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High-power short-duration ablation: The new standard for pulmonary vein isolation?

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Electrical isolation of the pulmonary veins (PV) by antral creation of transmural, continuous, and durable lesions by localized cellular damage is the cornerstone of catheter based atrial fibrillation (AF) ablation procedures. Conventional radiofrequency (RF) ablation with irrigated catheters involves delivery of relatively low power (20–40 W) for a relatively long duration (20–40 s) (low-power long-duration (LP-LD)) at a contact force range of 10–20 g. Despite progress of PV isolation (PVI) ablation techniques, AF recurrence, partially due to incomplete transmurality and/or reversible injury, remains high with 20–40% [1].

RF ablation lesion formation can be split into two consecutive phases. During the resistive phase, electrical current delivery via the catheter tip heats the tissue surface. A heat source extends then passively to deeper tissue layers during the conductive phase. Irreversible myocardial tissue injury with apoptosis and necrosis occurs at temperatures above 50 °C, whereas lower tissue temperatures often result in reversible tissue injury. Modifying the relationship between the resistive and conductive heating phases may help to achieve safer and more effective uniform and transmural lesions during PVI. For example, immediate heating to the full thickness of the human PV circumference can be delivered by increasing the resistive heating phase (higher power), and the collateral tissue damage can be limited by reducing the conductive heating phase by shortening the duration (shorter duration). These biophysical concepts resulted in a high-power and short-duration (HP-SD) ablation approach, that has been investigated in several preclinical studies [2,3]. HP-SD results in less deep, but wider and more contentious linear lesions [2,3]. Additionally, the ablation procedure is much shorter as RF ablation lesions can be created four-times faster when using 50 W vs 30 W [4]. The steam pop risks increase with power and time but delivering higher energy for a shorter time at one spot overcomes the challenges of catheter stability and tissue oedema, which makes the zone of reversible injury smaller and allows lesion formation within a shorter time [2].

Several prospective randomized and non-randomized studies comparing LP-LD versus HP-SD show that HP-SD is associated with higher first-pass PV isolation and significantly shorter procedural, ablation and fluoroscopy times compared with LP-LD [5–10]. Meta-analysis data demonstrate that HP-SD was associated with better procedural effectiveness when compared with conventional LP-LD ablation with comparable low rate of complications and esophageal thermal injury and shorter procedural duration [11,12]. Very HP-SD using 70 W for 5–7 s leads to significantly less arrhythmia recurrences after 1 year [6]. Tilz et al. used 90 W for 4 s and showed with this novel very HP-SD ablation mode a safe and effective PVI. Procedure duration and RF ablation time were substantially shorter in comparison to the control group [5].

Despite promising observations with HP-SD and very HP-SD ablations approaches, guiding energy delivery, in regard to power and duration, remains the limiting factor for both safety (too much

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ablation) and efficacy (inappropriate limitation of ablation). It is not clear which surrogate endpoints are best for HP-SD and direct comparisons are difficult. Some traditionally used surrogate endpoints for LP-LD RF delivery include loss of bipolar electrogram (EGM) voltage, change in unipolar EGM, impedance drop, loss of capture or algorithms incorporating contact force, time and power. However, these surrogate endpoints have been validated for LP-LD and it remains unclear, whether they are also suitable for HP-SD. For example, it is not clear that contact force has the same impact on lesion prediction with HP-SD ablation compared to low-power long-duration ablation. Contact is important, but the amount of force from 5 to 30 g may not be since the duration is too short. The same accounts for the prevention of collateral damage of structures around the left atrium such as the esophagus and the phrenic nerve. The temporal resolution of commercially available temperature probes for luminal esophageal temperature monitoring may not adequately capture the early and quick temperature rise to limit and guide RF delivery during HP-SD. A skilled operator may place the 3rd HP-SD lesion before the luminal esophageal temperature increase from the 1st lesion is fully recognized [4].

Better and accurate "real-time" monitoring of atrial lesion formation or validated surrogate endpoints during the procedure predicting quality of the mature lesion are required guiding HP-SD ablation procedures. Potentially, adding temperature rise and micro-EGM changes may provide important information. The DiamondTemp RF ablation catheter (Medtronic) was designed with a diamond-embedded tip (for rapid cooling) and 6 surface thermocouples to reflect tissue temperature [12]. The high-resolution EGMs from the split-tip electrode allows rapid lesion assessment. The QDot Micro RF (Biosense Webster) ablation catheter incorporates three microelectrodes and six thermocouples allowing real-time assessment of catheter-to-tissue interface temperature and therefore temperature-controlled ablation. Another strategy might be a tailored and dynamic power and duration setting guided by the underlying anatomical structure, wall thickness and proximity to surrounding anatomical structures derived by pre- or periprocedural imaging integrated in the 3D electroanatomical platform. Such tailored anatomy-guided approach, which is already used to guide radiation therapy in the cancer treatment (image-guided radiation therapy), may help to improve the precision and accuracy of energy delivery during interventional cardiac MRI procedures [13].

In summary, emerging data show the feasibility, safety, and efficacy of HP-SD modes for PVI. At the same time, this comes with a spin-off benefit including shorter procedure times, less fluoroscopy and shorter overall RF ablation time. However, the best setting for HP-SD to minimize the risk of major complications while maintaining maximal procedural efficacy remains controversial. Whether approaches such as HP-SD (50 W) or very HP-SD (70 W or 90 W) can increase the success rates of PVI procedures warrants further prospective randomized study. Finally, in addition to focusing on new more effective and safer ablation strategies alone, also the systematic implementation of combined risk factor modification programs is important to finally control sinus rhythm and reduce the recurrence of AF after PVI procedures [14,15].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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