. Statistical analysis was performed using IBM SPSS statistics version 20 (IBM inc., Armonk, NY, USA). A p-value of \leq 0.05 was considered statistically significant.

3. Results

Our study population consisted of sixty consecutive patients. Baseline characteristics are displayed in Table 1. There were 6 common PVs (2.6%), which were excluded from analysis. No LA thrombi were found during preoperative transesophageal echocardiography or CT scans. Table 2 describes the characteristics of the PV orientation in all patients.

3.1. Pulmonary vein isolation results

In 234 out of 234 PVs (100%), acute PV isolation after CFC ablation was confirmed. After a median follow up of 12.3 (interquartile range: 8.3–16.1) months, AF free survival was 57.6% after a single CFC PVI without the use of class I or III AADs.

3.2. Contact force data

Mean contact force was 15.0 g \pm 10.9 for the left upper PV (LUPV), 13.5 g \pm 9.7 for the left lower PV (LLPV), 17.9 g \pm 10.0 for the right upper PV (RUPV) and 15.6 g \pm 9.8 for the right lower PV (RLPV). PV orientation was not associated with contact force for the LUPV ($p = 0.236$), LLPV ($p = 0.491$), RUPV ($p = 0.143$) and RLPV ($p = 0.718$), as is displayed in the supplemental Table 1. Furthermore, no association was found between PV orientation and the number of lesions with a mean contact force < 10 g, as displayed in supplemental Table 2.

3.3. Association with AF free survival

In univariate analysis, none of the baseline characteristics were associated with AF free survival. Moreover, PV orientation was also not associated with AF free survival, as is also displayed in Fig. 2. Table 3 displays the univariate analysis. Of note, mean contact force was not associated with AF free survival, but the number of ablation points with a mean contact force < 10 g was significantly associated with AF free survival. However, in multivariate analysis, only AF duration was associated with AF free survival.

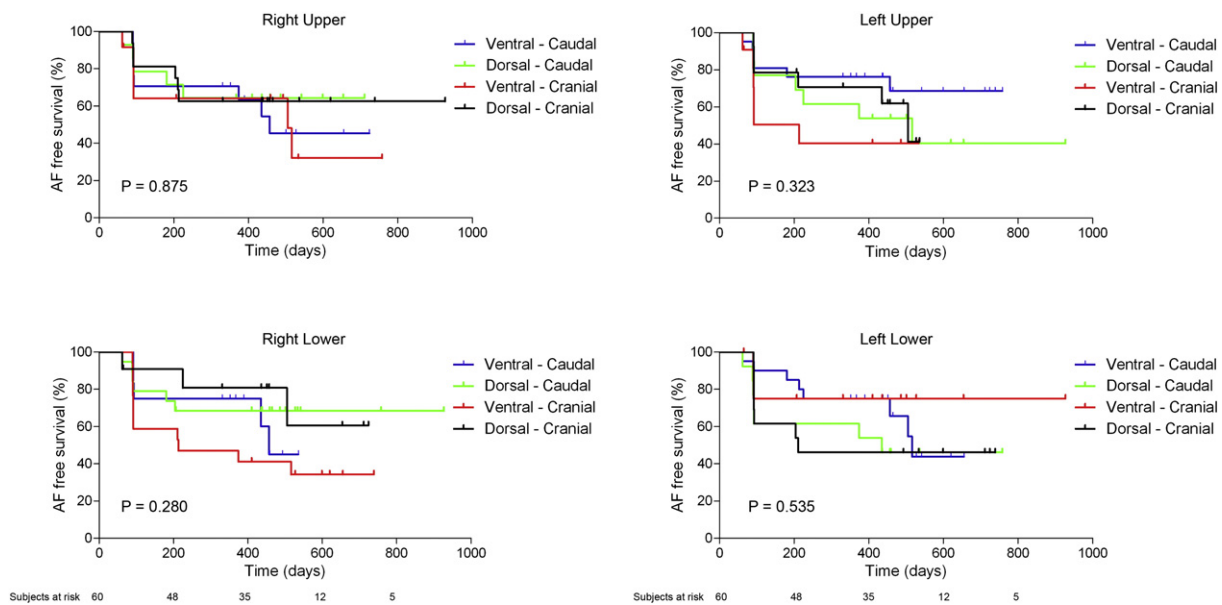


Fig. 2. Association of pulmonary vein orientation and atrial fibrillation free survival. This figure displays the association between PV orientation and AF free survival for all four PVs. There is no significant association between PV orientation and AF free survival. *P*-value between pulmonary vein orientation groups. AF: atrial fibrillation; PV: pulmonary vein.

4. Discussion

This study shows that in patients undergoing PVI with the CFC ablation system, PV orientation does not affect contact force and is not associated with AF free survival. These results suggest that durable PV lesion sets can be delivered independent of PV orientation with the CFC ablation system. PV orientation assessment does not appear to be necessary in patients undergoing CFC PVI.

4.1. Pulmonary vein anatomy and atrial fibrillation free survival

In a study of 100 patients who underwent RF catheter ablation, a smaller LA size and an atypical right-sided PV anatomy were associated with an increased AF free survival after PVI [7]. In another study of 118 patients who underwent RF catheter ablation, the absence of common PV trunks was associated with an increased AF free survival [13]. However, none of these studies assessed the association between PV

Table 3
Univariate and multivariate analysis of AF free survival.

Univariate analysis	p-value	Hazard ratio	95% CI	Multivariate analysis	p-value	Hazard ratio	95% CI
Female gender	0.882	1.072	0.428–2.687	Ablation points with mean contact force <10 g	0.333	1.017	0.983–1.053
Age	0.560	0.988	0.947–1.030	AF duration (per year)	0.017	1.128	1.021–1.246
BMI	0.605	1.031	0.918–1.158				
Paroxysmal AF	0.115	0.452	0.169–1.212				
AF duration (per year)	0.062	1.053	0.997–1.112				
Failed AADs	0.907	1.032	0.607–1.755				
LA dimension	0.468	1.028	0.954–1.107				
LVEF	0.645	1.028	0.913–1.159				
Hypertension	0.976	0.988	0.440–2.216				
Mean contact force	0.305	0.890	0.711–1.112				
Ablation points with mean contact force <10 g	0.042	1.036	1.001–1.072				
LUPV orientation	0.547						
Ventral-caudal ^a	0.643	0.755	0.230–2.481				
Dorsal-caudal ^a	0.712	1.229	0.412–3.665				
Ventral-cranial ^a	0.326	1.765	0.568–5.488				
LLPV orientation	0.641						
Ventral-caudal ^a	0.819	0.884	0.308–2.536				
Dorsal-caudal ^a	0.800	1.146	0.399–3.287				
Ventral-cranial ^a	0.285	0.478	0.123–1.852				
RUPV orientation	0.876						
Ventral-caudal ^a	0.671	1.258	0.436–3.628				
Dorsal-caudal ^a	0.928	0.947	0.289–3.103				
Ventral-cranial ^a	0.521	1.450	0.467–4.505				
RLPV orientation	0.299						
Ventral-caudal ^a	0.536	1.574	0.374–6.618				
Dorsal-caudal ^a	0.793	1.204	0.301–4.820				
Ventral-cranial ^a	0.137	2.644	0.735–9.513				

Univariate and multivariate analysis of the association between patient, procedural and PV characteristics and AF free survival after CFC PVI. BMI: body mass index; AF: atrial fibrillation; AAD: anti-arrhythmic drugs; LA: left atrium; PSLAX: parasternal long axis view; LVEF: left ventricular ejection fraction. LUPV: left upper pulmonary vein; LLPV: left lower pulmonary vein; RUPV: right upper pulmonary vein; RLPV: right lower pulmonary vein. CFC: contact force sensing catheter ablation system. *P*-values between AF free and AF recurrence groups.

^a As compared to the dorsal-cranial orientation group.

orientation and AF free survival, although in a recent study, PV orientation was significantly associated with AF free survival after laser balloon PVI [9].

4.2. Contact force sensing catheter system characteristics

The CFC allows contact force guided RF ablation of AF. Previous studies found an association between pressure–time curves recorded with the CFC and AF free survival, indicating that contact force sensing may assist in the application of durable lesion sets [14,15]. The present study is in line with these results, showing that the number of lesions with a contact force <10 g was associated with a diminished AF free survival. Hypothetically, pressure-guided ablation should allow the operator to identify inadequate lesions and apply additional ablations when deemed necessary.

4.3. Pulmonary vein orientation and AF free survival

AF recurrences are generally regarded as reconnection between the PV and the LA allowing electrical reconnection [16,17]. Therefore the durability of the applied circumferential lesions are essential in preventing AF recurrences. Hypothetically, the influence of PV orientation may be negated by allowing the operator to identify inadequate catheter–tissue contact due to PV orientation, and increase catheter–tissue contact accordingly, resulting in durable lesion sets.

4.4. Limitations

With regards to interpreting our data, the following limitations should be considered. This is a single center study with a limited number of patients. The patient cohort was limited to those having no or minimal structural heart disease and a normal left ventricular function.

5. Conclusion

This study showed that in patients undergoing PVI with the CFC ablation system, PV orientation does not affect contact force and is not associated with AF free survival. PV orientation assessment does not appear to be necessary in patients undergoing CFC PVI.

Conflict of interest

None.

Funding

None.

Acknowledgments

We thank ms. Vera Derks for the final preparation of this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.ijcha.2015.03.009>.

References

- [1] Calkins H, Kuck KH, Cappato R, Brugada J, Camm AJ, Chen SA, et al. 2012 HRS/EHRA/ECAS Expert Consensus Statement on Catheter and Surgical Ablation of Atrial Fibrillation: recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design. *Europace* 2012;14:528–606.
- [2] Haissaguerre M, Jais P, Shah DC, Takahashi A, Hocini M, Quiniou G, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. *N Engl J Med* 1998;339:659–66.
- [3] Kuck KH, Reddy VY, Schmidt B, Natale A, Neuzil P, Saoudi N, et al. A novel radiofrequency ablation catheter using contact force sensing: Toccata study. *Heart Rhythm* 2012;9:18–23.
- [4] Reddy VY, Neuzil P, Themistoclakis S, Danik SB, Bonso A, Rossillo A, et al. Visually-guided balloon catheter ablation of atrial fibrillation: experimental feasibility and first-in-human multicenter clinical outcome. *Circulation* 2009;120:12–20.
- [5] Van Belle Y, Janse P, Rivero-Ayerza MJ, Thornton AS, Jessurun ER, Theuns D, et al. Pulmonary vein isolation using an occluding cryoballoon for circumferential ablation: feasibility, complications, and short-term outcome. *Eur Heart J* 2007;28:2231–7.
- [6] Hof I, Chilukuri K, Arbab-Zadeh A, Scherr D, Dalal D, Nazarian S, et al. Does left atrial volume and pulmonary venous anatomy predict the outcome of catheter ablation of atrial fibrillation? *J Cardiovasc Electrophysiol* 2009;20:1005–10.
- [7] den Uijl DW, Tops LF, Delgado V, Schuijff JD, Kroft LJ, de Roos A, et al. Effect of pulmonary vein anatomy and left atrial dimensions on outcome of circumferential radiofrequency catheter ablation for atrial fibrillation. *Am J Cardiol* 2011;107:243–9.
- [8] Platonov PG, Mitrofanova LB, Orshanskaya V, Ho SY. Structural abnormalities in atrial walls are associated with presence and persistency of atrial fibrillation but not with age. *J Am Coll Cardiol* 2011;58:2225–32.
- [9] Sorgente A, Chierchia GB, de Asmundis C, Sarkozy A, Namdar M, Capulzini L, et al. Pulmonary vein ostium shape and orientation as possible predictors of occlusion in patients with drug-refractory paroxysmal atrial fibrillation undergoing cryoballoon ablation. *Europace* 2011;13:205–12.
- [10] van der Voort PH, van den Bosch H, Post JC, Meijer A. Determination of the spatial orientation and shape of pulmonary vein ostia by contrast-enhanced magnetic resonance angiography. *Europace* 2006;8:1–6.
- [11] Martinek M, Lemes C, Sigmund E, Derndorfer M, Aichinger J, Winter S, et al. Clinical impact of an open-irrigated radiofrequency catheter with direct force measurement on atrial fibrillation ablation. *Pacing Clin Electrophysiol* 2012;35:1312–8.
- [12] Park CI, Lehmann H, Keyl C, Weber R, Schiebeling J, Allgeier J, et al. Mechanisms of pulmonary vein reconnection after radiofrequency ablation of atrial fibrillation: the deterministic role of contact force and interlesion distance. *J Cardiovasc Electrophysiol* 2014;25:701–8.
- [13] Kubala M, Hermida JS, Nadji G, Quenum S, Traulle S, Jarry G. Normal pulmonary veins anatomy is associated with better AF-free survival after cryoablation as compared to atypical anatomy with common left pulmonary vein. *Pacing Clin Electrophysiol* 2011;34:837–43.
- [14] Neuzil P, Reddy VY, Kautzner J, Petru J, Wichterle D, Shah D, et al. Electrical reconnection after pulmonary vein isolation is contingent on contact force during initial treatment: results from the EFFICAS I study. *Circ Arrhythm Electrophysiol* 2013;6:327–33.
- [15] Reddy VY, Shah D, Kautzner J, Schmidt B, Saoudi N, Herrera C, et al. The relationship between contact force and clinical outcome during radiofrequency catheter ablation of atrial fibrillation in the TOCCATA study. *Heart Rhythm* 2012;9:1789–95.
- [16] Cappato R, Negroni S, Pecora D, Bentivegna S, Lupo PP, Carolei A, et al. Prospective assessment of late conduction recurrence across radiofrequency lesions producing electrical disconnection at the pulmonary vein ostium in patients with atrial fibrillation. *Circulation* 2003;108:1599–604.
- [17] Lemola K, Hall B, Cheung P, Good E, Han J, Tamirisa K, et al. Mechanisms of recurrent atrial fibrillation after pulmonary vein isolation by segmental ostial ablation. *Heart Rhythm* 2004;1:197–202.