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

Short title: Pulsed field ablation of the cavotricuspid isthmus

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Word count: 1423

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Funding: None
Disclosures: RW: has received research grants and speaker honoraria from Biosense Webster and JH has received research grants and speaker honoraria from Medtronic and Biosense Webster. All other authors no disclosures or conflicts of interest.

Keywords: Pulsed field ablation; electrophysiology; cavitricuspid isthmus; electroporation; ablation; cavitricuspid flutter; multispline catheter
Introduction:

Pulsed field ablation (PFA) has earned substantial attention because of its unique, non-thermal 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 after its safety and efficacy had been demonstrated in 4 controlled prospective trials: IMPULSE, PEFCAT, PEFCAT-2 and PersAFone(1-3). While the commercially available 12-French(F) 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 12-F deflectable focal PFA catheter (Faraflex, Farapulse Inc.) 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:

A 67-year-old male 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 atrial fibrillation (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 AV conduction but the episodes of AF with device mode-switch were symptomatic with worsening of heart failure and EHRA 3 symptoms. Despite of 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 un-interrupted oral anticoagulation, as a pulsed field ablation procedure with PVI under general anaesthesia. Preprocedural computed tomography (CT) scan, transesophageal and transthoracic echocardiograms were performed confirming left ventricular ejection fraction of 25%, a dilated LA of 64 ml/m2 with smoke but no thrombus in the left atrial appendage. At the time of procedure, the patient was in AF with biventricular pacing at a rate of 80 bpm. A rotational low-dose CT was done and aligned with the pre-procedural CT scan for optimal fluoroscopic anatomical guidance. Vascular access was obtained through the right groin and hereafter 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 15-French deflectable sheath was inserted and exchanged over the wire. PVI was performed with the 12-F, 31 mm multispline-electrode catheter, fluoroscopy guided with four paired applications of PFA.
per vein, two pairs in catheter “basket” formation and two pair 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 two kilovolts and acute isolation was confirmed by electrograms (EGM) 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.). During the mapping procedure the AF became regularized to a flutter with cycle length of 300ms with proximal to distal coronary sinus activation (CS). A 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 (supplementary Video-clip 1) with a positive entrainment manoeuvre from the CTI region. As the patient had already 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 RAO and LAO views with acceptable EGM recordings (Figure 1 A and B) was confirmed. During on-going flutter, delivery of the first (of five) two kilovolt pulse of PFA converted, within a maximum of 468ms, the rhythm to ventricular pacing from the CRT (Figure 2A, supplementary Video-clip 2). One additional PFA application and two more after an approximately 45-degree rotation were delivered over approximately two minutes of transpired time. CTI block was confirmed with bidirectional pacing across the CTI with a block of 172ms (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 B, 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 ECG-12 were recorded. The bidirectional block was re-evaluated after a 30-minute observation period and found to be unchanged at 172ms.

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 the 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(3) 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 (IQR: 5 to 7 sites) per CTI with an average of 9 minutes (IQR: 6 to 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 to 90 days) after index procedure showed 25% durability for the first four patients who were exposed to a lower initial PFA dose (called Focal-1 of 1.6 kilovolts) compared to 100% durability in eight out of eight patients with Focal-2 of 1.8 kilovolts 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 ECG signs of injury to the right coronary artery, 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 work-flow 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 one month after ablation.

Conclusion:
The unique insight from this case suggests that CTI block, when necessary, can be performed with high efficiency in the work flow 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.

References:


Figure 1, panel A and B:

Title: Intracardiac electrograms from the Farawave (Farapulse Inc.) multispline-electrode catheter and coronary sinus catheter and a left anterior oblique 40 degrees fluoroscopy image

Legend: Panel A: Cavotricuspid isthmus position of the PFA catheter and ongoing atrial flutter with cycle length of 300ms, proximal to distal coronary sinus catheter activation sequence. Panel B: PFA multispline-electrode catheter position on the cavotricuspid isthmus in left anterior oblique 40 degrees with no impingement or contact to the left ventricular lead or ICD right ventricle lead.

Figure 2, panel A and B:

Title: PFA delivery during CTI dependent flutter and intracardiac electrograms after pulsed field ablation of the cavotricuspid isthmus

Legend: Panel A: Five pulses of PFA delivery on the cavotricuspid isthmus and ongoing atrial flutter terminated within the first pulse of a maximum of 468ms. Panel B: Verification of 172ms cavotricuspid isthmus block on the lateral side (stimulus to A2) when pacing from proximal poles in coronary sinus catheter.

Figure 3, panel A and panel B:

Title: High-resolution bipolar voltage map of the isthmus region of the right atrium and local activation time propagation map of the isthmus region

Legend: Panel 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. Panel 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.
Key teaching points:

- PFA is a promising method for PVI
- Atrial fibrillation and co-existing 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 AV block and CRT-D
- 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, CS and lateral to the CTI