How to leverage local impedance to guide effective ablation strategy: A case series

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Introduction

Catheter-based radiofrequency (RF) ablation utilizes alternating electrical current to create a tissue lesion through the production of resistive heat and conductive heat, this latter spreading away from the point of contact. Several parameters affect lesion size: catheter tip temperature, power output, catheter diameter and orientation, the duration of ablation, and the degree of contact between the catheter and the tissue. Recently introduced catheters that can monitor the catheter–tissue contact force have been found to improve the efficiency of RF ablation in patients undergoing ablation for atrial fibrillation.[1–5] However, only little data are available on how to monitor lesion formation during RF delivery. Recently, a new technology, the DirectSense™ tool, has been proposed that assesses the real-time effectiveness of ablation[6] by means of a novel measurement of local impedance (LI) through mini-electrodes on the catheter tip of a dedicated ablation catheter (IntellaNav Mifi OI; Boston Scientific, Marlborough, MA). This system uses highly localized impedance measurements to provide insight into tissue characteristics, and may provide more useful information regarding catheter stability and lesion formation than the use of generator impedance alone.[7] Here, we describe how localized impedance information can be leveraged in order to guide the successful ablation of complex arrhythmias.

KEY TEACHING POINTS

- Evaluation of local impedance through dedicated technology is useful not only in assessing effective lesion formation but also in directing radiofrequency (RF) applications to proper sites.
- Local impedance could be more helpful than ablation signals in confirming the presence of the gap and in guiding the ablation strategy. Particularly, the highly sensitive detection of increased local impedance in the presence of gaps can be valuable in redo ablation procedures.
- A multiparametric approach can better define the structural, electrical, and contact properties of the ablation target, such as the combined use of localized electrical and impedance information, and it is mandatory in order to avoid unnecessary RF lesions.
- Ablation lesions in diseased tissue, unlike in healthy myocardium, are not always predicted by the amount of power and duration of the application.

Case report

Case 1: Spotting a gap in a case of redo pulmonary vein isolation

A 50-year-old man with a history of persistent atrial fibrillation underwent a redo procedure 2 years after his first ablation procedure. An activation map was acquired by means of the Orion™ catheter and the Rhythmia™ system (Boston Scientific) and revealed that all 4 veins had become reconnected. The propagation map (Supplemental Video 1) showed that a single gap in a wide antral circumferential ablation line reconnected both left veins. When the ablation catheter (IntellaNav Mifi OI) was positioned at the corresponding location, the fragmented signals due to gap conduction into the veins were barely visible on ablation traces and were completely different from the Orion signals previously recorded at the same location (Figure 1, left panel), suggesting either that the catheter tip was not exactly on the gap or that a large cancellation effect had occurred because of the wider field of view of the ablation electrodes than that of the Orion catheter one.[8] LI values at the same location showed an impedance value greater than 120 ohms (Figure 1, right panel), which was more compatible with the presence of

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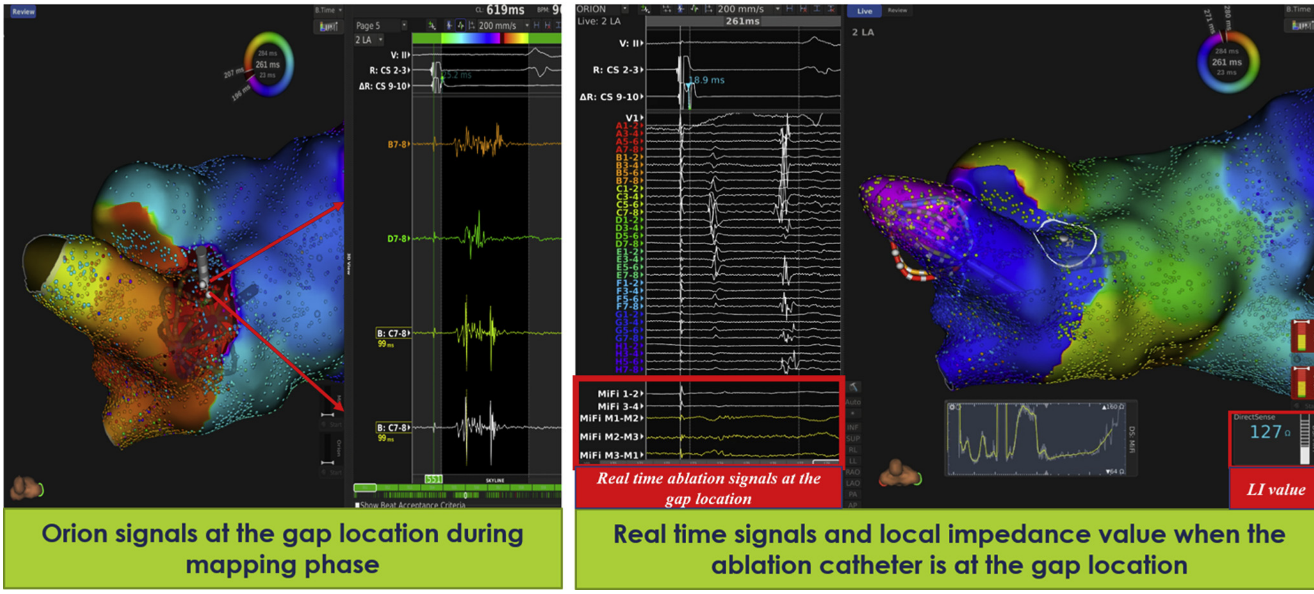

Figure 1 **Left:** The propagation map acquired with the Orion™ catheter (Boston Scientific, Marlborough, MA) revealed a single gap (dark red front) reconnecting both left veins. The electrograms detected by the Orion catheter at the gap location were highly fragmented and well represented. **Right:** The tip of the ablation catheter is at the gap location, as indicated by the white halo on the activation map. The real-time signal graph on the left shows both Orion signals (with far-field and pulmonary vein components) and ablation traces. Conventional ablation traces show no signals (white traces in the red rectangle) while mini-electrode tracings (yellow traces in the red rectangle) show very tiny and barely visible signals that are completely different from those previously detected by the Orion catheter at the same spot. The red rectangle on the right of the panel shows the real-time local impedance (LI) value when the catheter tip was at the location indicated by the white halo. This impedance value is more compatible with a conduction gap than with unexcitable tissue.

surviving myocardial fibers in a gap region than with nearly unexcitable tissue, as suggested by signals on the ablation traces (LI values were around 88 ohms in the blood and around 95 ohms at lines of block in this patient). We applied RF energy and the veins became isolated when the LI drop reached 20 ohms (Supplemental Video 2).

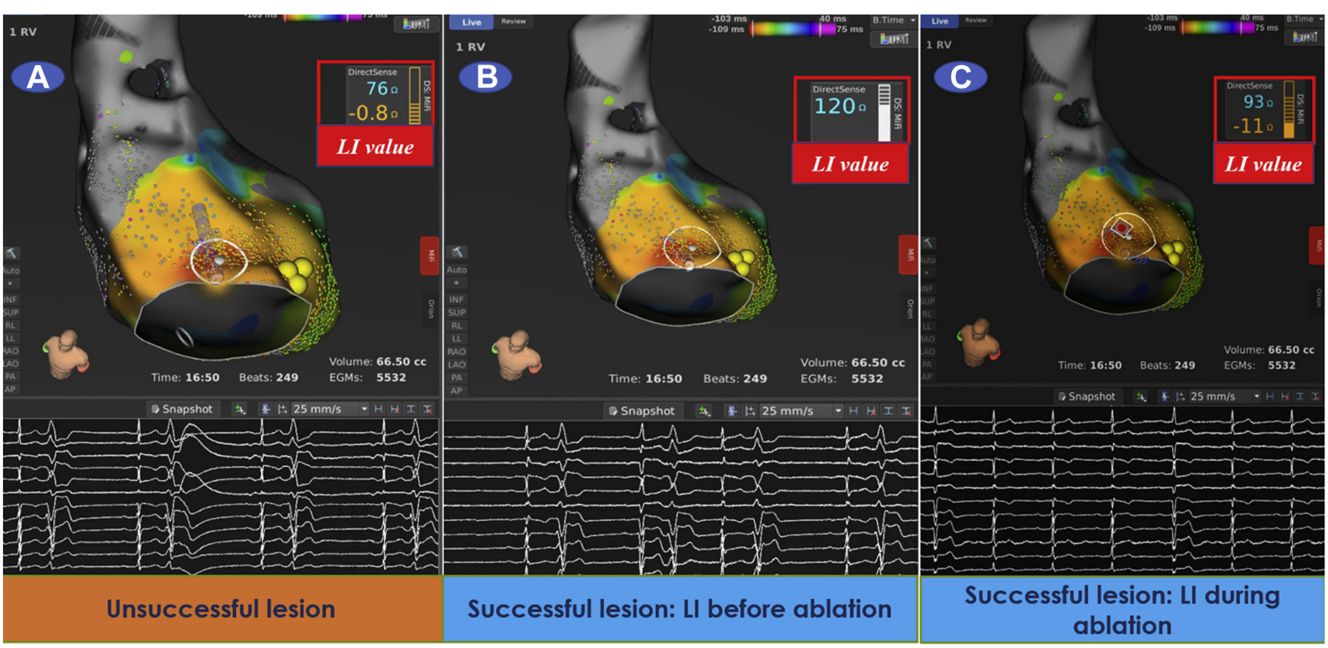

Figure 2 In each panel, the red spot on the activation map indicates the ablation target (earliest ventricular signal during premature ventricular contraction [PVC] mapping) while yellow tags indicate the position of the His bundle. **A:** A lower baseline local impedance (LI) value predicts a low impedance drop during unsuccessful ablation lesion. The orange value in the red rectangle (-0.8 ohm) represents the real-time LI drop calculated from start of ablation. **B:** On using a different approach ("reverse curve"), the ablation tip comes into contact with the ablation target, yielding a higher LI value, which is suggestive of better electrical coupling with the tissue and hence greater potential for resistive heating. With this approach, the baseline LI value is 120 ohms, as indicated in the red rectangle. **C:** Radiofrequency application with the reverse curve approach yielded a greater impedance drop (orange value, -11 ohms, in the red rectangle), causing PVC to disappear.

Case 2: Choosing the best ablation approach to tricuspid annular premature ventricular contractions

A 19-year-old man with premature ventricular contractions (PVC) was referred to our electrophysiology lab after a previous failed ablation procedure in another center. High-resolution mapping with the Orion catheter revealed that the PVC arose slightly anterior to the His bundle region. Figure 2A and 2B shows the Rhythmia activation map of this tricuspid annular PVC; the red spot indicates the ablation target (earliest ventricular signal during PVC) and yellow tags indicate the position of the His bundle. On approaching the parahisian region with the ablation catheter, we were never able to obtain a baseline LI value greater than 88 ohms, which was quite close to the blood LI value in this patient (around 80 ohms). Nevertheless, we decided to apply RF energy, since we were “visually” on the red spot of the map, and local signals were very early. We obtained a very low impedance drop, and the PVC did not disappear (Supplemental Video 3 and Figure 2A). Considering the young age of the patient and the high-risk location of the ablation target, we decided to create additional RF lesions only if the baseline LI value was greater than around 100 ohms, since these values were easily achieved with good contact in the adjacent right ventricle in this patient. Despite adopting a superior approach to the parahisian region or using a steerable sheath, we could not obtain a higher baseline LI value. Only by looping both the ablation catheter and the steerable sheath into the right ventricle apex and approaching the tricuspid valve by means of a “reverse” curve did we finally achieve a baseline LI value of around 115 ohms. RF applications at the same red spot as in the previous application immediately led to PVC disappearance (Figure 2C and Supplemental Video 4).

Case 3: High-power ablation in diseased left atrial tissue

A 60-year-old woman with rheumatic mitral valve disease was referred to our lab for RF ablation of atypical atrial flutter of 2 different morphologies. High-resolution mapping revealed that the 2 arrhythmias were clockwise and counterclockwise perimitral flutters with a critical isthmus at a very diseased anterior wall. Since it was difficult to achieve good LI drops by applying standard power, high-power (50 watt) RF lesions were created along the anterior line connecting the right superior vein to the anterior mitral annulus. Once the counterclockwise arrhythmia had been interrupted, the clockwise form was spontaneously induced when 1 application remained to complete the ablation line. Although the baseline LI was low at the remaining gap, signals on the mini-electrodes confirmed contact with a diseased tissue rather than with blood[6]; we therefore continued to apply 50 W. Although flutter interruption (Figure 3, left panel, and Supplemental Video 5) suggested a good lesion, a very low LI drop (only 2 ohms) did not. A validation map of the anterior line during pacing from the left appendage revealed a gap exactly where the previous ablation had failed to achieve a good LI drop (Figure 3, right panel). We decided to close the gap at an adjacent location, where an LI drop of at least 15 ohms could be achieved.

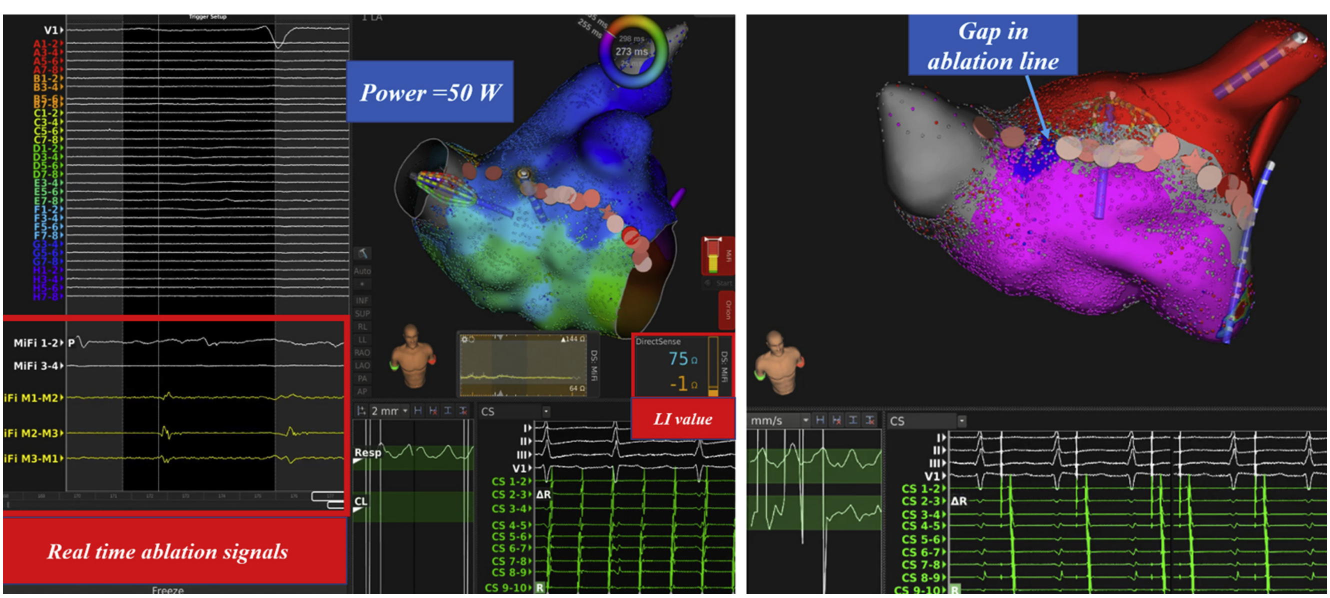

Figure 3 **Left:** The last remaining gap in the anterior ablation line is closed, while the clockwise form of the perimitral flutter is spontaneously induced. The presence of atrial signals detected by mini-electrodes (yellow traces in the red rectangle on the left) in combination with a low local impedance value (75 ohms in the red rectangle on the right) indicates that the catheter tip is in contact with diseased tissue. Despite applying 50 W, a very low impedance drop is achieved (orange value, -1 ohm, in the red rectangle on the right). **Right:** The validation map, acquired with the Orion™ catheter (Boston Scientific, Marlborough, MA) while pacing with the ablation catheter from the left atrial appendage, indicates a conduction gap at the exact location where previous high-power application had achieved a low impedance drop.

Discussion

With regard to emerging technologies, several knowledge gaps have been identified, including how to determine the best approach to safely achieving successful ablation in complex procedures, and a large amount of research is being focused on developing new tools that allow the creation of permanent transmural lesions.[9] LI is a direct measure of the resistive load on the ablation catheter and is a surrogate for the surface area of myocardium covered by the distal electrode[10]; its real-time evaluation is helpful in order to precisely assess the electrical contact of the catheter and tip stability. It also helps to distinguish catheter–tissue contact from noncontact[10] and might be an adjunct to fluoroscopy, local electrograms, and 3D maps in assessing tissue contact in low-voltage areas.[7] The cases presented are examples of how DirectSense capabilities are useful not only in assessing effective lesion formation but also in directing RF applications to proper sites. The first case showed that information derived from LI was more helpful than ablation signals in confirming the presence of the gap and in guiding the ablation strategy. Fractionated electrograms at gap locations may be completely filtered out by conventional ablation catheters (20% of gaps could be missed by a 3.5-mm-tip ablation catheter)[11] and, although signal resolution is improved by adding mini-electrodes at the tip, the best mini-electrode mapping resolution can still filter out some elements that would be detected by ultra-high-resolution catheters.[12] For this reason, the highly sensitive detection of increased LI in the presence of gaps can be valuable in redo ablation procedures. In the second case described, LI information was important in achieving complete and durable success, as the high LI values at the resulting ablation spots indicated a close catheter–tissue interface, a large resistive load, and therefore the ability to create significant resistive heating. This example demonstrates that multiparametric approaches that can better define the structural, electrical, and contact properties of the ablation target, such as the combined use of localized electrical and impedance information, are mandatory in order to avoid unnecessary RF lesions. Our last case perfectly highlights a puzzling conundrum that has recently emerged in the literature: ablation lesions in diseased tissue, unlike in healthy myocardium, are not always predicted by the amount of power and duration of the application.[13,14] In this case, LI revealed that no lesion was being created in the diseased tissue during the high-power application, thus prompting us to choose another ablation strategy. As contact-force sensing technology with impedance sensing was not available, we could not speculate the role of contact force in obtaining safe and effective lesions beyond the role of LI in our cases series.

Conclusion

LI is a helpful new parameter that can monitor RF lesions and guide ablation strategies in complex procedures.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2020.11.004.

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