ATRIAL FIBRILLATION

INNOVATIVE TECHNIQUES

Techniques to Optimize Catheter Contact Force during Ablation of Atrial Fibrillation

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Introduction

Radiofrequency ablation (RFA) has revolutionized arrhythmia management over the last three and a half decades and is the foundation of a paradigm shift in the treatment of atrial fibrillation (AF). As the bedrock of an evolving strategy, electrical isolation of the pulmonary veins (PVI) from the left atrium (LA) forms the basis of AF catheter ablation in the modern era; however, ensuring adequate ablation and ensuing full-thickness scar formation to result in long-lasting isolation represents the main challenge and limitation in this treatment approach. Transmural lesions are required for effective, durable electrical isolation, and minimizing the likelihood of excitable tissue recovery. The difficulty is gauging whether sufficient RFA energy has been delivered to local tissue: subendocardial lesions are prone to electrical reconnection (if isolation is initially achieved at all), while excessive energy can cause overheating, local injury, perforation, fistulae, steam pops, and char. The amount of energy delivered (and consequently the degree of tissue heating) is dependent on several variables, including ablation catheter tip size, contact vector at the catheter tip–tissue interface, duration and force of RFA application, wattage and presence of an irrigation mechanism, catheter stability, and contact force (CF). Steerable sheaths, high-frequency jet ventilation and high rate pacing have improved our ability to stabilize the ablation catheter; contact force-sensing (CFS) catheters have transformed our ability to target this parameter of lesion formation and thereby deliver more effective ablation lesions.

Contact force-sensing catheters

Use of CFS catheters in AF has been studied widely and two CFS catheters have received approval by the Food and Drug Administration for use in AF ablation. The first catheter approved was Biosense Webster’s (Diamond Bar, CA) Thermocool SmartTouch irrigated tip ablation catheter (February, 2014) followed by St. Jude Medical’s (St Paul, MN) TactiCath Quartz (Endosense) CFS ablation catheter (October, 2014). These catheters are now used in laboratories around the world, and their use is expected to grow. Accordingly, data from some studies have suggested that CFS-guided AF ablation procedures can be completed nearly 20% faster, with more than one-third less fluoroscopy, fewer RFA applications, and with higher success rates than standard ablation catheters (SACs).

In a study of 143 patients by Wutzler and colleagues, procedure time was reduced from 158 to 128 min in those patients treated with CFS catheters (n = 31), while findings from a smaller series from Wakili and colleagues showed a significant decrease in LA procedure time from 96 to 78 min with a reduction in fluoroscopy from 51 to 33 min. Regarding 1-year reconnection rates, data have demonstrated a reduction by more than half from 36.6% to 16.1% with up to 80% freedom from AF recurrence in the TOCCATA study, when average contact force > 20 g was achieved (Table 1).

Equally important, CFS-guided ablation has been found to be safe. Recent data from human heart specimens.
Table 1: Selected studies on contact force and catheter stabilization

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<th>First author</th>
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<td>300</td>
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<td>Freedom from AF at 1 year: 59.4% SAC (p = 0.78) and Recurrence of AF at 1 year: 16.1% CFS vs SAC (p = 0.031)</td>
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Management of antiarrhythmic drug (AAD) therapy varied across studies.3DIM: three-dimensional image integration; CF: contact force; CFS: contact force-sensing; FTI: force-time integral; HFJV: high-frequency jet ventilation; LA: left atrium; NSS: non-steerable sheath; PAF: paroxysmal atrial fibrillation; PVI: pulmonary vein isolation; SAC: standard ablation catheter; SS: steerable sheath.

indicate a minimum CF of 38 g and 57 g to ablated and non-ablated atrial tissue, respectively, can cause perforation.22 Accordingly, the low number of tamponade cases reported in the SMART-AF trial was associated with ≥40 g of CF during a significant portion of RFA time (>2.1%). With real-time, feedback operators are aware of exactly how much CF is applied at any given moment, minimizing the likelihood of applying too much force.22 Impedance drops measured at the catheter tip–tissue interface during lesion formation have served as a reliable surrogate for transmural ablation.8,17,31 While conflicting reports, there are considerable data supporting a correlation between CF greater than 10 g per lesion application and significant impedance drops,17,23–27 while mean CF greater than 20 g and a force-time integral (FTI) cut-off value of 400 g s have been associated with improved outcomes in AF ablation. Data from the EFFICAS trials demonstrated lower incidence of pulmonary vein (PV) reconnection at these values compared with mean CF < 20 g and FTI < 400 g s.28,29 This was corroborated in the TOCCATA study where in all patients treated with less than 10 g per average RFA lesion experienced PV reconnection. FTI below 500 g s per average RFA lesion was associated with 75% recurrence, which dropped to 31% with FTI above 1,000 per average RFA lesion (Table 1).20,21 Despite these data to support growing use of CFS catheters, some degree of skepticism and controversy remains about their clinical benefit in AF ablation. In large part, the paucity of favorable prospective
randomized outcome data is at the center of this debate, with results from the TOCCASTAR study (multicenter, prospective, randomized, non-inferiority design) on the horizon and eagerly awaited. Nonetheless, the development of CFS catheters is still perceived as a revolutionary advance bolstering the arsenal in AF management. As with implementation of most novel tools and techniques, to manifest their potential and derive the greatest benefit from their use requires a degree of skill and a certain level of experience on the part of each operator.

As suggested by Martinek and colleagues in their study of CFS catheters, the presence of a learning curve may play a significant and possibly confounding role in data analyses and should not be overlooked. This is often and understandably the case with new techniques and innovations, as has been noticed in other aspects of catheter ablation of AF including early use of steerable sheaths. To this end, it would stand to reason that better outcomes may be associated with achieving better CF rather than mere use of a CFS catheter. Still, myriad variables present during ablation in the LA pose geometric and safety limitations that go beyond the attributes of CFS technology. Challenging ridge anatomy between the left PV and LA appendage can thwart great efforts to achieve meaningful CF along the anterior antrum, while prohibitive esophageal heating can promptly limit RFA application along the posterior PV antra despite good CF. Recognizing these limitations and appreciating a steep learning curve affect the way we adopt and adapt to new innovations and could offer a difference in clinical outcomes.

**Steerable sheaths**

Indeed, with the development of CFS catheters we now have the ability to gauge with precision the quantity of CF delivered at the catheter tip–tissue interface. Yet this is merely half the battle, as the act of delivering adequate CF in a consistent, high-quality application (in other words, getting there and staying there) remains a separate challenge altogether. Unwanted catheter movement during ablation in the LA pose respiratory motion, which have been shown to minimize catheter dislodgement and destabilization at the catheter tip–tissue interface. In the original retrospective analysis of 72 patients, procedure time was significantly reduced among those who underwent PVI with HFJV from 260 to 170 min compared with standard intermittent positive pressure ventilation (IPPV). Mechanistically, catheter stability results from significant reductions in LA volume as well as maximum changes in LA volume, LA pressure, and PV flow, which were demonstrated during HFJV. Motility of the PV was assessed by the CARTO three-dimensional mapping system (Biosense Webster, Diamond Bar, CA) and found to be significantly reduced during HFJV, from 14 to 2 mm (left PV) and 11 to 1 mm (right PV) when compared with IPPV.

There were no procedural complications associated with either method of ventilation in this study, although Di Biase and colleagues appropriately point out that HFJV may not be the best modality for all patients. In part due to the need for muscle relaxation and paralysis, and the fact that spontaneous recoil is critical during expiration, those with normal airways and normal lung and chest wall compliance are best suited for HFJV, while those with compromised respiratory systems or ventilation mechanics (as in the obese population or those with significant pulmonary disease) could be at risk for complications and morbidity. Thus with careful patient selection, minimizing cardiac and catheter motion by respiratory control can enhance effective RFA lesion formation while maintaining procedural safety and possibly minimizing catheter-related complications.
High rate pacing

Another innovative technique in minimizing motion variation to optimize catheter stability and contact force is high rate pacing during RFA. Although data are less well reported in the literature than other techniques described in this review, this practice has become routine in our EP laboratory. Barring resting tachycardia, pacing is performed throughout the case, including mapping and ablation, at a cycle length between 500 and 700 ms from the coronary sinus (CS) or right ventricle (RV) depending on the presence of intrinsic sinus rhythm or AF, respectively. With shorter cycle lengths during pacing there is a reduction in stroke volume. This in addition to less RR variability, and regular ventricular contraction reduces atrial motion and catheter motion resulting in greater stability at the catheter tip–tissue interface as manifested by steady CF. Kumar and colleagues32 describe using CS pacing during AF ablation at 800 ms to minimize cardiac motion in their study of respiratory and ventilatory effects on CF. Our single center experience has been favorable, as well. We believe the added stability and consistency of CF during ablation offered by this technique has contributed to increased success rates of RFA and PVI in paroxysmal as well as persistent AF patients.

Combination strategies

Perhaps, unsurprisingly, combining techniques to enhance catheter stability and increase the likelihood of creating durable transmural lesions seems to have had an additive effect.7,8 In their study of 300 first-time AF ablation patients, Hutchinson and colleagues7 analyzed the combined effect of using steerable sheaths and HFJV in addition to three-dimensional image integration of pre-acquired computed tomography or magnetic resonance images with electroanatomical mapping (3DIM) on 1 year outcomes in PVI. Freedom from AF recurrence at 1 year increased from 52% to 66% when steerable sheaths and 3DIM were used compared with the standard treatment arm; when HFJV was added to the combined use of steerable sheaths and 3DIM a further increase to 74% was seen (p = 0.006). Patients treated with all three techniques were referred for repeat ablation procedures least (11%), and in the multivariate regression model combined use of all tools carried the most favorable hazard ratio (HR 0.32; 95% CI 0.17–0.60) associated with freedom from AF at 12 months (Table 1).7 Additionally, Reichlin and Michaud8 published an outline of their combined approach using multiple techniques to optimize catheter contact and maximize lesion durability in PVI. This includes use of steerable sheaths, intracardiac echocardiography for direct visualization of tissue–catheter contact (particularly in selected areas such as the ridge between the left PVs and the LA appendage), careful attention to impedance changes at the catheter tip, and use of general anesthesia with intermittent apnea. AF ablation endpoints after PVI were assessed with adenosine to test for dormant conduction and pace-capture mapping was used to inspect for excitable tissue. Although beyond the scope of this review, it is interesting and worthwhile to highlight the latter, post-PVI techniques as part of a comprehensive strategy of AF ablation. Their single-center experience has been encouraging with an annual AF recurrence rate of only 20%.8 Notably, neither this thorough review nor the well-designed study by Hutchinson et al.7 analyzed

**Figure 1:** Illustration of catheter stability with and without high-frequency jet ventilation.
contributions from CFS catheters nor the potentially additive benefits of their combined use during AF ablation and PVI. It is currently standard practice in our laboratory to employ a comprehensive strategy that draws on various innovations to enhance catheter stability and improve safety and effectiveness during AF ablation. This approach includes concomitant use of CFS catheters, steerable sheaths, HFJV, and high rate pacing for each PVI case (Figure 1). Beyond CF optimization, we routinely use adenosine after PVI to assess for acute reconnection and confirm the presence of bidirectional block across PVI ablation lines, as well as high output unipolar pace-capture mapping to identify excitable tissue among scar zones. (The latter is more commonly performed during re-do ablation procedures in search of reconnection gaps or along the posterior LA wall in selected cases.) Similarly, our experience with this combined strategy has been favorable. We believe this multifaceted approach optimizes catheter CF during ablation while maintaining procedural safety translating into better outcomes for our AF patients.

Conclusion

Cardiac electrophysiology remains a practice deeply engrained with innovation, and as more data become available AF ablation will continue to advance and improve. To this end, the partnership between research, innovation, practice, and patient care must continue to grow and strengthen in the new era. Indeed, as we depend on innovation, so too new techniques and novel tools depend on our engagement and dedication to realize their greatest potential, practice safe methods, and derive the greatest benefit for our patients. Keeping this in mind, the future of AF management will remain burgeoning.

References


