Local impedance to guide focal radiofrequency ablation: there is life in the old dog yet

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Abstract

Despite being first described over 30 years ago, focal radiofrequency (RF) continues to be the most widely used energy modality for catheter ablation. The fact that it has managed to hold its own against stiff competition from alternative energy sources used for pulmonary vein isolation (PVI) is down to continuous evolution based on enhancements in our understanding of its biophysical principles. In particular, the advent of contact-force (CF) based integrated indices such as Ablation Index have improved both efficacy and safety. However, a significant limitation of this approach is the absence of tissue feedback during lesion creation, which results in a blunt 'one-size-fits-all' approach. This limitation has been further brought into focus by the recent appreciation of the much greater importance of circuit impedance rather than delivered power as a fundamental determinant of RF lesion size.

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Despite being first described over 30 years ago, focal radiofrequency (RF) continues to be the most widely used energy modality for catheter ablation. The fact that it has managed to hold its own against stiff competition from alternative energy sources used for pulmonary vein isolation (PVI) is down to continuous evolution based on enhancements in our understanding of its biophysical principles. In particular, the advent

of contact-force (CF) based integrated indices such as Ablation Index has improved both efficacy and safety[1]. However, a significant limitation of this approach is the absence of tissue feedback during lesion creation, which results in a blunt 'one-size-fits-all' approach. This limitation has been further brought into focus by the recent appreciation of the much greater importance of circuit impedance rather than delivered power as a fundamental determinant of RF lesion size[2].

Historically, electrophysiologists have monitored the change in generator impedance (GI) in real time as a surrogate of RF lesion quality. However, GI is confounded by individual patient factors within the ablation circuit including subcutaneous tissue and hydration status[2,3]. The large contribution of these variables dwarfs the relatively low magnitude of GI change from ablation itself, thereby limiting its clinical usefulness. Catheter local impedance (LI) is a novel tool that attempts to minimize the influence of these confounding variables in the impedance circuit, potentially offering a more accurate representation of changes occurring close to the catheter-myocardial interface. A local potential field is generated by driving a non-stimulatory current between a distal and a more proximal catheter electrode; proximity to physical structures such as myocardium causes distortions in this local field which can be measured with one or more intermediate electrodes, allowing derivation of a LI value[4]. Bench work has shown that during RF application, LI drop dynamically follows the rate of intramural temperature rise (Figure 1)[5]. The resulting tissue feedback can potentially allow operators to individualize each RF application, and several groups have already reported on their clinical experience (Table 1) with a LI-sensing catheter.

In this issue of the Journal, Francesco and colleagues present the findings from the multicentre Italian CHARISMA registry, a study of 153 consecutive patients undergoing RF catheter ablation for AF using the MiFi™ OI catheter (Boston Scientific)[6]. Ablation lesions were delivered at 30-35 W, targeting a LI drop of at least 10 Ω over 30 seconds, up to a maximum of 40 Ω, and an inter-lesion distance (ILD) of 6 mm or less. After first-pass pulmonary vein encirclement, lesion success was defined by a failure of pacing capture at the lesion site. Offline assessment of LI and GI in 3556 first-pass ablation lesions showed that successful lesions were associated with higher LI and GI drops than unsuccessful ones, and ROC curve analysis found LI to be a far better discriminator than GI. Every 5-point drop in LI had an OR of 3.1 (CI 2.7-3.6) for lesion success, plateauing at 15 Ω. No steam pops or ablation-related adverse outcomes were observed. In their conclusions, the authors suggest a 15 Ω drop as an indicator of probable lesion effectiveness, with an upper safety limit of 30 Ω in order to avoid steam pops.

The authors should be congratulated for their study, which is the largest reported to date using LI, and the first one to use a LI-targeted approach for AF ablation. Although the study population was heterogeneous, combining both first time and redo cases as well as both paroxysmal and persistent AF, the low rate of arrhythmia recurrence on follow up is encouraging, and suggests potential for real world use for this novel technology.

It is notable that the results of the present study are consistent with suggested LI targets from the recently published multicentre LOCALIZE study, where the same catheter was used for first-time PVI in paroxysmal AF patients whilst blinded to LI[7]. Gaps in the ablated segments were assessed after a protocol-mandated 20-minute wait following first pass PV encirclement; a LI drop of 16.1 Ω in the anterior/roof segments had a positive predictive value (PPV) of 96.3% for absence of gap, while for posterior/inferior segments a LI drop of 12.3 Ω had a PPV of 98.1%. The largest LI drop associated with a conduction gap when targeting an ILD of 6 mm or less was 20.1Ω. The threshold value of approximately 15-20 Ω as being predictive of lack of gap was also observed by other groups, and so it appears that the technology is reproducible and predictive across a range of power and CF values.

In addition to being a marker of lesion quality, LI may also serve as an indicator of underlying substrate. LI is known to be independent of catheter orientation[4] and activation wavefront direction[8], and yet has been shown in the present study[6] and others[8,9] to be positively correlated with electrogram amplitude. Lower baseline LI values, as well as significantly lower response to RF ablation are seen in scarred as opposed to healthy tissue[10,11]. It is notable that Solimene and colleagues also observed a lower baseline mean LI in patients with persistent AF as compared to paroxysmal AF, although there was no difference in mean LI values between de novo and redo cases.

Successful evolution necessitates improvement beyond that which is currently available. Particularly with a very well-established procedure such as PVI, and with competition from single-shot and established RF energy delivery techniques, procedural efficiencies such as first pass PVI are very important. In this context, it would have been useful for the current study to include such data, so that the effectiveness of this technology could be put into context with that of other contemporary techniques. For instance, a recent large multicentre study systematically employing the CLOSE protocol reported a first-pass PVI rate of 82.4%[1]. Whether a LI-based approach can match such results, and preferably do so with more tailored but less overall RF energy delivery remains to be determined.

In conclusion, Solimene and colleagues provide real world clinical evidence in a sizeable multicentre real-life cohort of AF patients that supports the use of local impedance in guiding RF ablation for PVI. However as is often the case for such a rapidly evolving field, obsolescence for the OI MiFi catheter may already be on the horizon in the form of the recently released Stablepoint™(Boston Scientific) catheter that has the ability to simultaneously measure both CF and LI[12]. It remains to be seen how our recently acquired knowledge of LI will translate to this new platform, and whether LI data provide incremental benefit beyond what can be achieved already with standard composite metrics. Either way, it appears that humble focal RF energy may still have a lot to offer electrophysiologists, and its obituaries may be premature.

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Figure 1. Local impedance in action

A) Electric fish use sensors on their sides to feel the expansion and compression of the field lines created between their head and tail. In open ocean the field lines spread uniformly, but when an object enters the field the field compresses. If that object's resistivity decreases due to heat, the field expands proportional to volume heating. B) A local electrical field (˜) is created by driving non-stimulatory current from the tip of the catheter to the proximal ring electrode, while voltage (V) is measured from the tip to distal ring electrode. This allows the catheter to sense changes in volumetric dielectric properties surrounding the tip electrode. C) In this bench study, temperature profiles at varying depths were correlated with the local impedance measured during RF lesion creation. Thermocouples were placed into the tissue at the surface, at 2 mm depth, and at 4 mm depth. The local impedance drop was seen to dynamically follow the rate of intramural temperature rise at both low and high powers.

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