Very High Power Short Duration Ablation: It Takes Two to Make a Thing Go Right?

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High power short duration (HPSD) radiofrequency (RF) ablation, utilizing 45-50W for durations of 5-15 seconds per lesion, is increasingly accepted as a safe and effective technique to efficiently achieve pulmonary vein isolation to prevent atrial fibrillation (AF).[1] The next contender in the progression of hotter and faster RF technology is very high power short duration (vHPSD) RF ablation – 90W power for a duration of 4 seconds per lesion – using the QDOT-Micro ablation catheter (Biosense Webster, CA, USA). The catheter is designed to mitigate risks of vHPSD RF ablation by monitoring temperature at the catheter-tissue interface using six thermocouples embedded in the electrode's tip which allows for power modulation to maintain a target temperature during RF delivery.[2] Relative to HPSD ablation utilizing 45-50W, vHPSD ablation with 90W may further maximize shallow, resistive heating, while the shorter duration may additionally minimize deep, conductive heating.[2-4] The frequency and risk factors for the feared complications related to ablation, like steam pop, cardiac perforation, or esophageal injury, are not well understood for vHPSD.[5] Early clinical studies of vHPSD ablation reported first pass PVI in approximately 50% of cases, while first pass PVI was achieved in greater frequency with both conventional and HPSD RF ablation using recently described approaches such as the "CLOSE Protocol".[5-7] First pass isolation has been shown to be a powerful predictor of procedural efficacy,[3,8,9]thus a greater understanding of the underlying biophysics of lesions created with vHPSD RF ablation may inform optimization of timing and spacing to further improve outcomes for this new technology.

In this issue of the Journal, Yamaguchi and colleagues[10] undertook a detailed analysis of 480 RF ablation lesions created with the QDOT-Micro ablation catheter at 90W over 4 seconds in an *in-vitro* porcine myocardial model. They attempted to better elucidate the biophysics of single and multiple point-by-point RF ablation applications to inform creation of lesion sets using a vHPSD approach. Single application (SA) vHPSD ablation was compared to double repetitive application (DRA), in which a second vHPSD RF application was performed as soon as the mandatory four seconds RF lockout expired, and double non-repetitive RF application (DNRA), in which a second RF application was performed approximately one minute after initial ablation. Additional variables for lesion creation that were systematically evaluated include contact force (CF), temperature limit, and catheter orientation.[10]

The primary analysis evaluated lesion size (depth, volume) and surface areas as well as rates of steam pop. DRA resulted in the deepest and largest lesions followed by DNRA then SA (depth: 3.8 mm vs 3.3 mm vs 2.6 mm; volume: 177 mm^3 vs 145 mm^3 vs 97 mm^3, respectively). Similar trends were found regardless of catheter orientation (perpendicular versus parallel), with a perpendicular catheter orientation associated with slightly deeper lesions, but similar surface areas. Lesions created with target temperature of 60°C, compared to 55°C, were slightly larger, without increased risk of steam pop. Steam pop occurred significantly more frequently in the DRA arm (16%), compared to 7% and 4% in DNRA (7%) and SA (4%), respectively. In the double application group (DRA and DNRA arms combined), the authors found that lesions made with the DRA approach and, counterintuitively, CF$<$ 15g were found to be significant predictors of steam pop by both univariate and multivariate analyses.[10] Traditionally, higher contact forces have been associated with increased risk of steam pop with conventional and HPSD RF ablations.[11] Presumably, lower contact force during vHPSD ablation results in less robust ascertainment of tissue temperature and thus a lower ability to reduce power in response to significant tissue heating. Further investigation is required to better understand this unique relationship between vHPSD RF ablation and contact force.

The findings in the present study add to the growing body of evidence supporting the conclusion that inter-lesion spacing and timing significantly influence transmural lesion creation during point-by-point RF ablation. A prior study by Jankelson and colleagues using conventional power and duration RF ablation demonstrated that consecutively placed lesions resulted in a higher likelihood of transmural lesion creation compared to time-spaced lesions.[12] The present study by Yamaguchi and colleagues confirms the presence of a similar phenomenon with vHPSD ablation, likely related to a heat stacking effect which facilitates increased conductive heating of deeper tissue. This occurs despite vHPSD's inherent property of a time-limited ablation and a four second lockout period between lesions, both of which are meant to minimize deep heating.

While utilization of DRA to create deeper lesions may address the suboptimal first-pass isolation rate observed with vHPSD ablation, the risk of injury to collateral structures, such as the esophagus, requires further evaluation. *In-vivo* and *in-vitro* studies have shown significant, additive esophageal heating occurs with consecutive, adjacent, short duration, 50W RF applications compared to time-spaced lesions.[13,14] Given that esophageal temperature has been found to remain elevated for approximately 60 seconds after a single HPSD RF application,[14] the four seconds lockout period between vHPSD lesions in the DRA arm is unlikely to fully mitigate esophageal heat stacking. Furthermore, the *in-vitro*model utilized in the present study is not designed to evaluate the risk of injury to collateral structures during catheter ablation.

As RF ablation powers escalate and the potential to utilize repetitive RF applications to create deeper lesions in thicker tissue is better appreciated, an important question remains: what is the optimal delay between adjacent lesions? A one minute long delay, as utilized in the present study for the DNRA strategy, may be reasonable for ablating tissue overlying the esophagus, while DRA may be better suited in areas of thicker walls where there is minimal risk of collateral injury to surrounding structures. Currently espoused ablation strategies, such as the "CLOSE Protocol" specify inter-lesion spacing, but not inter-lesion timing.[5-7] Similarly, current electro-anatomic mapping systems are well suited for the ascertainment of numerous parameters for a single RF application and inter-lesion spacing, but do not easily allow consideration of inter-lesion timing for either clinical or investigational purposes. Better tools are needed to understand and optimize spacing and timing of lesions for the creation of complex ablation lesion sets.

Yamaguchi and colleagues should be commended for their innovative study design and execution of this *in-vitro* evaluation of vHPSD strategies. They highlighted the critical importance of optimizing inter-lesion timing while also elucidating a counterintuitive relationship between lower contact forces and increased risk of steam pop with vHPSD ablation. While single vHPSD RF applications appear to consistently produce safe and shallow ablation lesions, successful AF ablation requires numerous RF applications at anatomic locations with varied tissue thickness and risk of collateral injury. The present study highlights that understanding the biophysics of lesion creation of a single vHPSD lesion is a start, but it, in fact, takes two (or more) to make a thing go right.

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