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CASE REPORT
Electrophysiology

Lesion effects in terms of local impedance variations after pulsed-field ablation during pulmonary vein isolation: a case report

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Background To date, no information is available on highly localized impedance (LI) measurements during the ablation of pulmonary veins (PVs) via a new form of energy such as electroporation by means of pulsed-field ablation (PFA).

Case summary A 55-year-old man with a history of paroxysmal atrial fibrillation was admitted to our hospital for PV isolation (PVI). The procedure was performed with the new multi-electrode PFA catheter (FARAWAVE™). Before energy delivery, a high-density map of the left atrium was constructed with the Rhythmia™ system, while the IntellaNAV Mifi™ OI catheter was used to assess the baseline LI values of the four PVs. A manual tag was used to record the exact position where the IntellaNAV™ catheter measured the LI values for each segment of the vein before and after PVI. The LI values displayed a significant variation after PFA delivery (124.3 ± 5 Ω for baseline LI vs. 96.8 ± 6 Ω after PFA, $P < 0.0001$) with a mean absolute LI variation of 27.5 ± 7Ω and a mean percentage LI variation of 25.8 ± 8%. The differences between the average LI values pre- and post-PFA were 28.0 ± 5, 26.5 ± 9, 26.8 ± 3, and 28.8 ± 10 Ω for the superior, anterior, posterior, and inferior portions of the PV.

Discussion This is the first instance of the acute characterization, in terms of LI drop, of antral lesions created by a new PFA system. Local impedance variations at ablation sites seem to be larger than those recorded at successful ablation spots obtained by means of thermal energy sources.

Keywords Electroporation • Pulsed-field ablation • DirectSense • Local impedance • Catheter ablation • Tissue characteristics • Atrial fibrillation • Pulmonary vein isolation • Case report

ESC Curriculum 5.3 Atrial fibrillation • 5.4 Atrial flutter

Learning points

- Local impedance has been proved to have a stronger relationship with lesion size and ablation efficacy in the left atrium during atrial fibrillation ablation by means of radiofrequency delivery.
- Local impedance variations after pulsed-field ablation seem to be larger than those recorded at successful ablation spots obtained by means of thermal energy sources such as radiofrequency.

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Introduction

Catheter ablation via pulmonary vein isolation (PVI) is a well-established procedure for the treatment of both paroxysmal and persistent atrial fibrillation (AF). The most widely used technologies comprise cryothermal or radiofrequency (RF) energy sources, which destroy the target tissue by freezing or heating, respectively.[1] Freezing or heating affects biological systems at both the molecular and the cellular levels, which may alter their structure and composition and therefore their electrical impedance[2]; thus, the variation in impedance could be used to assess the quality of ablation lesions. The local impedance (LI) information, measured through mini-electrodes on the tip of a dedicated RF ablation catheter (IntellaNAV Mifi OI; Boston Scientific) and the DirectSense™ technology, has been proved to have a strong relationship with lesion size both in the atrium and in the ventricle,[3,4] and its variations seem not to be influenced by the energy source used to create the lesion (RF or cryoablation).[5] Recently, a new ablation technique, called pulsed-field ablation (PFA), is arousing increasing interest in the field of cardiac tissue ablation; the technique involves irreversibly electroporating cell membranes, without thermal damage, by using short-duration, high-voltage electrical impulses to create lesions.[6] The success rate of PVI by PFA is high, and major adverse events are low. Pulsed-field ablation is found to decrease the recurrence of atrial arrhythmia compared with thermal ablation.[7] However, lesion characteristics after PFA ablation, which are highly relevant for the electrophysiological endpoint as they are predictive of durable segment block, have not yet been studied. Here, we provide the first report of the effects of substrate modification in terms of LI variation, as assessed through a novel LI algorithm, after PFA ablation.

Timeline

Day 1	Admission to our hospital for PVI, transoesophageal echocardiography and cardiac computed tomography evaluation
Day 2	PVI procedure
Day 3	Patient discharge
Day 7	7-Days clinical evaluation and electrocardiogram (ECG)
Follow-up 3 and 6 months after hospitalization	Clinical evaluation, ECG, and 24 h Holter monitoring

Case presentation

A 55-year-old man with a history of paroxysmal AF was admitted to our hospital for PVI. No relevant comorbidities were present. Clinical examination was unremarkable. The patient underwent transoesophageal echocardiography and cardiac computed tomography prior to the procedure, in order to rule out thrombi in the left atrial appendage and to obtain a detailed three-dimensional anatomical picture of the left atrium (LA). Deep conscious sedation was induced by midazolam, fentanyl, and propofol in an operator-directed, nurse-administered fashion. The procedure was performed with the new multi-electrode 12F over-the-wire PFA catheter (FARAWAVE™; Boston Scientific; catheter size: 31 mm), which has 5 splines, each containing 4 electrodes (yielding a total of 20 ablative electrodes). Each spline navigated the wire via a 13F steerable sheath (FARADRIVE™; Boston Scientific) and was deployed in the desired shape and advanced into position at the antrum of each pulmonary vein (PV). Pulmonary vein isolation was performed by means of four applications in a basket configuration and four applications in a flower configuration per PV, as described previously (see Supplementary material online, *Figure S1*).[8] Between pairs of PFA applications, the catheter was rotated by ~30°/45° after the first two applications in each configuration, in order to cover the entire circumference.[7] Ablation was performed by using an amplitude setting of 2.0 kV for each of the four PVs. Before energy delivery, a high-density map of the LA was constructed with the Rhythmia™ system and the Orion™ catheter (Boston Scientific), while the IntellaNAV Mifi™ OI catheter was used to assess the baseline LI values of the four PVs. As previously reported,[5] each vein was divided into four segments (anterior, roof, inferior, and posterior) and a manual tag was used to record the exact position where the IntellaNAV™ catheter measured the LI values for each segment of the vein (*Figure 1A*). About 20 min after PVI, entrance and exit blocks were assessed by means of the multipolar PFA catheter for each PV, and then the LA was remapped (a total of 6620 points acquired) with the Rhythmia™ system and Orion™ catheter, using the same anatomical map acquired before PFA ablation had started. The manual tags previously placed at the four segments of each vein were used to guide the exact positioning of the IntellaNAV Mifi™ catheter at the same spots where baseline LI had been recorded, in order to record how these values changed after PFA. The map confirmed the electrical disconnection of the PVs (*Figure 1B*). The LI values displayed a significant variation after PFA delivery ($124.3 \pm 5\ \Omega$ for baseline LI vs. $96.8 \pm 6\ \Omega$ after PFA, $P < 0.0001$; *Figure 2A*) with a mean absolute LI variation of $27.5 \pm 7\ \Omega$ and a mean percentage LI variation of $25.8 \pm 8\%$. The differences between the average LI values pre- and post-PFA were 28.0 ± 5, 26.5 ± 9, 26.8 ± 3, and $28.8 \pm 10\ \Omega$ for the superior, anterior, posterior, and inferior portions of the PV, respectively (*Figure 2B*). After a follow-up of 9 months, no AF recurrence was documented by post-ablation ECG or reported by the patient.

Discussion

In this preliminary experience with the new FARAWAVE™ system, we observed a larger variation in LI drop (i.e. mean value variation >25 Ω or LI percentage variation >20%) than that reported in our previous experience with cryothermic energy[5] and in large studies involving RF energy.[3,4] In addition, the circumferential PVI area resulting from PFA seemed to easily involve the antral portion of PVs (see Supplementary material online, *Figure S2*), possibly resulting in a larger area of LA-ablated tissue than after thermal energy, whether cryothermal or RF. When the right amount of current is delivered with the right field strength, the electrical impulses delivered during PFA create pores in the cell membrane that cannot be repaired, leading to cell death and fibrosis. The threshold above which irreversible damage is induced by PFA depends on several factors, such as the pulse design, cell size, cell shape, and orientation of the cells within the tissue.[6] Other tissue effects, such as PV stenosis or oesophageal fistula, were not observed within the therapeutic range for cardiac ablation. Pulsed-field ablation does not rely on heating of the tissue, while it does result in permanent myocardial lesions. During ablation guided by LI information, the magnitude and the time course of the LI drop during RF delivery have proved to be associated with effective lesion formation[3,4] and an LI drop >15 Ω can be used as a predictor of a likely effective lesion and durable PV block. Interestingly, we observed a more pronounced drop in LI after PFA (>70% greater compared with RF) than that reported after the use of different energy sources (mean LI drop at the

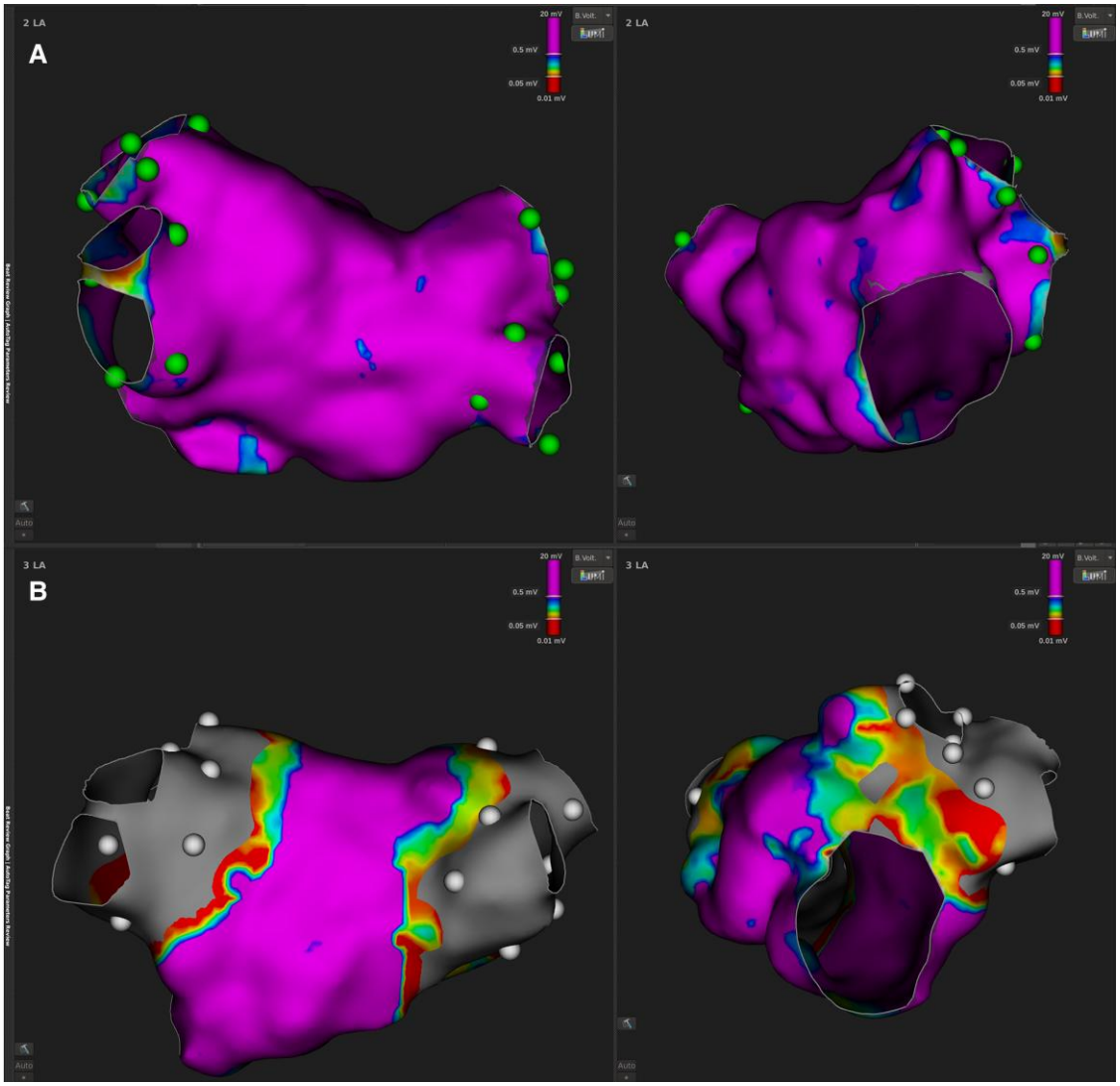

Figure 1 (*A*) Modified posteroanterior (left) and left anterior oblique (right) views of the left atrial voltage map before pulsed-field ablation was undertaken. The green tags indicate the exact vein segment positions where the IntellaNAV™ catheter measured the local impedance values. (*B*) Modified posteroanterior (left) and left anterior oblique (right) views of the left atrial voltage map after pulsed-field ablation. The grey colour of the veins shows their electrical disconnection. The same green tags previously used to measure the baseline local impedance values are now used (grey tags) to record how the local impedance changed after ablation. LAO, left anterior oblique; LI, local impedance; PA, posteroanterior; PFA, pulsed-field ablation.

successful ablation site obtained with an RF energy equal to $14 \pm 8\ \Omega$),[3] without experiencing any complications. With PFA, it is possible that the different energy delivery and other factors affecting lesion size (e.g. pulse trains and number of pulses per train, pulse width, voltage gradient, delivery time, configuration of the electrodes, and shape of the delivery catheter) resulted in a larger amount of targeted cardiac tissue and lesions of better quality, as measured through LI. As this was a case report, we were not able to adequately investigate other possible factors associated with LI variation, nor to make a direct comparison among different energy sources. Finally, neither the clinical effect nor the outcome in the medium–long term was evaluated. Further prospective studies are needed in order to investigate these aspects more deeply.

Conclusion

For the first time, acute characterization by means of LI drop has been assessed for PFA. A drop in LI recorded at ablation sites seems to be more pronounced than that recorded at successful ablation spots obtained by means of thermal energy sources, suggesting a better lesion formation.

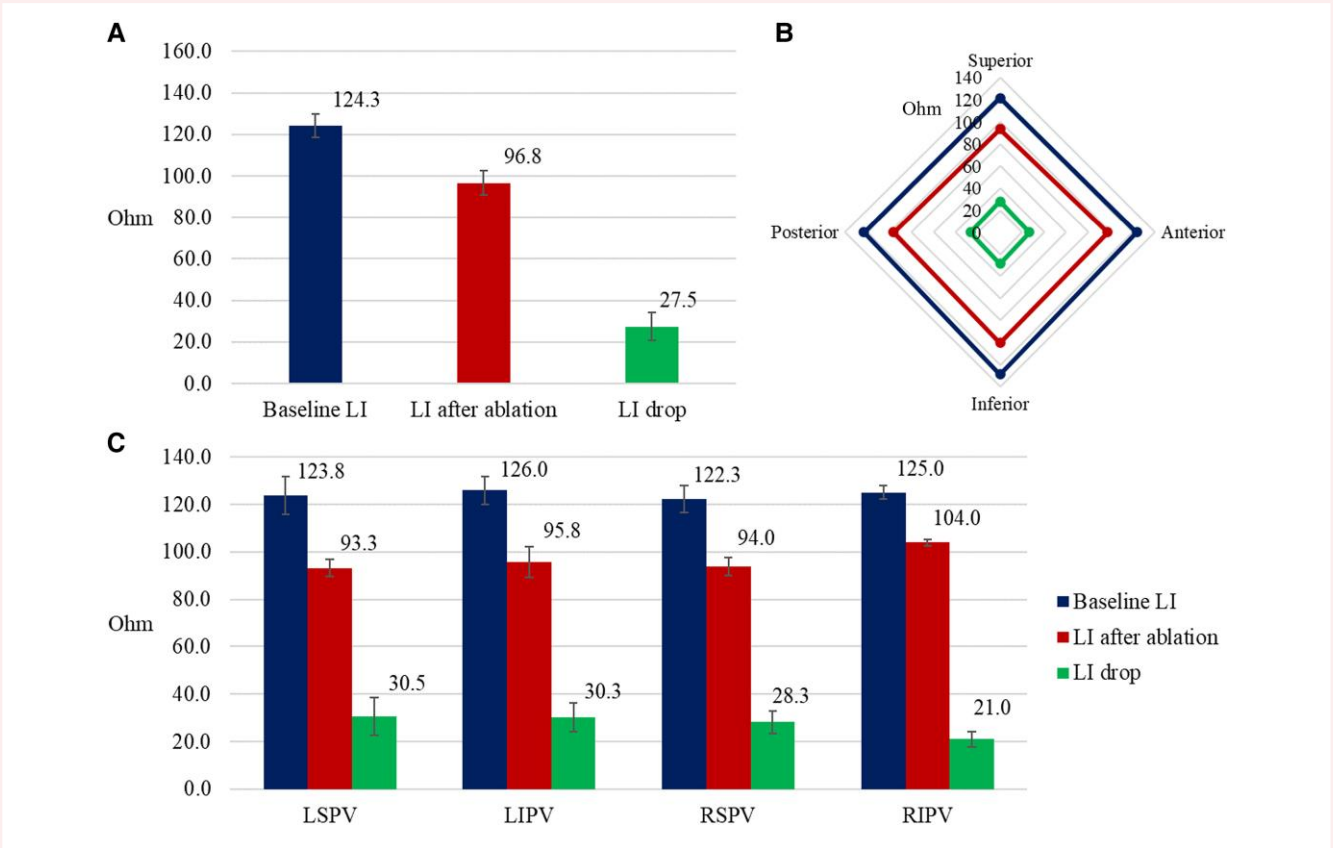

Figure 2 (*A*) Baseline local impedance, local impedance after ablation, and local impedance drop. (*B*) Radar plot shows the local impedance values according to location sites. The apexes of the chart represent different location sites (anterior, inferior, posterior, superior), whereas the lines represent different degrees of local impedance information (blue line for baseline local impedance values, red line for local impedance values after pulsed-field ablation, and green line for local impedance drop values). (*C*) Baseline local impedance, local impedance after ablation, and local impedance drop according to pulmonary veins. LI, local impedance; PFA, pulsed-field ablation; PV, pulmonary vein.

Lead author biography

Saverio Iacopino graduated from the University of 'Magna Graecia', Catanzaro, Italy. After completing his cardiology training and specialization in 2001, he is currently working as Director of the Department of Arrhythmia and Electrophysiology Maria Cecilia Hospital, Cotignola (RA), in the role of National Coordinator of Electrophysiology Unit, GVM Care & Research, Maria Cecilia Hospital.

Supplementary material

Supplementary material is available at *European Heart Journal – Case Reports*.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors acknowledge that written informed consent was obtained from the patient for the submission and publication of this case report, including images and associated text, in accordance with COPE guidelines.

Conflict of interest: M.M. is an employee of Boston Scientific. No other conflict of interest to report.

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Data availability

The data underlying this article are available in the article and in its online supplementary material.

References

1. Calkins H, Hindricks G, Cappato R, Kim YH, Saad EB, Aguinaga L, *et al.* HRS/EHRA/ECAS/APHRS/SOLAECE expert consensus statement on catheter and surgical ablation of atrial fibrillation. *Europace* 2017;**2018**:e1–e160.
2. Yu TH, Liu J, Zhou YX. Using electrical impedance detection to evaluate the viability of biomaterials subject to freezing or thermal injury. *Anal Bioanal Chem* 2004;**378**:1793–1800.
3. Solimene F, Giannotti Santoro M, De Simone A, Malacrida M, Stabile G, Pandozi C, *et al.* Pulmonary vein isolation in atrial fibrillation patients guided by a novel local impedance

algorithm: 1-year outcome from the CHARISMA study. *J Cardiovasc Electrophysiol* 2021; **32**:1540–1548.
4. Gunawardene M, Münkler P, Eickholt C, Akbulak RÖ, Jularic M, Klatt N, *et al.* A novel assessment of local impedance during catheter ablation: initial experience in humans comparing local and generator measurements. *Europace* 2019;**21**:i34–i42.
5. Iacopino S, Filannino P, Artale P, Placentino F, Pesce F, Petretta A. Antral lesion characterization of a new cryoballoon ablation system in terms of local impedance drop: the first reported case. *HeartRhythm Case Rep* 2020;**7**:182–185.
6. Boersma L. New energy sources and technologies for atrial fibrillation catheter ablation. *Europace* 2022;**24**:ii44–ii51.
7. Shtembari J, Shrestha DB, Pathak BD, Dhakal B, Upadhaya Regmi B, Patel NK, *et al.* Efficacy and safety of pulsed field ablation in atrial fibrillation: a systematic review. *J Clin Med* 2023; **12**:719.
8. Kueffer T, Baldinger SH, Servatius H, Madaffari A, Seiler J, Mühl A, *et al.* Validation of a multipolar pulsed-field ablation catheter for endpoint assessment in pulmonary vein isolation procedures. *Europace* 2022;**24**:1248–1255.