Pulsed field ablation of the cavotricuspid isthmus using a multispline-electrode pulsed field ablation catheter

Martin H. Ruwald, MD, PhD, Arne Johannessen, MD, DmSc, Morten Lock Hansen, MD, PhD, Rene Worck, MD, PhD, Jim Hansen, MD, DmSc

From the Division of Electrophysiology, Department of Cardiology, Herlev and Gentofte Hospital, Hellerup, Denmark.

Introduction
Pulsed field ablation (PFA) has earned substantial attention because of its unique, nonthermal tissue-preferential mechanism for cardiac ablation of arrhythmias and is used increasingly for pulmonary vein isolation (PVI). Recently, the Food and Drug Administration (FDA) approved the device for ablation in patients with paroxysmal and persistent atrial fibrillation (AF) after its safety and efficacy had been demonstrated in 4 controlled prospective trials: IMPULSE, PEFCAT, PEFCAT-2, and PersAFone. While the commercially available 12F multispline-electrode catheter Farawave (Farapulse Inc) is being used for PVI, the trial set-up in PEFCAT-2 and PersAFone also allowed for utilization of the 12F deflectable focal PFA catheter (Faraplex; Farapulse Inc, Menlo Park, CA) for supplementary cavotricuspid isthmus (CTI), posterior wall of the left atrium (LA), and mitral isthmus ablation. It is unknown to what extent the Farawave multispline-electrode catheter may be used for CTI ablation, and no description of such a case has been made.

Case report
A 67-year-old male patient with ischemic heart failure since 2004, left ventricular ejection fraction of 25%, NYHA functional class II with a cardiac resynchronization therapy-defibrillator (CRT-D) since 2015 and paroxysmal AF since 2018 and persistent AF since 2020 was evaluated. Heart failure medication was fully optimized and there was 100% biventricular pacing. There was no atrioventricular (AV) conduction but the episodes of AF with device mode-switch were symptomatic with worsening of heart failure and EHRA class 3 symptoms. Despite treatment with amiodarone, he had been cardioverted on several occasions, with symptomatic improvement. The patient was referred for PVI.

Management
The procedure was scheduled, in uninterrupted oral anticoagulation, as a PFA procedure with PVI under general anesthesia. Preprocedural computed tomography (CT) scan and transesophageal and transthoracic echocardiograms were performed, confirming left ventricular ejection fraction of 25% and a dilated LA of 64 mL/m² with smoke but no thrombus in the left atrial appendage. At the time of the procedure, the patient was in AF with biventricular pacing at a rate of 80 beats per minute. A rotational low-dose CT was

KEY TEACHING POINTS
- Pulsed field ablation (PFA) is a promising method for pulmonary vein isolation (PVI).
- Atrial fibrillation and coexisting cavotricuspid isthmus (CTI) flutter is a common problem and PVI and CTI ablation is often performed in the same procedure.
- In this case we describe the successful use of the multispline-electrode PFA catheter for PVI and supplementary ablation of the CTI in a patient with acquired atrioventricular block and cardiac resynchronization therapy-defibrillator.
- High-resolution voltage and propagation maps after PFA in the CTI showed extensive low voltage on the CTI region but normal voltage in the triangle of Koch and coronary sinus and lateral to the CTI.

KEYWORDS
Pulsed field ablation; Electrophysiology; Cavotricuspid isthmus; Electroporation; Ablation; Cavotricuspid flutter; Multispline catheter

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done and aligned with the preprocedural CT scan for optimal fluoroscopic anatomical guidance. Vascular access was obtained through the right groin and thereafter a fluoroscopy and pressure-guided transseptal puncture by use of SL1 sheath and BRK-1 needle was done as per standard. After access to the LA, systemic heparinization was done and a 15F deflectable sheath was inserted and exchanged over the wire. PVI was performed with the 12F, 31 mm multispline-electrode catheter, fluoroscopy guided with 4 paired applications of PFA per vein, 2 pairs in catheter “basket” formation and 2 pairs in “flower” formation, all pairs with an approximately 45-degree rotation, for a total of 8 applications per vein. The PFA applications were biphasic pulses of 2 kilovolts and acute isolation was confirmed by electrograms on the multielectrode catheter. After PVI a confirmatory map of the LA was performed with fast anatomical mapping and bipolar voltage amplitude map with a multielectrode Pentaray catheter ( Biosense Webster Inc, Irvine, CA). During the mapping procedure the AF became regularized to a flutter with cycle length of 300 ms with proximal-to-distal coronary sinus catheter activation sequence. A new local activation time, propagation, and coherence map was performed with the Pentaray catheter in the LA, showing passive activation of the LA through the CS and isolated veins. A new local activation time, propagation, and coherence map in the right atrium (RA) confirmed CTI-dependent counterclockwise flutter (Supplemental Video Clip 1) with a positive entrainment maneuver from the CTI region. As the patient already had complete AV block, it was deemed safe to attempt CTI ablation using the PFA multispline-electrode catheter (Farawave) in “flower” formation. Optimal CTI position of the petals of the catheter in right anterior oblique and left anterior oblique views with acceptable electrogram recordings (Figure 1A and 1B) was confirmed. During on-going flutter, delivery of the first (of 5) 2-kV pulse of PFA converted, within a maximum of 468 ms, the rhythm to ventricular pacing from the CRT (Figure 2A, Supplemental Video Clip 2). One additional PFA application and 2 more after an approximately 45-degree rotation were delivered over approximately 2 minutes of transpired time. CTI block was confirmed with bidirectional pacing across the CTI with a block of 172 ms (stimulus to A2, Figure 2B). A new voltage and activation map of the RA was made with pacing from the proximal poles of the CS catheter. The maps showed extensive low voltage indicating acute myocyte dysfunction and propagation block on the CTI (Figure 3A and 3B, Supplemental Video Clip 3), but with normal voltage and impulse propagation in the triangle of Koch and lateral regions of the CTI and RA. No damage to the phrenic nerve was observed and no changes in electrocardiogram 12 were recorded. The bidirectional block was re-evaluated after a 30-minute observation period and was found to be unchanged at 172 ms.

**Discussion**

This case demonstrates amazing efficiency of the PFA multispline-electrode catheter to achieve single-shot termination of CTI-dependent flutter and to perform CTI block. At this point, it is off-label use of the device, but we used it for ablation of the CTI in a patient with acquired AV block and CRT-D and thus at no risk of additional injury to the conduction system. Published studies supported by Farapulse Inc have utilized the focal PFA catheter, not yet FDA approved, but it may be technically possible and feasible to perform PVI and CTI ablation with the multispline-electrode PFA catheter alone. In the PersAFone study acute CTI bidirectional block was achieved in 13 of 13 (100%) patients using the focal catheter and PFA was in that study delivered at a median of 6 sites (interquartile range [IQR]: 5–7 sites) per CTI with an average of 9 minutes (IQR: 6–12 minutes) between the first and last PFA deliveries. As with PVI after PFA, the question of durability of the ablation of CTI remains.
Follow-up durability mapping from PersAFone at a median of 87 days (IQR: 76–90 days) after index procedure showed 25% durability for the first 4 patients who were exposed to a lower initial PFA dose (called Focal-1 of 1.6 kV) compared to 100% durability in 8 out of 8 patients with Focal-2 of 1.8 kV of PFA dosing. Lesion depth, required application energy intensity, and duration are still being explored and optimized for both the multispline-electrode and focal PFA catheters. We believe that our case shows that PFA of the CTI with the multispline-electrode catheter is technically possible and highly efficient. We could not assess the effect on AV conduction, since it was absent before ablation, but high-resolution voltage mapping suggests lesions to be at a safe anatomical distance from the apex of the triangle of Koch. However, it is well known that there are many variations in the anatomies of the CTI and the triangle of Koch, but also variations in the operator assessment of fluoroscopy-based catheter positions, which may compromise the safety of such an approach. The safety of this off-label use of the PFA multispline catheter in patients with intact AV conduction is uncertain. We did not observe electrocardiographic signs of injury to the right coronary artery.

Figure 2 Pulsed field ablation (PFA) delivery during cavotricuspid isthmus (CTI)-dependent flutter and intracardiac electrograms after pulsed field ablation of the CTI. A: Five pulses of PFA delivery on the CTI and ongoing atrial flutter terminated within the first pulse of a maximum of 468 ms. B: Verification of 172 ms CTI block on the lateral side (stimulus to A2) when pacing from proximal poles in coronary sinus catheter.

Figure 3 High-resolution bipolar voltage map of the isthmus region of the right atrium and local activation time propagation map of the isthmus region. A: The high-resolution bipolar voltage map shows extensive low voltage indicating acute block of the cavotricuspid isthmus region (in an inferior left anterior oblique 40-degree view) with normal voltage in the triangle of Koch and coronary sinus as well as lateral to the line. B: Local activation time propagation map of the isthmus region of the right atrium (in an inferior left anterior oblique 40-degree view) with pacing from the proximal poles of the coronary sinus catheter shows verification of block.
or PFA-induced ventricular arrhythmias. As highlighted in the referenced papers, PFA is a very promising single-shot mode of ablation for PVI and posterior LA wall isolation, and for patients with concomitant CTI-dependent flutter an optimal workflow could improve so ablation of the CTI could be performed with the same catheter if possible.

**Follow-up**
The patient was discharged the following day with no complaints or complications and with a well-functioning CRT-D device in DDD BIV-pace mode. It was planned to maintain amiodarone (200 mg once daily) for 1 month after ablation.

**Conclusion**
The unique insight from this case suggests that CTI block, when necessary, can be performed with high efficiency in the workflow of PVI, and with lesions seemingly at an anatomically safe distance from the AV node. The safety of this off-label use of the PFA device on the CTI is uncertain and needs to be explored systematically before it is applied to patients with intact AV node function.

**Appendix**

**Supplementary data**
Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2021.12.009.

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