

# Cryoballoon ablation for atrial fibrillation guided by real-time three-dimensional transoesophageal echocardiography: a feasibility study

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## Aims

Cryoballoon ablation (CBA; Arctic Front, Medtronic) has proven very effective in achieving pulmonary vein isolation. Real-time three-dimensional transoesophageal echocardiography (RT 3D TEE) is a novel technology, which permits detailed visualization of cardiac structures in a 3D perspective. The aim of the present study was to assess the feasibility, advantages, and safety of RT 3D TEE in guiding CBA in a series of patients affected by paroxysmal atrial fibrillation.

## Methods and results

Forty-five patients (34 males, mean age:  $63 \pm 12$  years) underwent CBA guided by 3D TEE. A total of 190 veins could be documented by TEE. Real-time three-dimensional transoesophageal echocardiography successfully guided the operator to position the CB in the pulmonary vein (PV) ostium and obtain complete occlusion in all 190 (100%) veins. Transoesophageal echocardiography identified leakages in 25 (13%) veins led to successful elimination of PV–left atrium (LA) backflow by guiding correct balloon repositioning. In four (2%) veins, this imaging tool led to perform successful pull-down manoeuvres. After a mean  $2.6 \pm 1.4$  applications, isolation could be documented in 190 (100%) PVs. Median procedural and fluoroscopy times were 145 and 24 min. During a median follow-up of 278 days, 37 (82%) patients did not experience atrial fibrillation recurrence following a 3-month blanking period.

## Conclusion

Cryoballoon ablation is safe and feasible under RT 3D TEE guidance. This imaging tool permits perfect visualization of all PV ostia and neighbouring LA structures. Most importantly, it proved very efficient in guiding the operator to achieve complete occlusion and successful isolation in all veins.

## Keywords

Atrial fibrillation ablation • Cryoballoon • 3D TEE

## Introduction

Pulmonary vein isolation (PVI) has become the standard of care in drug refractory atrial fibrillation (AF).<sup>1–4</sup> Cryoballoon ablation (CBA; Arctic Front, Medtronic) is a relatively novel technology that has proven to be very effective in achieving PVI in the setting of AF ablation.<sup>5–7</sup> Cryoballoon ablation consists in inflating an over-the-catheter balloon in the left atrium (LA) and then wedging it in the pulmonary vein (PV) ostium with the goal of

occluding the vessel. Total occlusion, generally demonstrated by the means of dye injection, is usually associated with lower temperatures and is vital to achieve PVI.<sup>8,9</sup> A tight adhesion to the tissue during CBA might lead to deeper lesions and by consequence ensure better outcome. However, the high degree of variability in PV anatomy,<sup>10–12</sup> frequently observed in the setting of AF ablation might be hampering when using this technology. Recent publications addressing the issue of CBA guided by echocardiographical imaging techniques have shown that both intracardiac

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## What's new?

- The present study is the first having analysed the feasibility, advantages, and safety of real-time 3D transoesophageal echocardiography in guiding cryoballoon (CB) ablation in a series of patients affected by drug-resistant paroxysmal atrial fibrillation.
- In our study, this imaging tool successfully guided the operator to position the CB in the pulmonary vein (PV) ostium and obtain complete occlusion and isolation in all veins. It also successfully documented all incomplete occlusions and guided the operator to reposition the balloon to eliminate all PV–left atrium backflows.
- Finally, it guided the operator to perform every step of the procedure in a safe manner.

echocardiography (ICE) and two-dimensional transoesophageal echocardiography (2D TEE) might prove useful in leading the operator to achieve perfect occlusion.<sup>13–15</sup> However, both above-mentioned technologies bear the obvious limitation of offering bi-dimensional images. Recently, real-time three-dimensional transoesophageal echocardiography (RT 3D TEE) has become available for clinical practice offering clear and detailed imaging of the cardiac anatomy. This new technology permits direct visualization of the cardiac structures in a 3D perspective.<sup>16</sup> In addition, it seems to provide better understanding of the spatial relationship among structures, and more accurate and reliable measurements of cardiac structures than 2D TEE.<sup>17</sup> To our knowledge, experience with RT 3D TEE-guided CBA procedure in a series of patients undergoing PVI has not yet been reported. The main aim of the present study was to assess the feasibility, advantages, and safety of this novel imaging method in guiding CBA in a series of patients affected by paroxysmal AF (PAF).

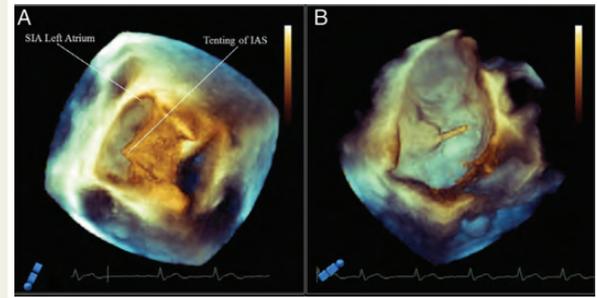
## Methods

### Patient characteristics

Consecutive patients who underwent CBA guided by RT 3D TEE at our centre for drug-resistant PAF were included in the study. All patients included in the study had experienced AF recurrence despite the treatment with at least one class I or III antiarrhythmic drug (AAD). Exclusion criteria were the presence of left atrial thrombus, severe uncontrolled heart failure, LA diameter >55 mm, and contraindications to general anaesthesia.

### Ablation procedure

Ablation was performed under general anaesthesia. A 6F decapolar catheter was inserted in the left subclavian vein and advanced to the coronary sinus. Another 6F decapolar catheter was inserted in the left femoral vein and advanced to the His bundle region. A single transseptal (TS) puncture was then performed under fluoroscopic and 3D TEE guidance using the right femoral venous approach (Figure 1). After gaining left atrial access, an intravenous bolus of heparin (70 IU/kg) was given. Two 0.32F wires (Cordis, Johnson & Johnson) were advanced in



**Figure 1** View of the IAS during the TS puncture: (A) 3D visualization of tenting of the IAS in the LA; (B) visualization of the needle accessing the LA.

the left superior pulmonary vein (LSPV). A steerable 15F over-the-wire sheath (FlexCath, Medtronic) and an SLO sheath were positioned in the LA. The first and the second serves as catcher support for the CB and for a circular mapping catheter (CMC; Inquiry, St Jude Medical), respectively. Next, we identified the number, site, and size of PVs using RT 3D TEE. Guided by the 3D TEE, a 28 mm double-walled CB was positioned in the ostium of each PV. After having placed the catheter in the PV ostium, all necessary refinements to balloon repositioning to achieve optimal vessel occlusion were guided only by RT 3D TEE. Once PV occlusion was estimated to have been reached and no PV–LA backflow was visible on the echocardiographic images, selective contrast injection was performed to confirm the latter. As previously described,<sup>7</sup> a semi-quantitative grading ranging from 0 (poor) to 4 (optimal) was used to evaluate occlusion.

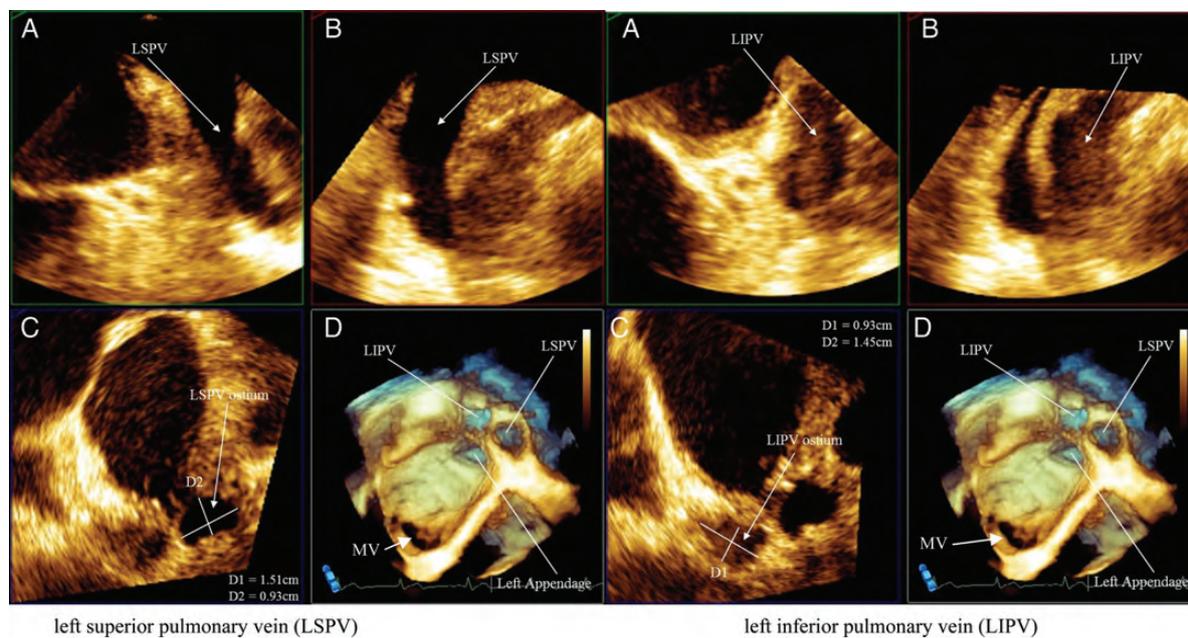
We treated the LSPV first, followed by the left inferior pulmonary vein (LIPV), then the right superior pulmonary vein (RSPV), and last the right inferior pulmonary vein (RIPV). Target temperature was considered to be  $\leq 40^{\circ}\text{C}$ . Cryoablation consisted of at least one grade 4 occlusion and lasting 5 min. To avoid phrenic nerve palsy (PNP)—a complication observed during RSPV and RIPV ablation with the CB—a quadripolar catheter was inserted into the superior vena cava, and diaphragmatic stimulation was achieved by pacing the ipsilateral phrenic nerve with a 600 ms cycle length at an output of 21 mA during right PVs ablation. During the whole procedure, activated clotting time was maintained over 250 s with supplements of heparin infusion as required.

### Assessment of pulmonary vein isolation

Pulmonary vein activity was recorded with the CMC before, and immediately after every cryoenergy application. To memorize the location of recorded potentials, positions of the mapping catheter were recorded fluoroscopically in left lateral and anterior–posterior views in each PV ostium before ablation. Successful PVI was achieved when all PV potentials (PVPs) were abolished or dissociated from atrial activity. If needed, pacing from the distal and/or proximal coronary sinus was performed to distinguish eventual far-field atrial signals from PVP recorded on the mapping catheter, respectively, for left- and right-sided PVs.

### Real-Time three-dimensional transoesophageal echocardiography

Real-time three-dimensional transoesophageal echocardiography images were obtained using a RT-3D Matrix transducer (X7-2t)



**Figure 2** Monoplane elaboration of the 3D image obtained using the zoom feature of RT 3D TEE: (A) longitudinal plane; (B) orthogonal plane; (C) coronal plane; (D) 3D image used to elaborate the monoplanar images.

utilizing the ultrasound system of IE33 Echocardiography system (Philips Medical Systems) during all CBA procedures.

### Assessment of pulmonary vein anatomy

Pulmonary veins were displayed in 2D images starting from 50° to 60 rotation of the matrix array probe for the right PVs and from 90° to 100 rotation for the left PVs. We switched to the x-plane view, which permitted the visualization of the two initially perpendicular planes illustrating the PV on the same screen and during the same cardiac cycles. Small changes in the probe depth and angle corrections were performed continuously to obtain an optimal PV view.

To obtain ideal images of the left PVs, the probe was positioned at a mid-oesophageal level. The left PVs cannot be seen on the same plane due to their oblique orientation. Therefore, to visualize the LSPV, we used the zoom 3D mode directly pointed at the left atrial appendage (LAA), and with a 20–30° counterclockwise rotation of the probe, we could visualize the LSPV ostium. To visualize the LIPV, due to its posterior orientation, we rotated the probe head a little further laterally and posteriorly. The x-plane then allowed us to have the images of LSPV and LIPV on the same bi-dimensional plane. The whole structure was then included in 3D zoom. The visualization of the ostia of left PVs will always appear in two different projections; however, for the CB procedure, the most important aspect is the ability to completely visualize each ostium.

To visualize the right PVs, the probe should be positioned at the upper-oesophageal level, and should be rotated clockwise to 70–90°. The right PVs are both visualized on the same plane on the long axis. To simultaneously visualize the ostia of both veins, a 3D zoom in which both veins are included was performed and with a rotation of the plane to position the two venous ostia en-face. Whereas, to visualize the right-sided PVs individually, it is sufficient to include the vein of interest in the pyramid of 3D zoom.

For this procedure, we used live, zoomed, 3D image with a narrow segment and good temporal resolution (Figure 2).

After the acquisition of the zoomed 3D image, we immediately elaborated the image in the QLab (the QLab is a feature incorporated in the Philips i33 3D system that can be activated by a touch on the left of the digital screen), which lasts a maximum of 1 min. This allowed us to obtain a perfect image of the short axis of every PV ostium and to measure both diameters, knowing that a cross-sectional view of the PVs is not circular but closer to an ellipse (Figure 2).

### Assessment of pulmonary vein occlusion with the cryoballoon

The occlusion of each PV was first verified by illustrating the vein in the x-plane, and later, looking at the CB occluding the PV in 3D. However, total verification was performed through the colour Doppler acquisition of the full volume in 3D, which showed exactly the anatomical location of eventual PV–LA leakage.

Surprisingly, the verification of the CB in the PVs is simpler than the identification of the PV, because the veins, after CB inflation, are more dilated, and the presence of an echogenic structure further assists the orientation and adjustment of the probe.

For the LSPV, the verification was performed with a 90–100° rotation with the orientation of the probe headed anteriorly, whereas for the LIPV, the orientation of the probe pointed posteriorly and laterally.

For the right PVs, the verification was performed by positioning the probe in the upper-oesophageal portion with a 20–30° clockwise rotation. The right PVs are on the same plane; therefore, it is sufficient only to select zoom 3D to verify the position of the CB in the vein of interest.

Through 3D TEE colour Doppler full volume acquisition, it was sufficient to include the whole CB in the 3D pyramid, so that the location of the PV–LA leakage (anterior, posterior, left, or right) could be

exactly pinpointed. In this way, we could guide the operator to reposition the CB to eliminate PV–LA backflow. However, special care should be taken in the orientation of the image of the echo screen so that the orientation points are not lost. For the left veins, it is easier to determine the orientation by including the LAA in the image, whereas for the right veins, including both ostia.

This measurement guaranteed the selection of the optimal CB position, which averts any leakage, thus improving the success of the procedure. The final optimal RT 3D TEE image was obtained by slightly moving the scroll ball to capture an optimal 3D perspective.

## Follow-up

Every patient underwent routine clinical evaluation and 24 h Holter monitoring at 1, 3, 6, and 12 months after ablation. A blanking period of 3 months was considered for the study. Atrial fibrillation recurrence during the blanking period was taken into consideration for final analysis.

## Statistical analysis

Data are expressed as mean  $\pm$  SEM (standard error of mean) (or SD). All statistics were performed with the use of the SPSS software (SPSS v19) and STATA software, version 11.1 (StataCorp). A *P* value  $\leq 0.05$  was considered statistically significant.

## Results

### Baseline characteristics

Forty-five consecutive patients (34 males, mean age:  $63 \pm 12$  years) formed the study group (Table 1). The mean duration of AF prior to the procedure was  $4.3 \pm 2.4$  years. Mean number of failed class I or III AADs prior to procedure was 1.1. Structural heart disease was present in four (9%). Mean LA diameter was  $42 \pm 5$  mm. Mean CHADS<sub>2</sub> score was 1.22 (range –4).

### Procedural characteristics

A 28 mm CB was used in all patients. Median procedural and fluoroscopy times were 145 min (range 120–210) and 24 min (range 18–43), respectively (Table 2).

**Table 1** Baseline characteristics of patients

	Paroxysmal AF patients (n = 45)
Gender, male/female (n)	34/11
Age (years)	$63 \pm 12$
Duration of AF (years)	$4.3 \pm 2.4$
Unsuccessful AAD > 2 (n)	11
Left atrial diameter (mm)	$42 \pm 5$
Left ventricular ejection fraction (%)	$55 \pm 10$
Hypertension (n)	33
CHADS <sub>2</sub> score $\geq 2$ (n)	11

AAD, antiarrhythmic drug.

### Transseptal puncture

The interatrial septum (IAS) could be perfectly visualized by RT 3D TEE in all 45 patients (Figure 1).<sup>18</sup> Real-time three-dimensional transoesophageal echocardiography led to uneventful TS access in all cases by clearly documenting the classical ‘tenting’ effect of the fossa ovalis (FO) indicating the correct TS assembly position. The mean distance from needle tip to aortic root and to the posterior wall were, respectively, 2 and 3 mm during maximal tenting of the FO suggesting a relatively central puncture site. In six (13%) patients, the TS assembly was repositioned in the FO based on the TEE image because of incorrect orientation.

### Assessment of pulmonary vein anatomy

All PVs could be identified under 3D TEE guidance (Figure 2). A total of 190 PVs were depicted. Normal PV drainage pattern was documented in 30 (66%) of patients, whereas 5 (11%) individuals exhibited a left common ostium. In addition, 10 (22%) patients presented with a right accessory vein. All right accessory veins were treated as separate vessels. In our population all common ostia were short and were treated by separately engaging the LSPV branch first and the LIPV next with the goal of ablating the widest possible area of the antrum. Mean PV dimensions are shown in Table 3.

**Table 2** Procedure data

Procedure time (min)	145 (120–210)
Fluoroscopy time (min)	24 (range 18–43)
PVO achieved (n) under RT 3D TEE	190 (100%)
PVI achieved under RT 3D TEE	190 (100%)
Mean number of application for PVI	LSPV: 2.6 (1–5) LIPV: 2.4 (1–5) RSPV: 1.3 (1–3) RIPV: 1.1 (1–2)

PVO, pulmonary vein occlusion; PVI, pulmonary vein isolation; LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein.

**Table 3** Average PV ostium diameters

PV ostium	Maximum diameter (mm)	Minimum diameter (mm)	Ratio (Max/Min)
LSPV	$16.5 \pm 1.8$	$11.3 \pm 1.5$	$1.52 \pm 0.28$
LIPV	$14.8 \pm 1.7$	$9.2 \pm 1.6$	$1.65 \pm 0.37$
RSPV	$16.9 \pm 1.2$	$15.7 \pm 1.8$	$1.09 \pm 0.15$
RIPV	$15.1 \pm 1.6$	$14.5 \pm 1.4$	$1.05 \pm 0.15$
L common PV	$22.6 \pm 3.7$	$16.1 \pm 3.2$	$1.48 \pm 0.42$
R accessory PV	$9.3 \pm 1.3$	$8.7 \pm 1.6$	$1.08 \pm 0.21$

Data are presented as mean  $\pm$  SD.

LSPV, left superior pulmonary vein; LIPV, left inferior pulmonary vein; RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein; L, left; R, right.

### Pulmonary vein occlusion

Real-time three-dimensional transoesophageal echocardiography successfully identified all leakages and guided the operator to eliminate any LA–PV backflow and obtain complete occlusion in all 190 PVs (100%) (Figure 3). Confirmation by selective angiography could confirm the echographical findings in 98% of veins showing grade 4 occlusions. In four (2%) RIPVs, a pull-down technique was necessary to achieve PV occlusion. In these veins, after having started cryoenergy application the pull-down manoeuvre was performed under 3D TEE until disappearance of the PV–LA backflow on the inferior portion of the vessel. Balloon repositioning prior to angiographical confirmation was necessary in 25 veins because of PV–LA backflow documented at RT 3D TEE (Figure 4). This finding was observed in 3 LSPV, 6 LIPV, 4 RSPV, and 12 RIPV. In all the above-mentioned, balloon repositioning led systematically to disappearance of the backflow.

### Pulmonary vein isolation

After a mean  $2.6 \pm 1.4$  applications, isolation could be documented in 190 (100%) of veins. The mean number of applications was 2.6 in the LSPV, 2.4 in the LIPV, 1.3 in the RSPV, and 1.1 in the RIPV. Left-sided veins required a significantly higher number

of applications to reach isolation if compared with the right-sided ones ( $P < 0,001$ ).

### Complications

Transient PNP occurred in two patients when ablating the RSPV. Diaphragmatic contraction completely recovered before the end of the procedure. No major complications occurred during any procedure that needed further treatment.

### Follow-up

Following the blanking period, a total of 37 (82%) patients were free of AF at a median follow-up time of 278 days (range 93–720) without AADs. In seven patients symptomatic AF recurrence was documented, only one patient had asymptomatic PAF at Holter electrocardiogram recording.

## Discussion

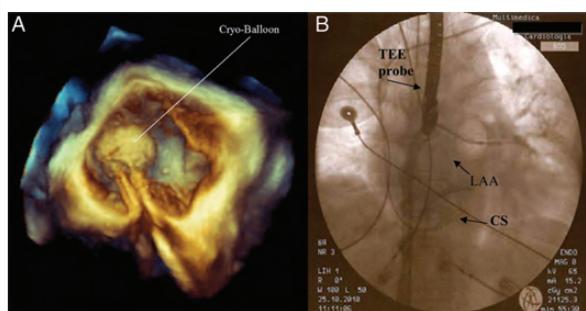
To our knowledge, this is the first study describing CBA guided by RT 3D TEE in a series of consecutive patients. The main findings of our study are that: (i) RT 3D TEE permitted detailed visualization and anatomical characterization of LA structures and in particular of all PV ostia's shape and orientation in all individuals, (ii) it led to achieve successful CB occlusion in all veins, and (iii) it guided the operator to perform every step of the procedure in a safe manner.

### Visualization of pulmonary vein ostia and left atrial structures

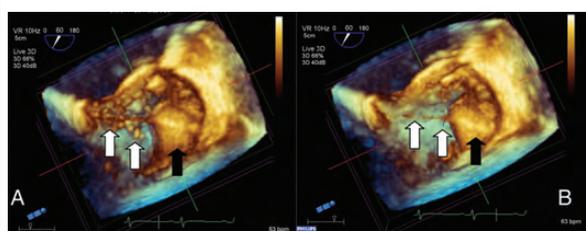
Pre-procedural visualization of the LA structures is of utmost importance. Recently, Faletra et al.<sup>19</sup> published a very interesting report on a stepwise approach to visualize all PV ostia and their surrounding structures by the means of RT 3D TEE. The approach permitted clear 3D imaging of all PVs. Furthermore, the authors stated that this imaging modality could be a valuable guiding tool in the setting of transcatheter AF ablation. Our findings were similar. In fact, in all patients every PV ostia and surrounding structures, including common ostia and right-sided accessory veins, could be identified with RT 3D TEE. Importantly, performing a 3D pre-procedural analysis with the RT 3D TEE, might bear the advantage of not having to achieve a computed tomography (CT) scan or an magnetic resonance imaging (MRI). The advantages of not performing the latter can be measured in time gain, in cost-containment, and in reducing X-ray exposure in the case of CT scan imaging. However, it should be mentioned that in the rare occurrence of long common trunks, CT or MRI imaging might be superior to RT 3D TEE in adequately defining the features of this anatomical variant.

### Pulmonary vein occlusion and isolation

Recently, various authors have reported their findings on echocardiographically guided CBA for AF. Siklody et al.,<sup>15</sup> published their experience on 30 consecutive patients who underwent CBA under 2D TEE assessment. However, although, virtually all PVs could be identified (99.2%), in only 64.5% the antrum could be completely visualized. Complete occlusion guided by 2D TEE and demonstrated by colour Doppler could be achieved in 90.2% of veins and was a positive predictive factor for electrical



**Figure 3** (A) Real-time three-dimensional transoesophageal echocardiography successfully guiding a grade 4 occlusion in an LSPV. (B) Confirmation by selective angiography of full occlusion.



**Figure 4** Real-time three-dimensional transoesophageal echocardiography images of a PV–LA leak documented by saline injection through the balloon (black arrow) with 3D visualization of bubbles (white arrows) (A) and eventually full occlusion by slight catheter repositioning with disappearance of PV–LA leak (white arrows) (B).

isolation. Schmidt *et al.*<sup>14</sup> were the first to report the use of ICE in this setting. Forty-three patients were randomized to either to ICE plus fluoroscopy or fluoroscopy alone-guided ablation. In contrast to Siklody's findings in the ICE group all antra could be visualized. The authors concluded that ICE-guided ablation resulted in significantly lower procedural and fluoroscopical times if compared with procedures performed with fluoroscopy alone (143 vs. 130 mn; 42 vs. 26 mn). Very shortly after, Nölker *et al.*<sup>13</sup> published their own experience on CBA under assessment with ICE. Similar to Schmidt's finding, all PV antra could be visualized with this imaging modality. In addition, the author's conclusion was that ICE allowed decision for adequate balloon sizing, precise balloon placement, and excluded acute PV narrowing.

In our study RT 3D TEE proved valuable in achieving isolation in all 190 PVs. In fact, in 98% TEE-guided occlusion was confirmed by direct angiographical control regardless of vessel dimensions and in the remaining 2% of veins this imaging modality led to successful 'pull-down' manoeuvres in four RIPVs. In the 25 veins that exhibited PV-LA Doppler-coded backflow TEE could successfully guide balloon repositioning until the latter disappeared and complete occlusion could be documented. In addition, it proved very useful in approaching four RIPVs (2%) when, after having started cryoenergy application; the pull-down manoeuvre<sup>6</sup> was performed under 3D TEE until disappearance of the PV-LA backflow on the inferior portion of the vessel. Echographic imaging might be superior to fluoroscopy in this setting. In fact, this manoeuvre is performed during the freezing process. At this point of time, angiographic confirmation of occlusion is not possible due to freezing of the inner lumen of the CB catheter. Finally, in our study, we confirmed the previously reported findings of Sorgente *et al.*<sup>20</sup> regarding the ovality of the veins and its influence on occlusion. In fact, similar to the abovementioned study, we observed that it took a significantly higher number of applications to isolate the left-sided veins if compared with the right-sided ones ( $P < 0.001$ ). This might be explained by the fact that left-sided PVs are usually more oval than the right-sided ones making the occlusion and therefore, the isolation potentially more difficult to achieve.

If compared with the above-mentioned studies, RT 3D TEE might bear some advantages. First, there is scientific evidence that RT 3D TEE provides excellent spatial and temporal resolution, better understanding of the spatial relationship among structures, and more accurate and reliable measurements of cardiac structures than 2D TEE.<sup>17</sup> This might also be true in the setting of CBA. In fact, if compared with 2D TEE,<sup>15</sup> our findings reported a better visualization of all portions of all PV antra. In addition, RT 3D TEE led to better documentation of PV occlusion if compared with traditional 2D TEE (100 vs. 90.2%). This might in part explain why our fluoroscopy times were much lower with respect to the ones observed in Siklody *et al.* report (22 vs. 40 mn). It is known that radiation exposure during PVI increases lifetime risk of fatal malignancy. Therefore, every effort should be made to reduce X-ray exposure. In this setting, we can safely speculate that 3D imaging should be preferred to bi-dimensional echocardiography if TEE is chosen to guide CBA.

If compared with both studies conducted with ICE, RT 3D TEE offered similar procedural and fluoroscopical times. Furthermore, rates of PV antrum visualization, PV occlusion, and isolation were

all very satisfactory and comparable. However, ICE is relatively expensive and may require special expertise. Furthermore, one must also not underestimate the need of an adjunctive 10 Fr venous access to insert the ICE catheter.

## Safety

Finally, CBA guided by RT 3D TEE proved to be safe in our series. Although TS puncture is relatively safe in experienced hands,<sup>21</sup> potential life-threatening effects such as aortic or atrial perforation, cardiac tamponade, thrombotic formation, or air embolism cannot be completely ruled out.<sup>22,23</sup> Many of the complications during AF ablation occur in this delicate step of the procedure. When occurring, complications are nearly all caused by incorrect puncture site.<sup>24</sup> Moreover, patients with AF often exhibit subverted left atrial anatomy, with consequences on the usual fluoroscopic landmark positions that define the FO localization.<sup>25</sup> Therefore, various operators prefer to perform TS puncture under echocardiographical guidance and have reported their favourable findings in the literature.<sup>26</sup> However, most of these described their experience with bi-dimensional imaging. Our experience confirms the findings reported in a previous report focusing on RT 3D TEE-guided TS puncture in a series of consecutive patients undergoing PVI.<sup>18</sup> In our study, all 45 TS punctures were carried out safely and successfully at the first attempt, therefore minimizing the risk of complications. All the neighbouring cardiac structures could be perfectly visualized during TS assembly positioning in the FO ('tenting' effect). Furthermore, RT 3D TEE permitted to avoid inserting the balloon in the LAA perfectly distinguishing its ostium from the left-sided veins. Finally, similar to other bi-dimensional techniques it permitted to constantly monitor the pericardial cavity; therefore, potentially identifying effusion in its very early stages. Recently, oesophageal haematoma has been described as a potential complication in TEE-guided AF ablation. Although rare, this complication can result in significant morbidity with long-term clinical manifestations including oesophageal stricture, persistent dysmotility, and vocal cord paralysis<sup>27</sup>. Although none of our patients exhibited such symptoms, oesophageal haematoma could not be excluded as post-procedural endoscopy was not systematically performed in our study.

## Limitations

Our study bears the obvious limitation of being a first experience conducted in a limited number of patients. Larger prospective randomized studies are needed in order to confirm our findings. No pre-procedural imaging or selective angiography of the PVs was performed, so that the diameters could not be confirmed by measurements obtained with other techniques. In addition, no control group was ablated with CB guided by dye injection solely, thus not allowing any comparison on efficacy, procedural, and fluoroscopy times. Furthermore, an echocardiographer and anaesthesiology personnel are required owing to the fact that the procedure is performed under general anaesthesia. Finally, one must not underestimate the risks associated to general anaesthesia and to the positioning of the TEE probe for long procedural times.

## Conclusion

Cryoballoon ablation is safe and feasible under RT 3D TEE guidance. This imaging tool permits perfect visualization of all PV ostia and neighbouring LA structures. Therefore, additional MRI or CT pre-procedural imaging might be avoided in the setting of CBA under RT 3D TEE guidance. Finally, it proved to be an efficient guiding tool to successful occlusion and isolation during this procedure.

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