Review Article

# Surgical Treatment of Atrial Fibrillation

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## Abstract

*Atrial fibrillation is the most prevalent permanent arrhythmia. It may be associated with other cardiac pathologies which need surgical treatment. Various types of surgery including the traditional cut-sew operations and operations using different energy sources are currently in use. In comparison with medical treatment, surgery is safe, effective, and has reliable results.*

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## Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia. It is estimated to occur in 3% of the general population, and its likelihood increases significantly in the elderly (Table 1). Far from being a harmless arrhythmia, AF may beget major complications or even mortality.[1-3]

Table 1. Number of cases with atrial fibrillation per 100 persons (examined in the Framingham study)

| Age groups (y) | Persons with atrial fibrillation (%) |
|---|---|
| 50-59 | 0.5 |
| 60-69 | 1.8 |
| 70-79 | 4.8 |
| 80-89 | 8.8 |

AF may cause:

1. Palpitation, which leads to anxiety and discomfort.
2. Decreased ventricular function due to the loss of atrioventricular synchrony and, in its extreme, heart failure.
3. Thrombus formation in consequence of the stasis of the blood in the left atrium.
4. Risk of systemic thromboemboli.

According to the Framingham Heart Study,[3] AF increases the odds ratio for death 1.5 to 1.9 times and the risk of embolic cerebrovascular accidents up to five times. The pharmacotherapy of AF has proved disappointing because of:

1. Failure to reverse arrhythmia to normal sinus rhythm in the majority of cases
2. Significant side effects of drugs
3. Need to long-term or even lifelong use of drugs
4. Exorbitant costs
5. Poor patient compliance

The AFFIRM Study (the Atrial Fibrillation Follow-up Investigation of Rhythm Management) showed that rhythm control in comparison to rate control offered no mortality benefits. Given the limitations of drug treatment for AF,

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other treatments based on percutaneous or surgical ablation are now the focus of interest.[4-6]

Patients with permanent AF require anticoagulation warfarin use, which is associated with major bleeding complications up to 2-3% per year. This is another reason for the interest in treatments that convert AF to normal sinus rhythm.

## *Electrophysiological basis of atrial fibrillation*

The commencement and continuation of AF require conditions which include:

1. A trigger that may be unifocal or mov ing or may be permanent or paroxysmal
2. Change in the refractory period of the atrium
3. Change in the conduction velocity
4. Change in the atrial dimensions allowing the continuation of AF

These conditions set off multiple macroreentrant circuits, which give rise to irregular atrial activation. Pathological conditions such as ischemia, inflammation, or increased atrial size provide a basis for change in the refractory period and conduction velocity; and once triggered, AF may continue.

The role of the pulmonary veins in AF is very important. The pulmonary veins contain no pacemaker tissue, but their refractory period is longer than that of the nearby atrial tissue. The anatomy of the pulmonary veins is highly variable in humans, and some studies have shown that the pulmonary veins are the trigger zone in more than 50% of cases.[7]

## *Classification of atrial fibrillation*

The most useful classification suggested to date is that by joint American Heart Association (AHA), American College of Cardiology (ACC), and Heart Rhythm Society (HRS), according to which AF may be:

1. Paroxysmal
2. Persistent
3. Permanent

Paroxysmal AF is recurrent AF (2 or 3 episodes) that is self-terminating; persistent AF is AF that is not self-terminating; and permanent AF is AF lasting more than 1 year in which cardioversion fails or is not indicated at all (Figure 1).

All types of AF may be treated surgically. However, persistent and permanent AFs comprise the bulk of the cases and tend to be associated with important concomitant cardiac pathologies such as coronary artery disease, valvular heart disease, and congestive heart failure. Surgical ablation is also applicable to AF without any associated pathology (lone AF).

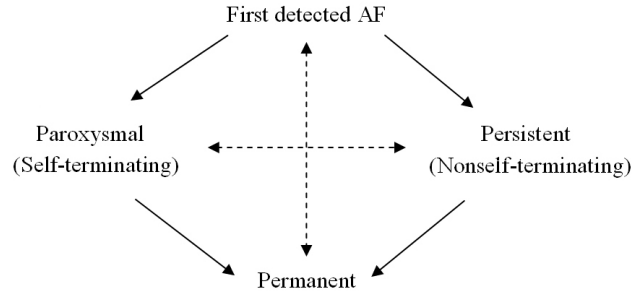


Figure 1. Different patterns of atrial fibrillation (AF)

The basic points in the surgical treatment of AF are the disruption of the pathways of AF wave conduction and the isolation of the trigger zones while saving normal atrioventricular conduction and effective atrial contraction. These goals may be fulfilled via the traditional cut-and-sew techniques or the use of different energy sources to create similar lesions in the atrial wall.[8]

## *Cut-and-sew procedures*

In the evolution of AF surgery, some historical operations merit special mention. They may have been ineffective or caused many complications or even mortalities, but they provided the knowledge which is the basis of modern AF surgery. The most salient of these operations are:

1. Left atrial isolation
2. Atrioventricular node ablation
3. Corridor procedure
4. Atrial transaction
5. Maze I and II operations

The only cut-and-sew operation still in use with acceptable results is Maze III operation, named Cox/Maze III operation in honor of its inventor (Figure 2).[9]

Cox/Maze III operation became the gold standard for the surgical treatment of AF when it was reported that 97% of the patients at late follow-up were free of AF. Since then, although this procedure has yielded acceptable outcomes in various institutions, it has failed to gain popularity due to the complexity and technical challenges that it poses to the average surgeon.

Recently, other types of cut-and-sew techniques have been devised which involve different lines of incision (radial incisions). Nonetheless, they are not popular and long-term results are unavailable. Cox/Maze III operation is the choice procedure for Huge LA (D>60 mm).

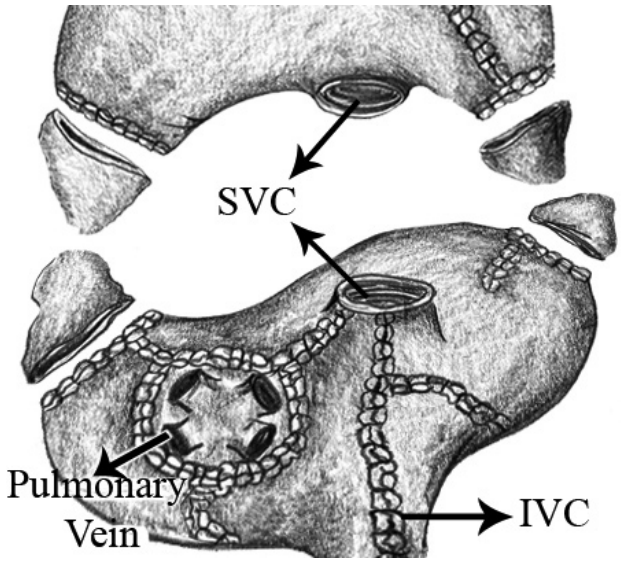


Figure 2. Cox/Maze III operation
SVC, Superior vena cava; IVC, Inferior vena cava

## *Procedures using alternative sources of energy*

The medical industry has made major strides in simplifying AF surgery and keeping it effective, so much so that an average surgeon can now perform AF surgery. There is presently a wide array of ablation devices available in a surgeon's armamentarium (Table 2).

Table 2. Various energy sources for AF ablation

| Energy source | Mechanism | Transmural lesion | Clinical experience | Thrombo-genicity |
|---|---|---|---|---|
| Radiofrequency | Radiofrequency current | 2 + | 4 + | 2 + |
| Microwave | Electromagnetic waves (2.45GHz) | 2 + | 1 + | 2-3 + |
| Cryothermal | N2O or helium | 2-3 + | 3-4 + | – / + |
| Ultrasound | Pressure waves | 4 + | 1 + | Unknown |
| Laser | Photon absorption | 1 + | 1 + | 2 + |

It is worthy of note, however, that any ablation device should fulfill certain important conditions:

1. The lesion created by the device must be transmural to provide bidirectional block.
2. It must be safe and not damaging to important cardiac tissue or adjacent organs.
3. It must be simpler than cut-and-sew techniques.
4. It should be applicable via the epicardial or endocardial route and have the potential to be usedvia minimally invasive routes.

Different devices available in clinical practice utilize different energy sources which include:

### *Cryothermy*

Cryotherapy is a well-known method of arrhythmia surgery and can create transmural lesions when applied to the atrial tissue. It causes myocardial cell necrosis but spares the collagen framework. The source may by N2O (-60 to -89.5°C) or liquid argon (-185.7°C). Recently, a laser-based cryothermal source has been introduced. It can be applied via the endocardium or epicardium or even in beating-heart surgery. Cryolesions are unique in that they are non-disruptive to vital cardiac organs and skeleton, and the likelihood of injury to the valves and the coronary artery is low. Cryothermy is very safe for the adjacent organs to the heart. The efficiency depends on the set of lesions and the experience of the surgeon in creating transmural lesions; the overall efficacy of the method is around 75-80%. Cox/Maze IV operation, which is a modification of Cox/Maze III operation, uses alternative sources of energy and is as effective as the standard Cox/Maze III operation (95% long-term AF cure) (Figure 3).[10-12]

### *Radiofrequency*

Radiofrequency is utilized to apply an alternative current of 350 KHz to 1 MHz to the heart tissue. The creation of a transmural lesion depends on the power of radiofrequency, impedance of the tissue, and time of application. Radiofrequency can create full thickes lesions if applied long enough and can be used as a unipolar or bipolar device (Figure 4). The dry mode now is not available, and irrigation radiofrequency is currently the device in use. Irrigation can decrease tissue charring and nearby organ injury and at the same time increase the depth of the atrial lesion. Radiofrequency is quick and safe, easily fits minimally invasive surgery, and can be applied via the epicardium or endocardium. It is, therefore, the most popular energy source. The overall efficiency of radiofrequency is around 60-80% in the long-term cure of AF. Biatrial radiofrequency AF ablation may cure AF in 85% of cases but is associated with unacceptable rates of A-V block (up to 10%).[13-16]

### *Microwave*

Microwave is a new source of energy that induces vibration in water molecules and creates thermal energy. The energy band in ablation surgery is between 915 and 2450 MHz. Microwave does not char the tissue and is able to create transmural lesions. When used in the correct set of lesions, microwave can cure AF in 65-80% of

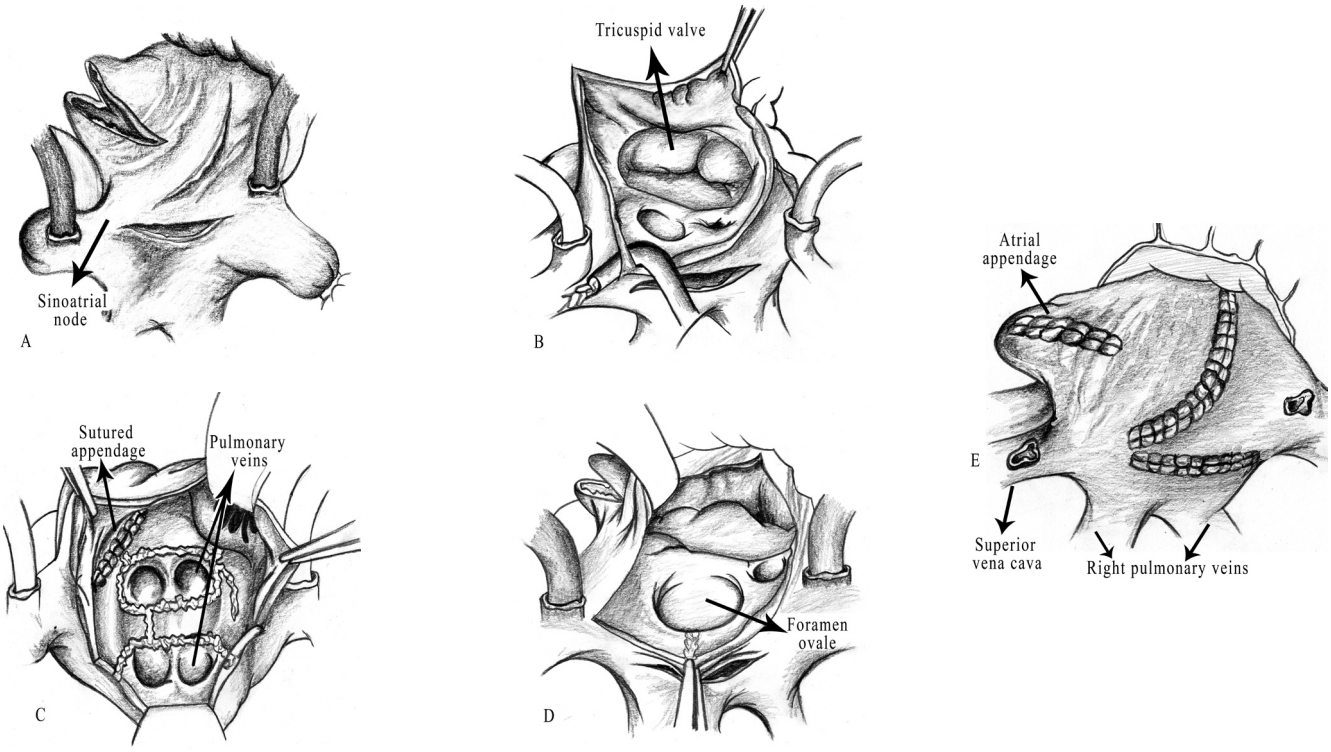


Figure 3. Cox/Maze IV operation

cases. In some studies, lesions created by microwave are not transmural. Microwave can be applied via the pericardium and in minimally invasive procedures.[17-18]

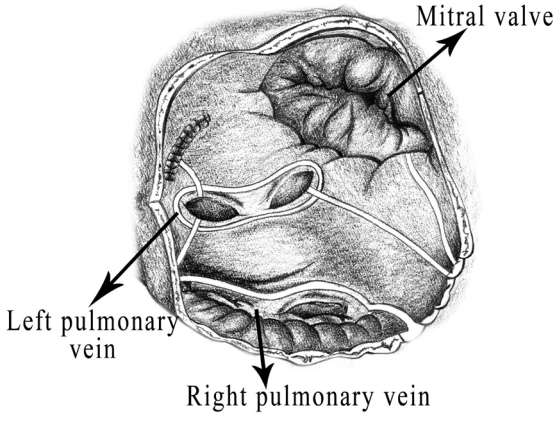


Figure 4. Left atrium lesion set in radiofrequency ablation of atrial fibrillation

### *Ultrasound*

Ultrasound transducers with frequencies of 2 to 20 MHz are now in use. Transducers convert the electrical energy to mechanical waves, and the absorption of the mechanical waves generates heat in the tissue. The depth of penetration can be set. Ultrasound may be focused or unfocused. Clinical experience with ultrasound is limited, but most studies have demonstrated that increasing the epicardial fat has no effect on the creation of transmural lesions (contrary to other energy sources). This is an advantage when this source of energy is used epicardially. An overall efficacy rate of up to 85% has been reported for this alternative source of energy, but the general figure must bearound 75-80%. The mean advantage of ultrasound is that it is contact forgiving and can focus the waves on the tissue.[19]

### *Laser*

Laser is a monochromic coherent beam generating tissue heating. The most popular laser for AF ablation is a diode laser with a continuous low energy power. Animal studies have shown transmural lesions, whereas clinical human studies are small and mid- and long-term results are not available.[20-21]

### *Contraindication of AF ablation using alternative sources of energy*

AF ablation is ineffective in the following conditions:

1. LA dimension more than 60 mm
2. Calcified LA wall
3. Very chronic AF (relative)

## Conclusion

AF is an important, epidemic arrhythmia and is frequently associated with major morbidity or even mortality. The medical treatment of permanent AF is frustrating, and lifelong anticoagulation is an additional problem.

Surgery opened a new horizon to the treatment of AF, but the only cut-and-sew operation that stood the test of time is Cox/Maze III operation with 97% long-term cure for AF.

Variations of Cox/Maze III operation that use alternative sources of energy have yielded results that approximate to the results of the standard operation. Due to the complexity and time-consuming nature of the standard or Cryo-Maze III operation, other energy sources are now available in practice with long-term cure rates of around 70-85% and very low complication rates.

AF ablation is a solid part of surgery of each patient with AF rhythm. Cryoablation or radiofquencyre ablation with various sets of lesions has acceptable results and few complications. Let's do it!!

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