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EDITORIAL

Is pulmonary vein isolation effective for permanent atrial fibrillation?

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Recently, various surgical ablation devices have been developed to simplify the maze procedure. Pulmonary vein isolation with no atrial incisions has become feasible using these ablation devices. Focal activation arising from the pulmonary veins is one of the mechanisms underlying atrial fibrillation (AF), and pulmonary vein isolation is effective for curing AF caused by this mechanism. It has been reported that the pulmonary veins are an important source of paroxysmal AF.[1] Electrophysiological studies revealed that approximately 90% of the ectopic foci originated from the pulmonary veins in patients with paroxysmal AF.

The mechanisms of AF are complicated. There are two major electrophysiological mechanisms that may participate in its initiation and perpetuation. In the case of the first mechanism, arrhythmogenic activity that originates in the muscle sleeves of the pulmonary veins may trigger and maintain AF, particularly paroxysmal AF. Such a primary driver can induce other secondary drivers, and AF may be perpetuated by the secondary drivers even if the primary driver terminates. High, frequent reentrant circuits or rotors can act as drivers of AF and are seen in the pulmonary veins or posterior left atrium during AF.[2] With this mechanism, AF can be cured by isolating the drivers in the pulmonary veins or posterior left atrium. The second other major mechanism is multiple wavelet reentry. It has been suggested that AF is the result of the random propagation of multiple wavelets across the atria. Based on the theory behind this mechanism, curing AF requires interrupting multiple changing circuits with linear atrial incisions.[3–5]

The article by Takasaki et al. demonstrated that the cryo-maze procedure was more effective in eliminating permanent AF associated with both mitral and tricuspid valve disease than was box pulmonary vein isolation.[6] It also warned against incomplete ablation, which was shown to cause postoperative atrial tachycardia. The mechanisms of AF are different in paroxysmal and permanent AF. Whereas the most common cause of paroxysmal AF is focal activation arising from the pulmonary veins, the cause of permanent AF is not just simply focal activation arising from the pulmonary veins but also macro-reentry around the right or left atrium. Particularly in the case of permanent AF patients with both mitral and tricuspid valve disease, the atrial wall often shows greater hypertrophy of cardiomyocytes or more intercellular fibrosis than that of patients in sinus rhythm.[7] This difference results in inhomogeneous conduction. Inhomogeneous conduction around the right or left atrium participates in developing permanent AF. Therefore, in addition to pulmonary vein isolation, biatrial incisions are also needed to cure permanent AF.

Regarding outcomes from surgical therapy, it has been noted that pulmonary vein isolation was more effective for paroxysmal AF than for permanent AF. The AF cure ratio of pulmonary vein isolation was reported to be approximately 70%–80% for paroxysmal AF and 50%–60% for permanent AF.[8–12] These results suggest that focal activation arising from the pulmonary veins must be a major cause of paroxysmal AF. On the

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other hand, the full-maze procedure, which utilizes bilateral atrial incisions and pulmonary vein isolation, has been known to be effective for all types of AF, including permanent AF.[13–15] In patients with mitral and tricuspid valve disease, intraoperative mapping has shown that focal activation from the pulmonary veins and macro-reentry around the right or left atrial free wall occur simultaneously during permanent AF.[16] In these patients, pulmonary vein isolation alone fails to cure AF because of the macro-reentry around the right or left atrium.[9] Moreover, some permanent AF cases have repetitive activations arising from the posterior left atrium between the right and left pulmonary veins.[16] Pulmonary vein isolation cannot cure this type of AF (nonpulmonary vein focus). In such cases, box pulmonary vein isolation described in the present article is needed to address the focal activation arising from the posterior left atrium.[6] It has been shown that isolating the entire posterior left atrium by creating a box lesion is more effective in eliminating AF than a single connecting lesion between the right and left pulmonary veins.[17,18] Therefore, surgical procedures should be chosen after careful consideration of the individual mechanism of AF.

If we use surgical ablation devices instead of the "cut and sew" technique, it is important to avoid incomplete ablation lesions. The "cut-and-sew" technique can completely prevent propagation of abnormal activation and interrupt reentrant circuits. However, ablation devices, including traditional cryoablation and radiofrequency ablation, do not necessarily guarantee transmural and continuous necrosis.[19,20] Because focal activations that originate from the pulmonary veins are thought to trigger and maintain AF, complete pulmonary vein isolation is essential to successful AF surgery. It is necessary to confirm complete conduction block when performing pulmonary vein isolation by pacing from the pulmonary veins during beating heart surgery. If pulmonary vein pacing shows that pulmonary vein isolation was incomplete, then additional applications of ablation energy are required to achieve complete conduction block during surgery. Moreover, in clinical and experimental studies, it has been noted that a nontransmural ablation lesion causes a conduction gap on the mitral or tricuspid annulus, resulting in atrial reentrant tachycardia after surgery.[6,21–23] A small amount of viable myocardium can propagate across the ablation lesion with slow conduction. This slow conduction in the reentrant circuit causes stable reentrant activation, which allows atrial reentrant tachycardia to occur. Takasaki et al. also described incomplete ablation of the pulmonary veins, or the mitral and tricuspid annuli created recurrence of AF or atrial tachycardia after surgery, resulting in a low AF cure ratio.[6] Taking care to create complete conduction block in all ablation lesions can improve the AF cure ratio after surgery no matter which surgical procedures are performed to cure AF.

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