Catheter Ablation of Atrial Fibrillation
Advent of Second-Generation Technologies*

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“Vision is the art of seeing what is invisible to others.”
—Jonathan Swift (1)

Although the exact mechanisms by which pulmonary vein isolation (PVI) results in freedom from paroxysmal atrial fibrillation (AF) are still the subject of inquiry and debate, this procedure is an effective alternative to drug therapy for rhythm control (2). The technique of catheter-based PVI has evolved through several stages, from focal ablation within the pulmonary vein (PV) (3), to segmental ostial isolation (4), and to antral circumferential and wide-area isolation (5), with or without additional lesion sets targeting non-PV foci (6) or modifying atrial substrate. All of these techniques initially used point-by-point ablation with radiofrequency (RF) ablation catheters.

Single-procedure success rates for catheter ablation of paroxysmal AF are in the 60% to 80% range; however, the procedure is technically demanding, highly operator-dependent, and carries a substantial risk of complications. Moreover, regardless of acute procedural outcome or clinical success, late reconnection of PVs is common (7). Therefore, a variety of technologies have been developed with the goal of making the procedure shorter, safer, more predictable, and more durable. An evolutionary change has been the incorporation of contact force sensing into RF ablation catheters, allowing real-time assessment of catheter-tissue contact and potentially improving efficacy and reducing complications, but still requiring a point-by-point lesion set.

Another approach is to apply RF energy at multiple sites simultaneously around a circular catheter positioned outside of each PV ostium (8,9). This has the theoretical advantage of allowing circumferential energy delivery instead of requiring the operator to move the ablation catheter to each site around the vein, which might result in more rapid PVI. In addition, energy can be applied selectively to certain electrodes, allowing fine control over how much ablation occurs. However, maintaining adequate contact between PV antral tissue and each of the ablation electrodes simultaneously is not always possible. Another concern is that the level of PVI might be closer to the vein ostium than the wide-area point-by-point lesion set favored by many operators. Some of the technical issues that hampered early adoption of these catheters have been mitigated (10), but it remains to be seen whether they will become standard equipment for AF catheter ablation.

Balloon-based technologies are another method of delivering energy around the PVs to achieve isolation. High-intensity focused ultrasound appeared promising as an energy source, with significant lesions created even in the absence of firm tissue-balloon contact. Unfortunately, ablation with this catheter (ProRhythm, Ronkonkoma, New York) caused collateral damage, including phrenic nerve injury and atrioesophageal fistula, and human trials were suspended. One possible explanation for these complications was the obligatory circumferential energy delivery; the operator could not choose which part of the balloon would deliver ablative energy or adjust the intensity of tissue destruction around the balloon. As a result, the portion of the left atrium adjacent to the esophagus or phrenic nerve received the same energy as those areas where deeper lesions were desired.

The most widely used balloon-based technology for PVI to date is the cryoballoon catheter, with over...
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100,000 cases performed worldwide (Arctic Front Advance, Medtronic, Minneapolis, Minnesota). The catheter delivers nitrous oxide to an inner balloon, where it undergoes phase change from liquid to gas resulting in a temperature near –80°C. The balloon catheter has a central lumen for a spiral mapping catheter to guide balloon position, reduce perforation risk, and record PV potentials during ablation. A steerable sheath (FlexCath, Medtronic) facilitates positioning of the balloon at each PV antrum. Ablation with this technology has been proven more efficacious than antiarrhythmic drug therapy in the multicenter, randomized STOP AF (North American Arctic Front) trial (11), with an acceptable safety profile, although 11.2% of patients had transient or persistent phrenic nerve injury. A large, randomized comparison of RF catheter ablation and cryoballoon has finished recruiting patients, and results are expected soon (12).

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Given this rapidly expanding array of technologies for PV isolation, do we really need another balloon-based ablation catheter? In this issue of the Journal, Dukkipati et al. (13) report the results of a large randomized trial comparing point-by-point RF catheter ablation (without contact force sensing) to visually-guided ablation using a laser balloon (HeartLight, CardioFocus, Marlborough, Massachusetts). In theory, this technology has distinct advantages over both point-by-point ablation and the cryoballoon catheter. It offers stable catheter position and contiguous lesions like other balloon-based technologies, along with an ability to selectively titrate energy to each part of the circumferential lesion set like point-by-point RF ablation. In addition, the laser balloon diameter can be changed dynamically to suit each PV antrum, and this is the first ablation technology to allow the operator to directly visualize tissue changes during ablation. However, theoretical advantages notwithstanding, the value of any ablation technology derives from its clinical results.

Before examining those results, we should emphasize that RF ablation catheters have improved since this study was initiated, especially with the introduction of contact force sensing (14). However, we should also keep in mind that most of the laser balloon operators were inexperienced, and there was a trend toward better results with increasing experience. An obvious strength of this study, as opposed to those previously published on the laser balloon, was the prospective, randomized treatment assignment, which should minimize bias.

Overall, acute procedural results were similar in the laser balloon and control groups. Procedures were longer and required more fluoroscopy with the laser balloon, but both resulted in complete PVI in > 95% of patients. Although the adverse event rate seems quite high in both groups (11.8% in laser balloon, 14.5% in RF), this was largely driven by cardioversion, a Food and Drug Administration-mandated primary adverse event. Adverse events besides cardioversion totaled 5.9% in the laser balloon arm and 6.4% in the control arm. The most concerning complications with the laser balloon were a 3.5% risk of persistent diaphragmatic paralysis and 1.2% risk of stroke, but these estimates are necessarily imprecise due to the small number of patients and events. In clinical follow-up, the recurrence-free survival curves were superimposable, with both groups showing nearly 40% AF recurrence rate, somewhat higher than that seen in contemporary studies on paroxysmal AF ablation.

These initial randomized results are not yet compelling enough to predict that the laser will become a major energy source in catheter ablation of AF, but the early experience is promising and is another piece of evidence that the days of point-by-point ablation for PVI are numbered. One day we might routinely visualize changes in tissue as we perform catheter ablation, allowing us to see what has so far been invisible. The advent of second-generation technologies for catheter ablation also provides a moment to focus on the fact that we still need a better understanding of the mechanisms of this devastating arrhythmia to improve therapeutics.

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