EXPERT COMMENTARY

Catheter Contact Force: A Review of Emerging Techniques and Technologies in AF Ablation

After the first reports of successful clinical application in 1987, radiofrequency catheter ablation (RFCA) rapidly became the preferred energy modality for percutaneous treatment of a wide range of arrhythmias. As a logical consequence, RFCA has been used in the treatment of atrial fibrillation (AF) for more than two decades. Over that timeframe, significant changes have been applied to procedural technique as well as to technical aspects of RFCA in the setting of AF treatment. These changes have been driven by safety concerns such as pulmonary vein (PV) stenosis and systemic embolization, but also in no small part due to the observation that long-term freedom from AF recurrence remains an elusive goal in many patients.

Pulmonary vein isolation (PVI) is the contemporary standard of care for catheter-based treatment of AF (1). From the early implementation of this approach, a near universal correlation between AF recurrence and PV reconnection has been reported (2). However, using invasive reassessment of all patients after ablation - even if AF recurrence has not (yet) occurred - 2 out of 3 patients are reported to have PV reconnection of at least one vein (3). Finally, studies reporting on long-term follow-up after several PVI procedures for both paroxysmal and persistent AF report similarly high proportions of patients ultimately exhibiting lasting PVI despite recurrent AF – suggesting non-PV triggers in these patients (4,5). Consequently, a fundamental issue regarding catheter based treatment of AF remains unresolved: while a substantial amount of patients with clinical recurrence of AF may have received appropriate yet incomplete treatment (incomplete long term PVI), at least a portion of patients seem to experience recurrence despite lasting PVI – patients that might be considered either PVI non-responders or patients with progressive disease.

Current basic insight in the mechanisms of AF is insufficient to predict which patient will respond to PVI even if such therapy could be guaranteed to be efficient. However, observations from surgical approaches to PVI (whether intentional such as in cut and sew AF surgery or incidental such as after heart or lung transplant) seem to indicate that lasting PVI is a realistic goal with excellent outcomes (1). Therefore, considerable effort has been invested in improving RFCA approaches for PVI.

The review by Sohns and coworkers focuses on technological advances in catheter design, and in particular on the implementation of real-time contact force (CF) sensing to improve lesion formation (6). Tip-tissue contact is a crucial determinant of lesion formation, the biophysics of which is well understood in bench models. As clearly described in the text, in vivo assessment of contact in all its aspects (magnitude, direction, variation) has relied on indirect criteria such as fluoroscopy assessment, impedance drop and temperature rise - until the recent introduction of CF sensing catheters.

The benefits of CF sensing are clearly stated in the paper and can be broadly be summarized into two categories: safety improvement (by reducing the number of RF applications needed and avoiding excessive force) and efficacy enhancement (by avoiding suboptimal lesion formation due to inadequate contact). For the purpose of illustrating the benefits of CF sensing, it may be worthwhile to conceptually regroup those benefits into the single concept of measurement before ablation (“learning before burning”).

Even if one – for the sake of argument – were to consider indirect parameters such as impedance drop or temperature rise as equivalent assessment of contact, those parameters by their very nature can only be assessed during or after ablation. CF sensing therefore offers invaluable information needed to make every single lesion as appropriate as possible with a single application. There is increasing evidence that inappropriate lesions – besides obvious safety implications – lead to edema formation that will inhibit further permanent transmural lesion formation, regardless of further attempts at energy delivery (6). Therefore, CF sensing is information that can neither be disregarded nor discarded, not even after a learning phase where an operator might feel an appropriate level of expertise has been reached.
Limitations of current technology are equally well described and mainly involve other aspects of lesion formation, several of which are still not directly measurable. In particular, important regional variations in anatomy exist, making a uniform CF threshold for transmural lesion formation – even if a validated one were to exist today – mostly meaningless. However, imaging modalities such as contrast-enhanced MRI are able to identify atrial tissue characteristics and the effect of RFCA on those tissues. The group to which the authors belong has been consistently pushing the envelope of what is technologically feasible in this field, and the current paper reports on state-of-the-art insights in the field.

In addition, CF sensing is limited by the nature of catheter manipulation in a moving, beating heart, leading to potentially intermittent contact and – even worse – to significant catheter motion during application. While technology such as ablation tracking (e.g. the VisiTag module in the CARTO system) alleviates this limitation, it is still perfectly feasible for an operator to inadvertently move a catheter during ablation within a single respiration cycle, which will not be registered as catheter instability by the system. Total ablation integrated values for single lesions such as force-time integral or force-time-power integral will therefore remain an estimation of local lesion formation until catheter stability can be conclusively demonstrated. Average CF values for complete ablation lesion sets such as reported in the TOCCATA and EFFICAS studies suffer from the same problem, compounded by the numerous lesions contributing to the single reported average value.

The moving nature of the human heart is in fact a benefit from a safety point of view – if one considers the tip-tissue interface as a static reference frame, the extracardiac tissue becomes a moving target due to movement of the whole heart within the pericardial sac. Ablation effects on surrounding tissue are therefore less concentrated than on local myocardium. In delicate regions such as the posterior wall however, this motion is much less pronounced due to anchoring by the pulmonary veins.

Concluding remarks by the authors on evolving developments such as MRI and near-field ultrasound, both of which may offer direct visualization of tissue thickness and ablation effect, are therefore of particular interest in further advancement towards the goal of highly efficient and safe AF treatment.

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References