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Comparison of Cryoballoon and Pulsed Field Ablation in Patients with Symptomatic Atrial Fibrillation: First 6-Month Experience

ABSTRACT

Background: Catheter ablation is an effective treatment for patients with symptomatic atrial fibrillation (AF), and pulmonary vein isolation (PVI) is the cornerstone of AF ablation. Unlike thermal ablation, pulsed field ablation (PFA) uses nonthermal energy to irreversibly electroporate myocardial tissue without affecting adjacent structures such as the esophagus, phrenic nerve, and PV tissue. The aim of this study was to compare the efficacy and safety of the 2 most widely used single-shot ablation techniques worldwide: Cryoballoon (CB) and PFA. To date, this is the first PFA study to be published from Türkiye.

Methods: Consecutive AF patients who underwent PFA and CB-based PVI between July 2025 and February 2026 were enrolled. Cryoballoon PVI was performed using the 28-mm CB; PFA was performed using a 31 mm pentaspline catheter under fluoroscopic guidance.

Results: A total of 100 patients were included in the study (66% male, 64% with paroxysmal AF, mean age: 61.7 ± 11.8 years). There were 55 patients in the CB group and 45 patients in the PFA group. The skin-to-figure-of-8 time was significantly shorter in the PFA group than in the CB group (30.00 [25.00-35.00] vs. 53.00 [47.00-55.00] minutes, $P < .001$). No cerebrovascular events, groin complications, or pericardial effusions were observed in patients in either group. During the 6-month follow-up period, 4 (8.9%) cases of atrial arrhythmia were observed in the PFA group, compared to 7 (12.7%) in the CB group ($P = .406$).

Conclusion: Both CB and PFA are safe and effective treatment methods for symptomatic patients diagnosed with AF. Compared to CB, acute procedure success rates and complications are similar in PFA, but procedure times are shorter.

Keywords: Atrial fibrillation, cryoballoon ablation, pulsed field ablation

ORIGINAL INVESTIGATION

Fatih Erkam Olgun[1]
Berhan Keskin[1]
Aykun Hakgör[1]
Ümeyir Savur[1]
Aysel Akhundova[1]
Mehmet Beşiroğlu[1]
Zafer Güven[2]
Muhammed Furkan Çeleğen[3]
İbrahim Oğuz Karaca[1]
Fethi Kılıçaslan[1]

[1]*Department of Cardiology, Faculty of Medicine, İstanbul Medipol University, İstanbul, Türkiye*
[2]*Department of Cardiology, İstanbul Gaziosmanpaşa Training and Research Hospital, İstanbul, Türkiye*
[3]*Department of Cardiology, Karadeniz Ereğli State Hospital, Zonguldak, Türkiye*

Corresponding author:
Fatih Erkam Olgun,
✉ f_erkam@hotmail.com

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INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in adults and is associated with higher morbidity and mortality.[1] The prevalence of AF is expected to double in the next few decades as a consequence of the aging population, an increasing burden of comorbidities, improved awareness, and new technologies for detection.[2] Catheter ablation is an effective treatment for patients with symptomatic AF, and pulmonary vein isolation (PVI) is the cornerstone of AF ablation.[1] Multiple randomized clinical trials have demonstrated that PVI is a safe therapeutic option and is superior to antiarrhythmic drug therapy (ADT), particularly with regard to symptom improvement, increased exercise capacity, and enhanced quality of life.[3,4]

Pulmonary vein isolation can be achieved using either point-by-point radiofrequency (RF) ablation or a single-shot ablation device such as a cryoballoon (CB). Compared with RF ablation, CB showed non-inferiority and has become one of the most frequently used devices to achieve PVI.[5] The reasons for its widespread use are its steep learning curve, good reproducibility, and favorable safety profile, as well as its significantly shorter procedure time compared to conventional RF PVI.[6]

With traditional thermal ablation methods (namely RF and CB), the thermal effects cannot differentiate between tissues and can extend beyond the target

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myocardium to affect adjacent tissues. This can result in infrequent, but potentially serious, complications such as phrenic nerve injury resulting in diaphragmatic paralysis, PV stenosis, or most dangerously, damage to the esophagus, which can result in atrioesophageal fistula.[7]

Pulsed field ablation (PFA) is a largely nonthermal energy modality using microsecond-scale, high-voltage electrical fields to irreversibly electroporate tissue.[8] Preclinical and clinical studies have demonstrated that PFA destabilizes cell membranes, causing cellular necrosis. It exhibits sufficient ablative tissue specificity to ablate myocardial tissue without affecting adjacent structures such as the esophagus, phrenic nerve, and PV tissue.[7]

This study sought to compare the efficacy and safety of CB and PFA techniques. To date, this represents the first published PFA study from Türkiye.

METHODS

Patient Population

This is a single-center, retrospective, and observational study. The data were retrieved for consecutive patients with symptomatic AF who underwent their first AF ablation at the center between July 2025 and February 2026. The procedures were performed using either a CB catheter or a pentaspline PFA system. Exclusion criteria included (1) presence of intracavitary thrombus; (2) left atrial (LA) anterior-posterior diameter > 55 mm; (3) serum creatinine level of >2.0 mg/dL; (4) severe valvular heart disease; and (5) pregnancy.

Atrial fibrillation type was categorized as paroxysmal AF (lasting <1 week or episodes that are cardioverted within 7 days) and persistent AF (lasting >1 week and episodes that are terminated by cardioversion, either with drugs or by direct current cardioversion after ≥7 days) (2).

The choice of ablation system was dependent on logistical reasons. Since PFA is not yet covered by the country's general health insurance, it was only administered to patients who requested it. Patient characteristics or anatomical criteria did not affect the choice of modality.

The study protocol was approved by the local ethics committee and adhered to the principles of the Declaration of Helsinki. All participants were thoroughly informed about the procedure and written informed consent was obtained from each patient. Artificial intelligence and assisted technologies were not used in the study.

Procedure

All PFA procedures were performed under general anesthesia, while CB ablation was performed under deep sedation involving the administration of midazolam and pethidine hydrochloride in bolus doses. All interventions were performed with uninterrupted oral anticoagulation. Vitamin K antagonist was continued with a target international normalized ratio between 2.0 and 2.5 without bridging therapy. Transesophageal echocardiography (TEE) was performed on patients with AF on the day of the procedure, in order to rule out the presence of a thrombus. The procedures were performed under fluoroscopic guidance. Following femoral vein puncture, 5000 units of intravenous heparin were administered. A decapolar coronary sinus (CS) catheter was inserted into the CS. Left atrial access was obtained with a single transseptal puncture (TSP) (BRK-1 needle, 8.5F transseptal sheath; HeartSpan, Merit Medical Systems Inc.), guided by fluoroscopy and TEE if needed. Subsequently, TSP was performed and the remaining heparin dose was administered according to the patient's weight. Measurements were taken every 15 minutes throughout the procedure to ensure an active clotting time of at least 350 seconds. Additional heparin applications were performed as required.

Cryoballoon Ablation

A 28 mm CB (Arctic Front Advance; Medtronic Inc.) was used for CB ablation and delivered to the LA through a 12F sheath (FlexCath Advance, Medtronic Inc., Minneapolis, MN, USA). The balloon was introduced into the PV ostium over the achieve catheter (Medtronic Inc.). Local PV occlusion was assessed by contrast injection through the distal CB lumen. A single freezing period of 180 seconds was applied for each PV isolated in less than 60 seconds. Extra CB applications were applied when PV was not isolated. If the balloon nadir temperature exceeded −55°C, CB would be terminated. During CB ablation of the right-sided PVs, right phrenic nerve stimulation was performed using a CS catheter within the superior vena cava. The cryo application was immediately terminated when loss of pacing capture occurred. Following the procedure, exit and entrance block of all PVs was confirmed by pacing maneuvers. If patients were not in sinus rhythm following CB ablation, cardioversion was performed.

Pulsed Field Ablation

A 31 mm pentaspline catheter was used for PFA and a voltage of 2.0 kV was used for all patients during the ablation procedure. A 13F Faradrive sheath (Boston Scientific, Natick, MA, USA) was advanced into the LA over a guidewire. To prevent vagal reactions that could lead to bradycardia or asystole during PFA, 1 mg atropine was administered. Under fluoroscopic guidance, a PFA catheter (Farawave, Boston Scientific, Natick, MA, USA) was placed into each PV ostium through the sheath. Selective venography was performed on each PV. The catheter was navigated with a J-tip guidewire to reach a stable position at the PV ostia. The Farawave ablation catheter has 5 splines with 4 electrodes on each spline with the outer electrodes that record electrograms

HIGHLIGHTS

- Cryoballoon ablation is widely used due to its steep learning curve, good reproducibility, and favorable safety profile.
- Pulsed field ablation (PFA) uses non-thermal energy to irreversibly electroporate myocardial tissue without affecting adjacent structures.
- Pulsed field ablation is widely used in Europe and the USA but has only recently begun to be adopted in this country.
- This is the first PFA study to be published from Türkiye.

and perform pacing. At least 4 basket-shaped and 4 flower-shaped applications of PFA were performed on each PV. Following the initial 2 applications within each configuration, the ablation catheter was rotated in order to alter the spline direction and ensure complete circumferential isolation. This was followed by a further 2 applications (Figures 1 and 2).

While adhering to the current recommendations for PVI using the pentaspline PFA system, the standard protocol was expanded by adding further applications. After isolating the left superior PV, additional applications are routinely performed to the anterior portion of the left superior PV and left carina. Similarly, after isolating the right superior PV, additional applications are performed to the anterior portion of the right superior PV and right carina (Figures 3A and B). No additional measures were taken to monitor the phrenic nerve when PFA was applied to the right PVs. Pulmonary vein isolation was defined as the absence of LA to PV conduction, as assessed by the pentaspline catheter placed in the PV ostium in an olive (is a smaller version of the basket shape) configuration (Figure 2). If patients were not in sinus rhythm following PFA, cardioversion was performed. Entry and exit blocks were demonstrated to show PVI. The position of the diaphragm and its movement during respiration were routinely assessed under fluoroscopy after the patient had been extubated. In patients with cardiac implantable electronic devices (CIEDs), pre- and post-procedure device interrogation was performed to check the device and leads.

Periprocedural Care and Hemostasis

Acute procedural success, defined as the complete isolation of all PVs, verified through both entry and exit block. The total procedure time is defined as the time period from when the patient is brought to the operating table until they are removed. The time from femoral vein puncture to figure-of-8 suture is defined as skin to of 8 time.

After ablation, a transthoracic echocardiography (TTE) was performed to rule out pericardial effusion. Hemostasis was reached via a figure of 8 suture, followed by 6 hours of bed rest. Direct oral anticoagulants (DOACs) were reintroduced 6 hours after the procedure. Patients were monitored in the hospital for at least 1 day and assessed for complications. To rule out hemolysis-related anemia that might develop in the PFA group, complete blood count and creatinine tests were carried out on both groups 1 day after the procedure. Patients were also asked about any changes in the color of their urine to identify macroscopic hematuria.

The first 2 months were designated as the blanking period. Anticoagulation and ADT were continued during this period.

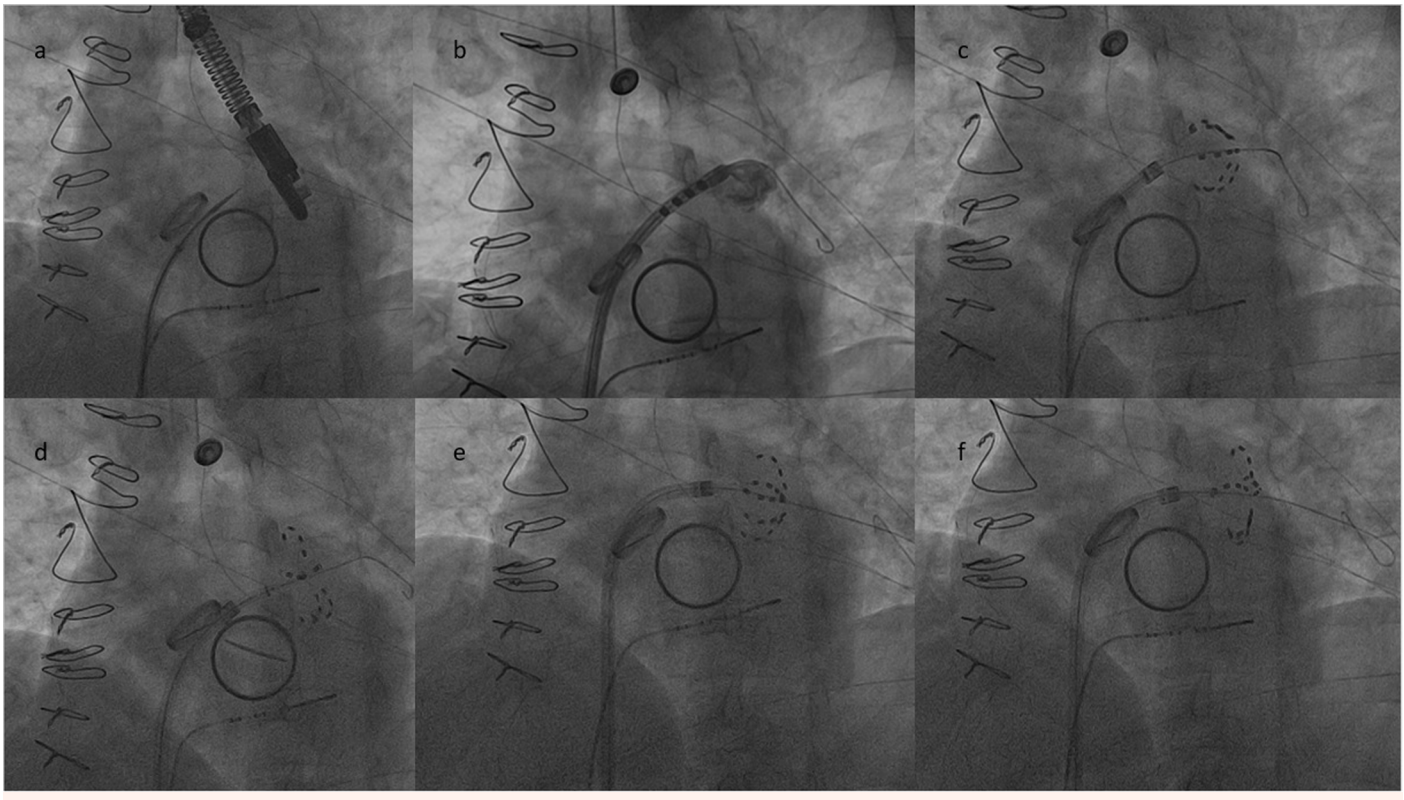


Figure 1. (a) Transseptal puncture in the left anterior oblique (LAO) projection using a Brockenbrough needle, under transesophageal echocardiographic (TEE) guidance, in a patient with aortic and mitral valve prostheses. (b) Venography of the left superior pulmonary vein (PV) in the LAO projection. (c) Application of pulsed-field ablation (PFA) to the left superior PV using the Farawave (Boston Scientific, Natic, MA, USA) catheter in a basket configuration in the LAO projection. (d) Application of PFA to the left superior PV using the Farawave catheter in a flower configuration in the LAO projection. (e) Application of PFA to the left inferior PV using the Farawave catheter in a basket configuration in the LAO projection. (f) Application of PFA to the left inferior PV using the Farawave catheter in a flower configuration in the LAO projection.

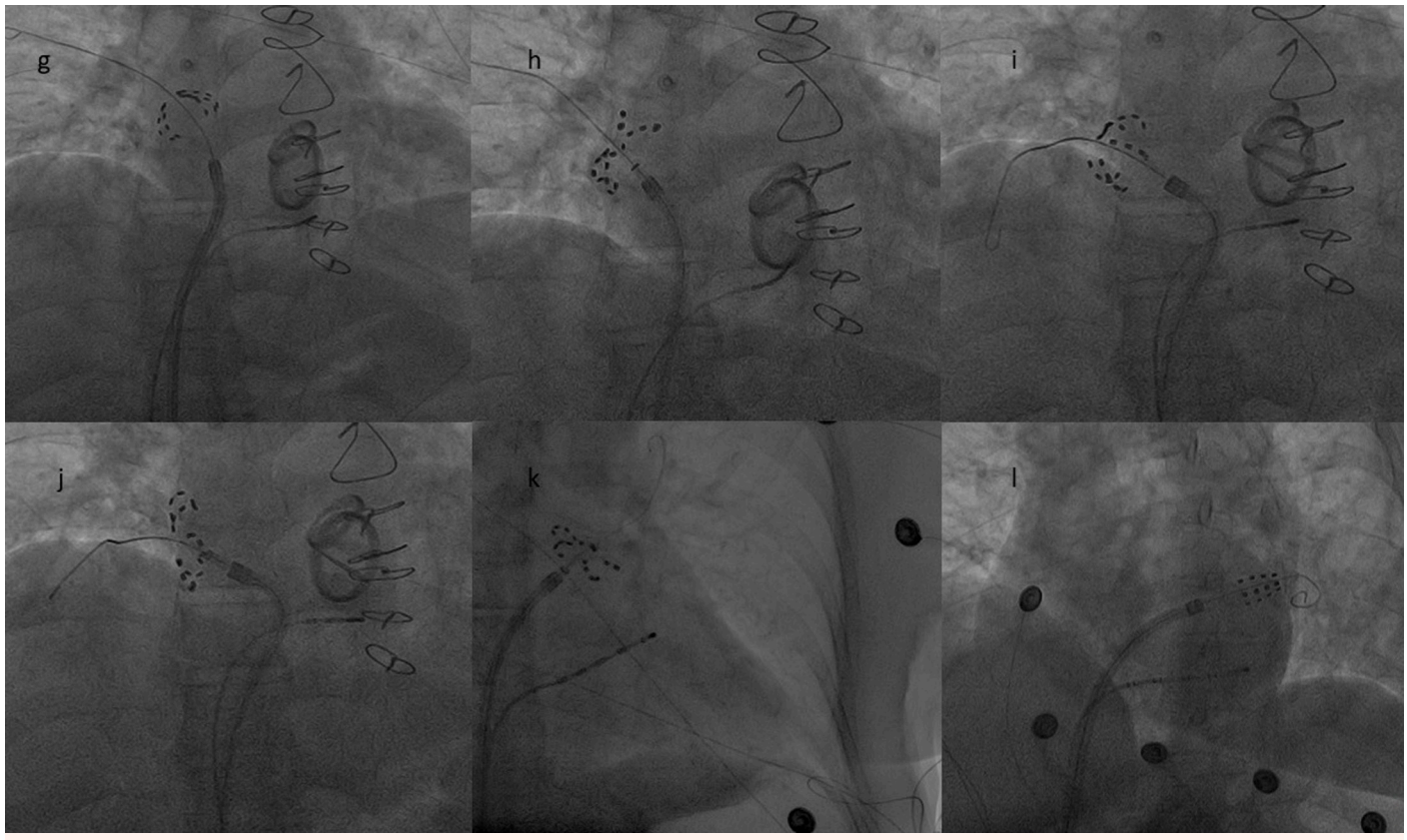


Figure 2. (g) Application of PFA to the right superior PV using the Farawave catheter in a basket configuration in the right anterior oblique RAO projection. (h) Application of PFA to the right superior PV using the Farawave catheter in a flower configuration in the RAO projection. (i) Application of PFA to the right inferior PV using the Farawave catheter in a basket configuration in the RAO projection. (j) Application of PFA to the right inferior PV using the Farawave catheter in a flower configuration in the RAO projection. (k) Application of PFA to the anterior aspect of left superior PV using the Farawave catheter in a flower configuration in the LAO projection in another patient. (l) An example of an olive configuration of the Farawave catheter in the left inferior PV in the LAO projection. LAO, left anterior oblique; PFA, pulsed field ablation; PV, pulmonary vein; RAO, right anterior oblique.

After 2 months, anticoagulation was continued according to the stroke risk, as determined by the CHA_2DS_2-VA (congestive heart failure, hypertension, age ≥ 75 years, diabetes mellitus, prior stroke or transient ischemic attack, vascular disease, age 65-74 years) score or the presence of a prosthetic valve. After the blanking period, it was advised that antiarrhythmic drugs should be discontinued and only reintroduced after a documented recurrence.

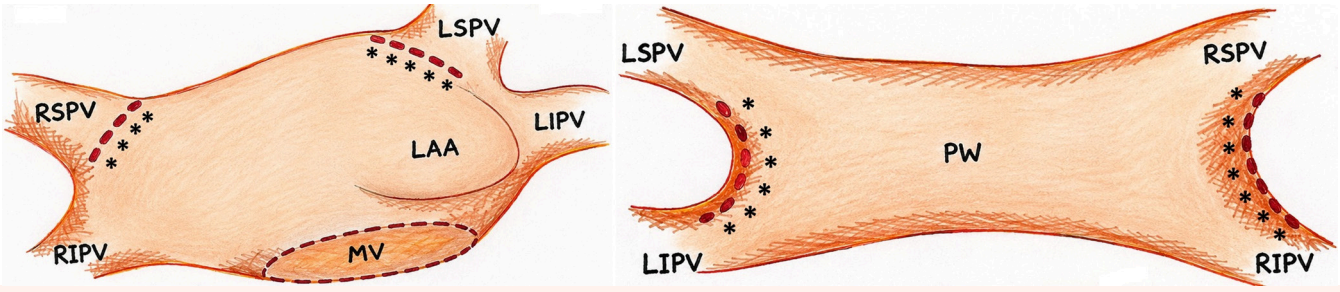


Figure 3. A. Additional PFA applications targeting the anterior segments of the superior PVs (marked with *) were delivered following counterclockwise rotation of the sheath to optimize catheter orientation. Anatomical positioning was confirmed using both LAO and RAO fluoroscopic projections. B. Additional PFA applications targeting the carina of the superior and inferior PVs (marked with *) were delivered following clockwise rotation of the sheath to optimize catheter orientation. Anatomical positioning was confirmed using both LAO and RAO fluoroscopic projections. LAA, left atrial appendage; LAO, left anterior oblique; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; MV, mitral valve; PFA, pulsed field ablation; PV, pulmonary vein; PW, posterior wall; RAO, right anterior oblique; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.

Follow-Up

Patients were recalled for outpatient clinical visits including physical examination, 12-lead electrocardiogram (ECG), TTE, and 24-hours ECG monitoring at 1, 2, and 6 months following the procedure. Recurrence was defined as any episode of AF, atrial flutter (AFL), or atrial tachycardia (AT) on a 12-lead ECG or lasting at least 30 seconds on 24-hour ECG monitoring. Any atrial arrhythmias that occurred during the blanking period were termed "early recurrences." Those observed after this period were classified as "late recurrences."

Statistical Analysis

All statistical analyses were performed using Python, version 3.14.0 (Python Software Foundation, Wilmington, DE, USA), with Pandas, NumPy, SciPy, and Statsmodels libraries. The normality distribution was evaluated using the Kolmogorov–Smirnov test. Continuous variables were compared using the independent-samples *t*-test or Mann–Whitney *U*-test, as appropriate. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. A *P* level of <.05 was accepted as statistically significant with a 95% CI and a 5% margin of error.

RESULTS

Study Population and Baseline Characteristics

This study included a total of 100 (mean age 61.7 ± 11.8 years, 66% male) consecutive patients who underwent AF ablation between July 2025 and February 2026. The cohort was divided into 2 groups based on the ablation system used: CB group (n = 55), PFA group (n = 45). Baseline characteristics, laboratory, and echocardiographic findings of the patients are summarized in Tables 1 and 2. The majority of patients in both groups had paroxysmal AF (PFA: 32 [71.1%]; CB: 32 [58.2%], *P* = .180). Five patients in the CB group and 7 in the PFA group had CIEDs. Three patients in

Table 1. Baseline Clinical Characteristics

Variables	Cryoablation Group (n = 55)	PFA Group (n = 45)	*P*
Baseline characteristics			
Age (years)	63.00 [55.50-71.00]	61.00 [51.00-70.00]	.325[a]
Gender (male), n (%)	36 (65.5)	30 (66.7)	.678[b]
Body mass index (kg/m^2)	30.90 [27.57-32.12]	30.30 [27.95-32.75]	.950[a]
Atrial fibrillation type (paroxysmal), n (%)	32 (58.2)	32 (71.1)	.180[b]
CIEDs presence, n (%)	5 (9.1)	7 (15.6)	0.360[b]
CHA_2DS_2-VA Score, (mean)	1.00 [1.00-2.00]	2.00 [1.00-3.00]	.498[a]
HASBLED Score, (mean)	1.00 [1.00-2.00]	1.00 [0.00-2.00]	.322[a]
Comorbidities			
Diabetes mellitus, n (%)	13 (23.6)	11 (24.4)	.925[b]
Hypertension, n (%)	46 (83.6)	31 (68.9)	.081[b]
Congestive heart failure, n (%)	14 (25.5)	12 (26)	.891[b]
Coronary artery disease, n (%)	13 (23.6)	11 (24.4)	.925[b]
Hyperlipidemia, n (%)	30 (54.5)	23 (51.1)	.732[b]
Hypothyroidism, n (%)	4 (7.3)	5 (11.1)	.728[c]
Hyperthyroidism, n (%)	0 (0.0)	1 (2.2)	.450[c]
Chronic obstructive pulmonary disease, n (%)	4 (7.3)	4 (8.9)	1.000[c]
Chronic renal disease, n (%)	0 (0.0)	0 (0.0)	N/A
Prior valvular surgery, n (%)	3 (5.5)	3 (6.7)	1.000[c]
Mitral valve repair (%)	2 (3.6)	1 (2.2)	
Mitral valve prosthesis (%)	1 (1.8)	1 (2.2)	
Mitral and aortic valve prosthesis (%)	0 (0.0)	1 (2.2)	
Medications			
DOAC, n (%)	54 (98.2)	43 (95.6)	.620[c]
Warfarin, n (%)	1 (1.8)	2 (4.4)	.620[c]
Beta blocker, n (%)	52 (94.5)	44 (97.8)	.625[c]
ACEi/ARB, n (%)	46 (83.6)	34 (75.6)	.315[b]

ACEi, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; CHA_2DS_2-VA, congestive heart failure, hypertension, age ≥ 75 years, diabetes mellitus, prior stroke or transient ischemic attack, vascular disease, age 65-74 years; CIEDs, cardiac implantable electronic devices; DOAC, direct oral anticoagulants; PFA, pulsed field ablation. HASBLED, hypertension, abnormal renal function or abnormal liver function,stroke, belleding, labile INRs, elderley (>65 years), drugs or alcohol.

*Variables are reported as median (interquartile range) or n (%). *P* < .05 statistically significant.

**The statistical method used is specified at the end of the *P*-value.

[a]Mann–Whitney *U*.

[b]Pearson chi-square.

[c]Fisher's exact test.

Table 2. Laboratory and Echocardiographic Findings

Variables	Cryoablation Group (n = 55)	PFA Group (n = 45)	*P*
Laboratory findings			
Creatinine (mg/dL)	0.80 [0.70-0.90]	0.82 [0.75-0.90]	.989[a]
WBC (x10^3/μL)	8.00 [7.30-10.00]	7.87 [7.06-9.90]	.434[a]
Hemoglobin (g/dL)	13.00 [12.00-14.05]	14.00 [12.00-14.50]	.133[a]
ALT (U/L)	20.00 [17.00-25.00]	21.00 [18.00-33.00]	.137[a]
AST (U/L)	23.00 [18.00-26.50]	22.00 [18.00-28.00]	.800[a]
TSH (mIU/L)	2.20 [1.90-2.69]	2.24 [1.82-3.15]	.396[a]
Echocardiographic findings			
LV ejection fraction (%)	65.00 [62.50-65.00]	63.00 [63.00-68.00]	.926[a]
LV end-diastolic diameter (mm)	48.00 [46.00-49.50]	48.00 [44.00-50.00]	.714[a]
LV end-systolic diameter (mm)	32.00 [30.50-33.50]	32.00 [30.00-33.00]	.444[a]
Left atrial diameter (mm)	41.80 ± 3.98	42.18 ± 4.85	.676[b]
PASP (mm Hg)	30.00 [20.00-35.00]	30.00 [25.00-35.00]	.354[a]
Laboratory findings after the procedure			
Hemoglobin (g/dL)	13.00 (11.70-13.95)	13.20 (11.80-14.50)	.221[a]
Creatinine (mg/dL)	0.72 (0.69-0.83)	0.80 (0.69-0.85)	.372[a]

ALT, alanine transaminase; AST, aspartate transaminase; LV, left ventricular; PASP, pulmonary artery systolic pressure; PFA, pulsed field ablation; TSH, thyroid stimulating hormone; WBC, white blood cell.
*Continues variables are reported as mean (±SD) or median (interquartile range).
Categorical variables are reported n (%).
P < .05 statistically significant.
**The statistical method used is specified at the end of the *P*-value.
[a]Mann–Whitney *U*.
[b]Student's independent-samples *t*-test.

each group had previously undergone cardiac valve surgery. Of the patients in the PFA group, 1 had a prosthetic mitral valve, 1 had undergone mitral valve repair, and 1 had prosthetic aortic and mitral valves. Ablation was performed under DOAC therapy (97%) in the majority of patients, while in patients with prosthetic valves, ablation was performed under Warfarin therapy (3%). Moreover, LA diameter (PFA: 42.18 ± 4.85 mm, CB: 41.8 ± 3.98 mm, *P* = .676), left ventricular ejection fraction (PFA: 63.00 [63.00-68.00], CB: 65.00 [62.50-65.00], *P* = .926), and body mass index (PFA: 30.30 [27.95-32.75] kg/m^2, CB: 30.90 [27.57-32.12] kg/m^2, *P* = .950) were similar in both groups. No statistically significant differences were observed among the groups regarding baseline parameters.

Procedural Characteristics

The isolation of all PVs was achieved in all patients in both groups. Median 44 [40-46] applications were performed in the PFA group and 5 [5-6] applications were performed in the CB group, In 9 (9%) patients, the left PVs were connected to the LA through a common ostium (PFA: 4 [8.9%]; CB: 5 [9.1%]; *P*: 1.000).

The skin-to-figure-of-8 time was significantly shorter in the PFA group than in the CB group (30.00 [25.00-35.00] vs. 53.00 [47.00-55.00] minutes, *P* < .001). Likewise, the total procedural time was also shorter in the PFA group (50.00 [45.00-60.00] vs. 58.00 [52.50-60.00] minutes, *P* = .028). One patient in the PFA group underwent AFL ablation using the CARTO 3 mapping system (Biosense Webster, California, USA) for cavotricuspid isthmus (CTI) ablation. This enabled a scar map to be created of the patient's LA and PVs, demonstrating that all PVs had been isolated.

No cerebrovascular events, groin complications, or pericardial effusions were observed in patients in either group. Temporary phrenic nerve paralysis was observed in 1 patient from each group. A diaphragm examination performed under fluoroscopy on 1 patient in the PFA group following extubation revealed that the right hemidiaphragm was elevated and not moving with respiration. A follow-up fluoroscopic examination prior to discharge showed that the diaphragm had returned to its normal position and was functioning normally. During cryoablation of the right superior PV, loss of phrenic nerve capture was observed in a patient in the CB group while pacing with a CS catheter, and the ablation was immediately terminated. At the 1-month follow-up, it was determined that the position and movement of the patient's diaphragm had returned to normal. Therefore, no persistent phrenic nerve injury was reported in the overall cohort. No complications related to general anesthesia or deep sedation were observed in either group. All procedural characteristics are displayed in Tables 3 and 4.

Follow-Up

Overall, there were 4 (8.9%) atrial arrhythmia recurrences in the PFA group and 7 (12.7%) in the CB group in the 6-month follow-up. Four of these recurrences occurred during the 2-month blanking period after the procedure, which is defined as an early recurrence. The early recurrence rates were similar in both groups (PFA 1 [2.2%]; CB 3 [5.5%]; *P*: .620). Of the patients with early recurrence in the PFA group, 1 patient had AT. Of those in the CB group, 2 patients had AF and 1 patient had AFL. Early recurrences of atrial tachyarrhythmia were treated with electrocardioversion or ADT.

Table 3. Procedural Data and Clinical Outcomes

Variables	Cryoablation Group (n = 55)	PFA Group (n = 45)	*P*
Procedural data			
Procedure time (minutes)	58.00 [52.50-60.00]	50.00 [45.00-60.00]	**.028**[a]
Skin to figure of 8 time (minutes)	53.00 [47.00-55.00]	30.00 [25.00-35.00]	**<.001**[a]
Left common pulmonary vein, n (%)	5 (9.1)	4 (8.9)	1.000[b]
Complications			
Death, n (%)	0 (0.0)	0 (0.0)	N/A
Stroke/TIA, n (%)	0 (0.0)	0 (0.0)	N/A
Pericardial effusion/cardiac tamponade, n (%)	0 (0.0)	0 (0.0)	N/A
Hemolysis-related transient renal injury, n (%)	0 (0.0)	0 (0.0)	N/A
Pericarditis, n (%)	0 (0.0)	0 (0.0)	N/A
Vascular access complications, n (%)	0 (0.0)	0 (0.0)	N/A
Transient phrenic nerve paralysis, n (%)	1 (1.8)	1 (2.2)	1.000[b]
Persistent phrenic nerve paralysis, n (%)	0 (0.0)	0 (0.0)	N/A
Anesthesia related complications, n (%)	0 (0.0)	0 (0.0)	N/A
Clinical outcomes			
Early recurrence, n (%)	3 (5.5)	1 (2.2)	.620[b]
AF (%)	2 (3.6)	0 (0.0)	
AFL (%)	1 (1.8)	0 (0.0)	
AT (%)	0 (0.0)	1 (2.2)	
Late recurrence, n (%)	4 (7.3)	3 (6.6)	1.000[b]
AF (%)	3 (5.5)	2 (4.4)	
AFL (%)	0 (0.0)	0 (0.0)	
AT (%)	1 (1.8)	1 (2.2)	

AF, atrial fibrillation; AFL, atrial flutter; AT, atrial tachycardia; PFA, pulsed field ablation; TIA, transient ischemic attack.
*Variables are reported as median (interquartile range) or n (%).
P < .05 statistically significant.
**The statistical method used is specified at the end of the *P*-value.
[a]Mann–Whitney *U*.
[b]Fisher's exact test.

Only 1 patient in the CB group underwent CTI ablation during the blanking period.

There were 3 (6.6%) late recurrences in the PFA group and 4 (7.3%) in the CB group (*P*: 1.000). Of the patients with late recurrences in the PFA group, 2 patients had AF, and 1 patient had AT. Of those in the CB group, 3 patients had AF, and 1 patient had AT. Late recurrences of atrial tachyarrhythmia were treated with electrocardioversion or ADT.

In total, 2 patients in the CB group underwent repeat procedures after the blanking period due to arrhythmias that were refractory to ADT. One patient underwent roof-dependent left AT ablation, while the other underwent AF RF ablation. All PVs were found to be isolated in both patients. During RF AF ablation in that patient, box isolation of the posterior wall was performed alongside ablation of the roof and bottom lines. Ablation of the mitral isthmus and CTI was also performed. In contrast, patients in the PFA group remained asymptomatic following the change in ADT.

DISCUSSION

Main Findings

This study presents the first comparison of patients treated with CB or PFA for AF from Türkiye. Main findings are as follows: (1) both techniques are highly effective at achieving acute PVI, (2) the PFA group had significantly shorter skin-to-figure-of-8 and total procedural times than the CB group; (3) no significant difference in the safety profile was recorded, (4) the 6-month success rate was similar for both technologies in AF ablation (PFA: 91.1%; CB: 87.3%).

Procedural Efficacy

A high acute PVI success rate (100%) was observed with both techniques. These rates were comparable to those reported in previous CB and PFA reports (99.5% and 100%, respectively).[9]

The lower difference in the total procedure duration in both groups is associated with PFA procedures being performed under general anesthesia, as well as the prolonged duration due to patient intubation and extubation. However, the time taken from groin puncture to placement of the figure-of-8 suture was found to be significantly shorter in the PFA group than in the CB group. This was associated with the shorter first-pass PVI time in the PFA group. Similar results were reported by Urbanek et al[9] in their CB and PFA comparison.

In a recent article, Badertscher et al[10] reported that they had expanded the standard protocol by adding 2 extra applications to the anterior part of the right-sided carina prior to

Table 4. Procedural Application Characteristics

Variable	Cryoablation (n = 55)	PFA (n = 45)	*P*
Total number of applications	5.00 (5.00-6.00)	44.00 (40.00-46.00)	**<.001**
LSPV, number of applications	2.00 (1.00-2.00)	16.00 (12.00-16.00)	**<.001**
LIPV, number of applications	1.00 (1.00-2.00)	8.00 (8.00-8.00)	**<.001**
LCPV, number of applications	4.00 (3.00-4.00)	16.00 (16.00-16.50)	**.016**
RSPV, number of applications	1.00 (1.00-2.00)	12.00 (12.00-16.00)	**<.001**
RIPV, number of applications	1.00 (1.00-1.00)	8.00 (8.00-8.00)	**<.001**

LCPV, left common pulmonary vein; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; PFA, pulsed field ablation; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.
*Variables are reported as median (interquartile range).
P < .05 statistically significant.
**The Mann–Whitney *U* test was used as the statistical method.

isolating the right inferior PV, following the isolation of the right superior PV. Histopathologic studies found that myocardial sleeves are the thickest inferior to the superior PVs and superior to the inferior PVs.[11] In addition, epicardial connections between the right-sided PV carina and the right atrium have been reported.[12]

Since additional PFA applications are routinely performed on the right and left PV carina and the anterior segments of both upper PVs during AF PFA ablation, the median application rate (44.00 [40.00-46.00]) is higher than that reported in previously published studies (33 ± 4, 32 [32-34]).[13,14] Kueffer et al[15] noted that PV reconnections are most commonly observed on the anterior aspect of the upper veins (40%) and the inferior aspect of the right inferior vein (21%). Another study by Ruwald et al[16] found that the gaps were significantly more prevalent in the right-sided anterior carina than in other regions.

The prevalence of common left PVs, which are defined as those that connect the left upper and lower PVs to the LA via a single ostium, ranges from 10% to 30%.[17] In this study, the incidence of common left PVs was found to be similar in both groups (PFA: 4 [8.9%]; CB: 5 [9.1%]; *P*: 1.000). Additional sets of applications were performed by directing the guidewire into the separate branches during the isolation of the left common PVs.

Procedural Safety

One of the key findings of this study is that both techniques have a benign safety profile. This study found that complication rates were similar across the CB and PFA groups. Temporary phrenic nerve paralysis was observed in 1 patient from each group. No cases of persistent phrenic nerve injury were reported in the overall cohort. Notably, there were no vascular complications, strokes, cases of cardiac tamponade, esophageal injuries, or deaths, which highlights the strong safety profiles of both CB and PFA ablation strategies. A study by Urbanek et al[9] comparing the safety of PFA and CB noted that one of the most important findings was that both techniques had a favorable safety profile similar to that observed in this study.

The MANIFEST 17-K study reported that none of the 17 642 patients who underwent AF ablation with PFA developed permanent phrenic nerve paralysis. It was also noted that general anesthesia was used in 46.9% of procedures and deep sedation in 53.1%. No anesthesia-related complications were reported in either group.[18] Similarly, Badertscher et al[10] noted that various centers continue to perform PFA procedures using both anesthesia methods, as there is no standardized sedation protocol, and patient comfort may be improved when procedures are performed under general anesthesia. It has also been reported that centers that routinely perform PFA under deep sedation carry out the procedure using general anesthesia and intubation on high-risk patients.[19,20]

Patients with a CIED in both groups were found to be similar. As in previous studies, the results of this study suggest that performing PFA in patients with CIEDs is feasible and safe.[21] Interrogation of the devices before and after PFA revealed no significant alterations to CIED parameters or functions.

The patients with mechanical heart valve prostheses were similar in both groups. No complications related to the prosthetic valves were observed during the PFA procedure. A recently published study of 30 patients with mechanical heart valve prostheses who underwent AF ablation via PFA demonstrated that there were no instances of catheter or wire entrapment. Furthermore, TTE assessment at the time of discharge did not identify any prosthetic valve dysfunction.[22]

Follow-Up

During the blanking period, the early recurrence rate was similar in both groups (CB, 5.5%; PFA, 2.2%; *P* = .620) but showed different characteristics. Two patients in the CB group developed AF and 1 patient developed AFL, while 1 patient in the PFA group developed AT.

In the long term, an overall freedom was observed from atrial arrhythmias of 87.3% in the CB group and 91.1% in the PFA group after 6 months of follow-up. Published studies of patients who underwent AF ablation reported 1-year atrial arrhythmia-free follow-up rates of 74.6% for CB and 88% for PFA.[3,23] Similarly, studies by Urbanec et al[9] comparing CB and PFA found 1-year atrial arrhythmia-free follow-up rates of 78.1% and 74.5%, respectively. The higher success rates observed in this study compared to previous studies may be related to the follow-up period being limited to 6 months.

Following the PFA procedure, 1 patient underwent CTI ablation for AFL using the CARTO 3 mapping system. This

catheter showed that all PVs were isolated. The same was demonstrated in patients in the CB group who underwent ablation for late recurrences. In a study published by Kueffer et al,[15] atrial arrhythmia recurrence was observed in 23% of the 1184 patients who underwent PFA for AF at 7 centers across the Europe. Of these patients, 144 underwent re-ablation guided by a 3-dimensional mapping system within the LA. Complete isolation of all PVs was achieved in 38% of these patients.

In the MANIFEST-REDO study, Scheer et al[24] investigated 427 patients who underwent repeat ablation due to recurrence of atrial arrhythmia following their first PVI procedure using a pentaspline PFA catheter. At the beginning of the repeat procedure, all PVs were durably isolated in 45% of patients. In a study by Lemoine et al,[25] patients who experienced atrial recurrence following PFA or CB AF ablation were examined. Reconnection was detected in 31 (38%) of the 82 PVs isolated with PFA and in 63 (37%) of the 169 PVs isolated with CB. The high rates observed in the study are probably due to the brief follow-up period and limited patient sample size.

Study Limitations

This was a single-center, retrospective study with a limited number of participants. Furthermore, PFA is not yet covered by general health insurance in the country and it is rather costly for patients. Therefore, the possibility of selection bias cannot be ruled out. However, no differences were found between the 2 groups' baseline characteristics.

Another limitation of the study is that the anesthetic technique was not standardized across the groups. While this may have introduced bias with regard to procedural safety, the absence of anesthesia-related complications in both groups suggests that they were comparable in this respect.

Follow-up data was primarily based on serial 24-hour ECG recordings and outpatient visits involving 12-lead ECGs. As an implantable loop recorder was not used, it is probable that the chronic success rate has been overestimated. However, these limitations apply to both groups and do not affect the validity of the relative comparison.

Finally, the PFA procedures were guided by fluoroscopy, and intracardiac echocardiography (ICE) was not used for direct visualization of the PFA catheter. Although recent studies have shown that there is no advantage to using ICE, would the results have been different if ICE had been used to clearly demonstrate the catheter's exact location and contact with the tissue?[26] Further prospective randomized trials should evaluate potential benefits of PFA compared to CB for AF ablation.

Ethics Committee Approval: This study was approved by the Ethics Committee of İstanbul Medipol University University (Approval No.: E-10840098-50.04-3306; Date: 12/05/2026).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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