POINT OF VIEW

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Ablation of Atrial Fibrillation

HAKAN ORAL, M.D., and FRED MORADY, M.D.

From the Division of Cardiology, University of Michigan, Ann Arbor, Michigan, USA

Introduction

Recognition that the initiation of atrial fibrillation often is dependent on arrhythmogenic foci within the pulmonary veins[1] opened a new chapter in our understanding of the mechanisms of atrial fibrillation, which in turn has led to dramatic improvements in our ability to ablate atrial fibrillation.

Based on experimental studies and clinical studies that used a variety of catheter and surgical ablation techniques, it is possible to postulate two major mechanisms for the initiation and perpetuation of atrial fibrillation.

1. *Primary drivers.* Some types of atrial fibrillation, particularly paroxysmal atrial fibrillation, may be primarily dependent on tachycardias that initiate and drive the atrial fibrillation.[2] Although often located in the pulmonary veins, the drivers also may originate from within other thoracic veins,[3] such as the superior vena cava, vein of Marshall, or coronary sinus, or within the left or right atrium. Furthermore, secondary tachycardias that also may function as drivers may develop in any of these arrhythmogenic sites, particularly the pulmonary veins,[2] in response to the primary driver. Once the primary driver induces secondary drivers, the perpetuation of atrial fibrillation may become more likely because even if the primary driver is extinguished, the other drivers may still function.

Elegant studies by Jalife[4] demonstrated that rotors with a very short cycle length exist during atrial fibrillation and can play a critical role in the perpetuation of atrial fibrillation. It appears that these rotors may have anchor points within the left atrium, near the pulmonary veins. In another experimental model, atrial fibrillation was found to be caused by an atrial flutter with a very short cycle length that resulted in fibrillatory conduction throughout the atria.[4]

Based on this mechanism, successful ablation of atrial fibrillation requires elimination of the primary and secondary drivers with strategies such as pulmonary vein isolation, isolation of the coronary sinus from the left atrium, or elimination of the rotors.

2. *Multiple wavelet reentry.* As described by Moe,[5] the multiple wavelet hypothesis proposes that a critical number of circulating wavelets is needed for the perpetuation of atrial fibrillation and that an important determinant of the number of wavelets is the wavelength (the product of refractory period and conduction velocity). Factors that shorten refractoriness or slow conduction will shorten the wavelength and facilitate the attainment of the critical number of wavelets. Based on this mechanism, ablation of atrial fibrillation requires modification of the atrial substrate to prevent the critical number of circulating wavelets from developing.

Ablative Therapy: Evolving Strategies

Based on these mechanistic considerations, ablation strategies for atrial fibrillation would target either the drivers—whether they originate within a pulmonary vein, in the left atrium, or elsewhere—or the left atrial substrate, such that atrial fibrillation can no longer occur even in the presence of a driver. Of course, a hybrid approach also could be used.

Clinical studies have demonstrated that complete electrical isolation of the pulmonary veins results in freedom from recurrent atrial fibrillation in ~70% of patients with paroxysmal atrial fibrillation and ~25% of patients with persistent atrial fibrillation. Although often interpreted as a technical failure to achieve permanent electrical isolation, these results more likely reflect the fact that pulmonary veins are responsible for paroxysmal atrial fibrillation in approximately two thirds of patients and that they play only a minor role in persistent atrial fibrillation. This should not be surprising given the multitude of potential mechanisms of atrial fibrillation and the fact that pulmonary vein isolation addresses only one of these mechanisms.

Because it is unlikely that all possible sources of premature depolarizations and drivers could be eliminated by catheter ablation, it is possible that some sort of left atrial modification is needed to improve the outcome of catheter ablation. This may explain the success of a hybrid approach that combines some degree of left atrial modification with pulmonary vein isolation.[6] Recently, a randomized study demonstrated that left atrial ablation, with ablation lines that encircle the pulmonary veins, is ~20% more effective than pulmonary vein isolation in preventing recurrences of paroxysmal atrial fibrillation.[7] This higher efficacy may be expected as left atrial ablation also may eliminate driver tachycardias that originate from structures other than the pulmonary veins and the rotors that develop outside the pulmonary veins. It also may result in left atrial substrate modification and debulking, and possibly in alterations of the autonomic innervation of the left atrium.

Several clinical studies have demonstrated that right atrial ablation has a very low probability of eliminating atrial fibrillation. Atrial fibrillation occasionally may be generated by

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Address for correspondence: Hakan Oral, M.D., University of Michigan, Division of Cardiology, TC B1 140D, 1500 E. Medical Center Drive, Ann Arbor, MI 48109-0311. Fax: 734-936-7026; E-mail: oralh@umich.edu

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reentry through gaps in the crista terminalis,[8] but in most cases the right atrium is simply passively activated from the left atrium.[4]

Future Directions for Ablation

There has been much progress in catheter ablation of atrial fibrillation within the last few years, and the field is rapidly evolving. Atrial fibrillation now has become a primary target of arrhythmia research. Given the magnitude of the potential target population, atrial fibrillation has become an area of major interest to electrophysiologists, cardiac surgeons, hospitals, and the biomedical industry.

The ultimate goal is to learn how to ablate atrial fibrillation with the minimum amount of ablation. Given the mechanistic heterogeneity of atrial fibrillation, it seems unlikely that there will ever be one minimum set of ablation lesions that will be effective for all patients. Our challenge is to learn how to recognize the various subtypes of atrial fibrillation and tailor the therapy accordingly.

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