Radiofrequency ablation of the pulmonary veins: Can it stop atrial fibrillation at its source?

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ABSTRACT

Recent work from France indicates that many cases of atrial fibrillation arise from foci of rapidly firing cells, most of which are located not within the atria but within the pulmonary veins. Armed with this new knowledge, we are pursuing strategies of permanently preventing atrial fibrillation by destroying these foci using radiofrequency ablation.

IMPORTANT NEW FINDINGS that many cases of atrial fibrillation are caused by rapidly firing foci in the pulmonary veins[1] are opening a promising new area for research into finding a permanent cure for atrial fibrillation.

There is an urgent need for new, benign, more effective therapies for atrial fibrillation. Anticoagulation and antiarrhythmic drug therapy are often ineffective and carry a substantial risk of adverse side effects, while surgical therapies are often too extreme for patients with atrial fibrillation who are otherwise healthy.

This article briefly reviews recent findings that are revising theories of the cause of atrial fibrillation, the therapeutic options that might permanently prevent atrial fibrillation, and the substantial research challenges that remain.

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THE DEBATE OVER THE ORIGINS OF ATRIAL FIBRILLATION

In normal sinus rhythm, electrical activation of the heart begins in the sinoatrial node in the upper portion of the right atrium, and proceeds as a single orderly wave front. The most common form of atrial fibrillation occurs when this wave front is broken up into multiple components, called wavelets, each rapidly and chaotically circulating through the atria.

Theories as to what sets off this chain of events have changed several times over the last few decades. At first, it was thought that atrial fibrillation had focal origins, ie, that abnormal electrical firing of single points within the heart disrupted the normal wave front Then, in classic computer modeling studies, Moe et al[2] proposed that atrial fibrillation was due to multiple wandering reentrant wavelets.

Recent findings offer new hope of treatment

Most recently, in a remarkable study from Bordeaux, France, Haïssaguerre et al[1] inserted multielectrode ECG catheters into the right and left atria of 45 patients with frequent episodes of atrial fibrillation. They found that 94% of episodes were triggered by ectopic foci, located not within the heart but within the pulmonary veins (FIGURE 1).

This finding is leading to a theory of the origin of atrial fibrillation that is a synthesis of the initial two theories, in which:

- Ectopic foci, primarily in the pulmonary veins, initiate atrial fibrillation; and
- A suitable substrate in the atria allows the multiple reentry wavelets to perpetuate the chaotic electrical activity.

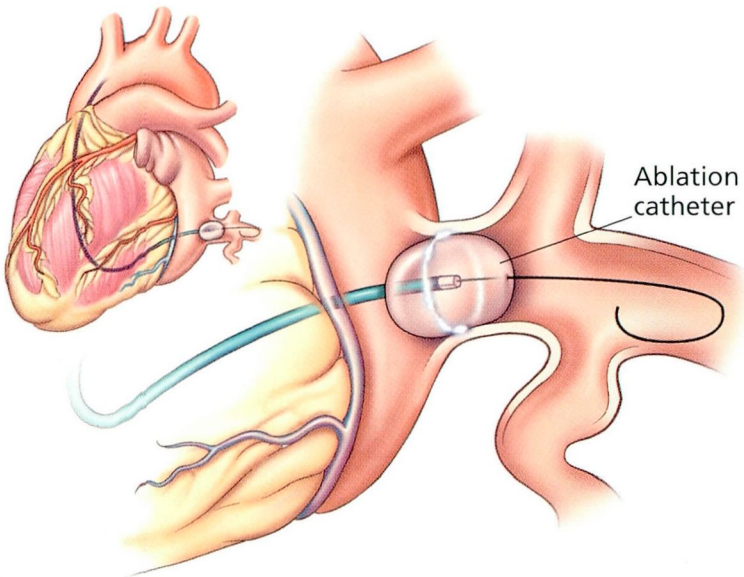
Implications for treatment

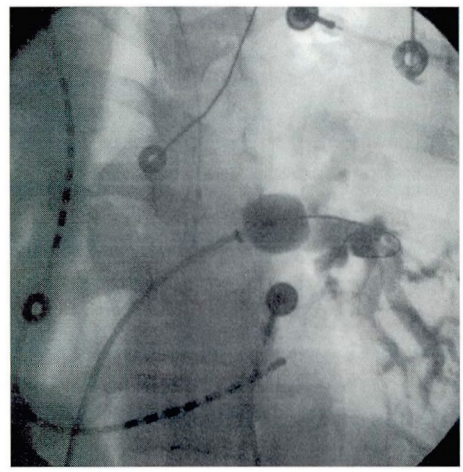
In addition, the French investigators[1] found that after the foci in the pulmonary veins were

Pulmonary vein ablation: A new treatment for atrial fibrillation

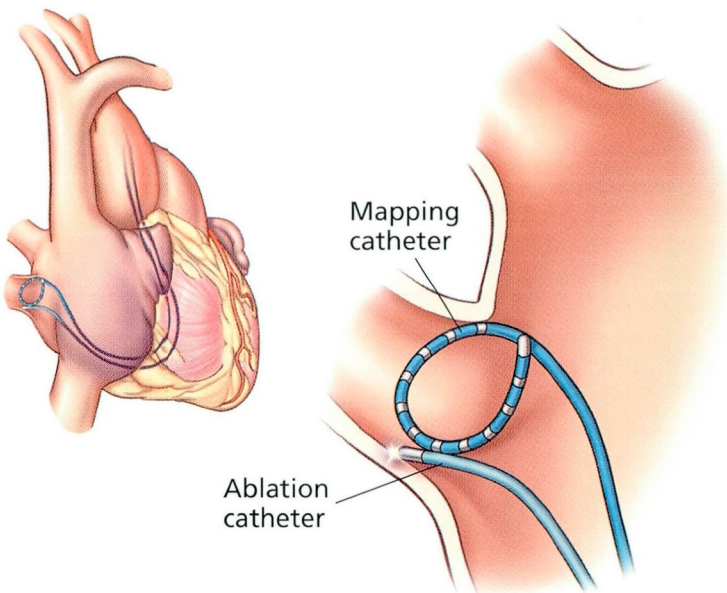
Most cases of atrial fibrillation arise from ectopic foci located in the pulmonary veins, according to a recent study.[1] This location makes these foci relatively easy to isolate using radiofrequency ablation.

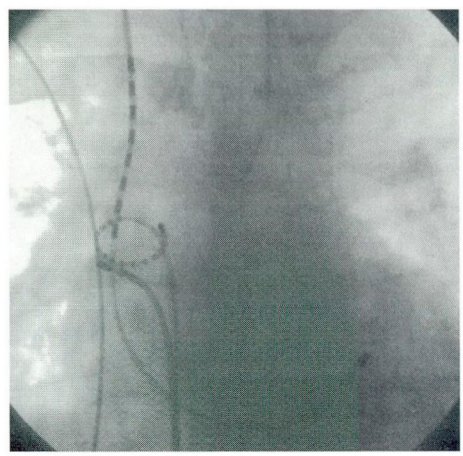
Location	% of foci
Left superior pulmonary vein	45%
Left inferior pulmonary vein	16%
Right superior pulmonary vein	25%
Right inferior pulmonary vein	9%
Atria	6%





A new type of ablation catheter has an inflatable tip. Shown here, the catheter is inserted into the ostium of the left inferior pulmonary vein and filled with normal saline solution. The radiofrequency current is then turned on, creating a ring of scar tissue that electrically isolates the ectopic focus that is causing the atrial fibrillation.





A second method uses two catheters: a loop-shaped mapping catheter to mark the ostium and an ablation catheter. Here, the ablation catheter creates a ring of discrete lesions in the right inferior pulmonary vein.

FIGURE 1

treated with radiofrequency ablation, 28 patients (62%) remained free of atrial fibrillation at a median follow-up of 7 months. Therefore, this study offers hope that many patients might be successfully treated with a relatively benign procedure.

Accordingly, we have been investigating catheter-based approaches to treating these foci either by destroying the foci itself or by isolating them electrically from the heart.

PROBLEMS WITH CURRENT THERAPIES

Current treatments for atrial fibrillation are directed toward trying to reestablish a normal heartbeat and prevent stroke, and are primarily supportive and palliative rather than curative.

Antiarrhythmic drugs, the most common treatments for atrial fibrillation, often become less effective over time, and approximately half of patients eventually develop resistance to them. In addition, they can have severe side effects, including pulmonary fibrosis, impaired liver function, and new arrhythmias. In the Stroke Prevention in Atrial Fibrillation (SPAF) trial,[3] patients who received antiarrhythmic drugs had an incidence of sudden death that was 3.7 times higher than patients who did not receive antiarrhythmic drugs, and the risk was even higher in patients with structural heart disease.

New treatments for atrial fibrillation are urgently needed

Rate control and anticoagulation. Many patients with persistent atrial fibrillation take beta-blockers or digoxin to slow the heart rate and warfarin to reduce the risk of stroke. However, this palliative approach is also frequently ineffective and can cause side effects: warfarin can cause bleeding, beta-blockers and digoxin can cause bradycardia, and beta-blockers can additionally cause hypotension, fatigue, and worsening of asthma and heart block.

Implantable defibrillators, a newer treatment, originally raised concerns that the devices would trigger life-threatening episodes of ventricular tachycardia. These fears proved unfounded, but the electrical shocks are painful and unacceptable to some patients, especially if they receive frequent shocks.

AV node ablation and pacemaker insertion. An approach for permanent atrial fibrillation is to ablate the AV node, severing the electrical connection between the atria and ventricles, and install a pacemaker. Studies have found that AV node ablation and pacemaker insertion improves the quality of life, functional performance, and ejection fraction in patients with atrial fibrillation[4]; it does not, however, appear to reduce the mortality rate or the risk of stroke. Single-chamber ventricular pacemakers place the patient at higher risk of stroke because the atria, particularly the left atrium, still do not beat effectively. For patients with sick sinus syndrome, a dual-chamber pacemaker that stimulates both the atria and the ventricles reduces the risk of stroke.

Surgery for atrial fibrillation. In an early procedure, surgeons created an electrical pathway or corridor from the sinus node to the atrioventricular node by cutting into the endocardium and sewing it back together.[5] The maze procedure is similar, but instead of creating a corridor the surgeon creates a maze to interrupt the conduction routes of the most common reentrant circuits while also directing the normal sinus impulse to the atrioventricular node. The maze procedure has proved safe and shows some success,[6] but because it requires open-heart surgery it will probably never be widely adopted.

The maze procedure can also be performed percutaneously by radiofrequency catheter, avoiding the risks of open heart surgery. But with current technology (ie, a catheter that requires the operator to ablate multiple individual points), the procedure is very long—up to 12 hours—and exposes the patient and staff to a substantial x-ray dose. New catheters under development that ablate tissue along their length should shorten the procedure considerably. Nevertheless, the maze procedure only blocks or dampens atrial fibrillation once it has started.

TARGETING THE SOURCE OF FIBRILLATION

The ideal therapy would stop the fibrillation easily and permanently at the source. Haïssaguerre et al[1] demonstrated not only that episodes of fibrillation arise from discrete ectopic foci that occur in predictable locations

(ie, in the pulmonary veins), but that ablating these foci may be a reasonable option.

However, there are a number of drawbacks to focal ablation. It can be difficult to isolate the ectopic foci, the procedure is quite lengthy, and it requires multiple catheters. Even if we successfully isolate one focus, if others exist but are not detected, the patient may be at risk of further episodes of atrial fibrillation. Also, long-term follow-up of patients who underwent ablation of ectopic foci in the pulmonary veins revealed a potentially serious complication: strictures of the pulmonary vein, which could potentially lead to pulmonary hypertension.

To avoid these problems, we tried another approach, creating a ring of ablation around the ostium of the pulmonary vein. In theory, this procedure should isolate the ectopic focus from the atrium, so that the abnormal electrical impulse remains confined to the pulmonary vein.

In practice, this was hard to do: the geometry of the area is tricky, and using available ablation catheters, it is difficult to avoid missing a spot through which the abnormal impulses can escape.

Technology may come to the rescue. We are working with Atrionix Inc. (Palo Alto, Calif) to develop a special ablation catheter for this application. The catheter has a balloon tip that is inflated with normal saline solution once it is positioned in the ostium, creating a tight seal all around. The normal saline solution transmits the radiofrequency energy to the walls of the vein around the equator of the balloon, creating a doughnut-shaped zone of ablation.

So far we have tested the new catheter in 30 patients and the results are promising, with cure of atrial fibrillation in about 60% of them.[7] If this device, modified to address the limitations observed in early trials, ultimately wins approval, we hope that it will make it possible to cure atrial fibrillation if applied in the early stages of the disease.

Another approach we are exploring with the help of two companies uses a circular mapping catheter in the pulmonary vein which helps target critical sites around the circumference of the ostium, facilitating catheter ablation to isolate the abnormal foci. With these new tools, ablation and cure of atrial fibrillation have become a reality for many patients.

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