Surgical treatment of atrial fibrillation, systemic review 2019

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Abstract

Atrial fibrillation (AF) is one of the most common cardiac arrhythmias. There are over 6 million people in Europe suffering from the disease. According to a systematic review of worldwide population-based studies estimated that the number of individuals with AF in 2010 was 33.5 million. AF is predicted to affect over 17,9 million people in Europe by 2060 and over 12 million people in the USA by 2050.AF is predicted to affect over 17,9 million people in Europe by 2060 and over 12 million people in the USA by 2050. This scale of prevalence makes AF a pandemic. The most common risk factors for AF are: hypertension, advanced age, metabolic factors like diabetes and hyperthyroidism, ischemic heart disease, congestive heart failure, valvular heart defects, obesity, obstructive sleep apnea syndrome and the use of stimulants. Thromboembolic complications are the most serious consequences of AF. It is estimated that AF causes 15-20% of all strokes. The exact mechanism of AF is still not well understood. Several hypotheses have been proposed. External aggravating factors, such as structural heart diseases, hypertension or diabetes, but also AF itself, cause a slow, progressive process of structural and electrical remodeling of the atria. In the 1980s, numerous medical researchers began developing procedures for the surgical treatment of AF. There are many pharmacological and non-pharmacological therapies for atrial fibrillation. The understanding of AF pathophysiology and potential treatment has greatly increased over the past decades. The significant development of new surgical methods and procedures using alternative energy sources for ablation of atrial fibrillation has been made.

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Introduction

Atrial fibrillation (AF) is the most common tachyarrhythmia, which is characterized by uncoordinated work of the atria leading to the loss of haemodynamic efficiency of the heart. Atrial fibrillation occurs in 1-2% of the general population. There are over 6 million people in Europe suffering from the disease [1]. According to systematic review of worldwide population-based studies the number of individuals with AF in 2010 was 33.5 million [2]. AF is predicted to affect 6–12 million people in the USA by 2050 and 17.9 million people in Europe by 2060 [5,6]. The incidence of this arrhythmia increases with age from <1% among people aged 40–45 to >10% among people >80 years. Patients> 80. years of age account for 36% of the population with this arrhythmia [7].

AF is often asymptomatic (the so-called silent AF) and detected incidentally in up to 30% cases when performing a standard ECG recording [1,2]. Symptomatic AF manifests itself as irregular heartbeat, weakness, fatigue, dizziness, confusion, shortness of breath and results in quality of life impairment. In many cases it is diagnosed only due to the presence of complications such as stroke or heart failure.

Men suffer more often than women and the most common risk factors are: hypertension, advanced age, metabolic factors: diabetes and hyperthyroidism, ischemic heart disease, congestive heart failure, valvular heart defects, obesity, obstructive sleep apnea syndrome and the use of stimulants.

Thromboembolic complications are the most serious consequences of AF. It is estimated that AF causes 15–20% of all strokes [8,9]. It is associated with the presence of a thrombus in the left atrium, most commonly in the left atrial appendage [10,11].

Clinically, AF can be classified more precisely as: AF episode, early persistent AF, paroxysmal AF, persistent AF, permanent AF (Table 1) [12]. There are many pharmacological and non-pharmacological therapies for atrial fibrillation. The review summarizes surgical treatment options of AF.

Table 1.
Atrial fibrillation definitions

Term	Definition
First episode AF	AF not diagnosed before irrespective of the duration of the arrythmia
Paroxysmal AF	AF that terminates spontaneously or with intervention < 7 days
Early persistent AF	AF sustained <7 days but it less than 3 months in duration attempt to restore sinus rhythm
Persistent AF	Continuous AF that is sustained >7 days Attempt to restore sinus rhythm
Long-standing persistent AF	Continuous AF >12 months in duration, Attempt to restore sinus rhythm
Permanent AF	Accepted by the patient and physician; No attempts to restore or maintain sinus rhytm will be undertaken

AF – Atrial Fibrillation; ECG – Electrocardiogram

Mechanism of AF

The exact mechanism of AF is still not well understood. Several hypotheses have been proposed. External aggravating factors, such as structural heart diseases, hypertension or diabetes, but also AF itself, cause a slow, progressive process of structural and electrical remodeling of the atria [13]. Hence it can be divided into electrical, structural, and autonomic remodeling. The structural reconstruction causes electrical dissociation between the muscle fiber bundles and local conductive heterogeneity [14], which promotes re-entry waves and maintenance of arrhythmias [15]. Because this structural remodeling is irreversible at some point, it is desirable to start treatment very early [16].

According to the experimental concept of Allessie et al., the mechanism responsible for atrial fibrillation is the circling reversal wave - the reentrant wave. The most important pathogenic mechanism is the increased excitability of the atria, which is associated with the refraction of the atrial muscle dependent on the duration of AF.

Therapeutic goals in AF

Due to the fact that AF is associated with significant morbidity and mortality it is essential to provide effective treatment very quickly. The management includes methods treatment affecting the prognosis (anticoagulant therapy), as well as symptomatic treatment (ventricular rate and heart rhythm control) [17].

Antiarrhythmic drugs and anticoagulant therapy are recommended by practice guidelines as a first-line therapy in patients with AF [18]. In many situations antiarrhythmic therapy is ineffective. In such cases, surgical treatment of AF might be used. Surgical treatment of AF is currently recommended by guidelines as a second-line therapy in patients with paroxysmal and persistent AF whenever at least 1 antiarrhythmic drug does not work. However, under special circumstances it can be offered as first-line therapy [9].

Surgical treatment and its history

In the 1980s, numerous medical researchers began developing procedures for the surgical treatment of AF. Left atrial isolation procedure was performed and described by Williams and colleagues. The goal of the procedure is to create anatomical blocks so that AF is entrapped within the isolated left atrium. As a result the regular rhythm and hemodynamic stability are restored [19]. In 1985, Guiraudon and his team performed the corridor procedure, isolating the area of atrial septum with the SA and AV nodes. As a consequence, they were able to restore a regular ventricular response while both atria continued to fibrillate leading to hemodynamic insufficiency [20].

Cox's and co-authors' work led to the creation of the AF system for human mapping, which confirmed the multi-reentry theory of AF. According to Cox, the decisive role in supporting AF is played by: crista terminalis in the right atrium, the opening of the coronary sinus, the opening of the vena cava and the opening of the pulmonary veins in the left atrium. This led to the first effective surgical treatment for AF, known as the Cox-Maze procedure (CMP), performed by James Cox, MD, in 1987 [21,22]. During the Cox-Maze operation, areas of the right and left atria were separated. A series of surgical incisions reduce the atrial muscle mass and electrically isolate pulmonary venous openings, coronary sinus and right atrial isthmus. As a result the electrical impulses are isolated from the SA node and prevent reentrant circuits forming [23,24]. Observation of patients who underwent Cox-Maze I procedure showed significant chronotropic failure and in some cases, left atrial dysfunction, which was considered to be the result of cuts performed near the sinus node [25].

The procedure was modified and renamed the „Maze II" procedure, in which no incisions were made around the sinus node, and several changes were made to the cut lines made within the left atrium. After several modifications the operation was called the „Maze III" procedure. It significantly improved the technical and functional aspects of the therapy. The Cox-Maze III operation became a standard for

surgical treatment of AF. An 8.5-year large observational study revealed that 93% of patients were arrhythmia-free (without antiarrhythmic therapy) and 97% of patients were free from complaints [26].

Ablation procedure of AF

For a few decades many medical centers have worked to replace the traditional surgical cut-and-sew lesions of the Cox-Maze III with a much simpler, faster and less complicated ablation using different energy sources [27].These linear ablation lines have been created using different sources of energy including radio frequency (RF) energy, microwave, cryoablation, laser and high-frequency ultrasound energy [28,29]. The development of ablation technologies has revolutionized the surgical treatment of AF. Nevertheless indications for the ablation treatment of AF include a numerous problems associated with ineffective pharmacotherapy or in cases of bradycardia, ineffective treatment with permanent cardiac pacing. Before the ablation procedure, an electrophysiology (EPS) examination is performed, which gives a map showing how electrical impulses circulate in the atria and precisely determine where the ablation should be performed.

Surgical Ablation of AF

The Cox-Maze IV (CM-IV) procedure has replaced the "cut-and-sew" technique of the original Cox-Maze operation with lines of ablation created using bipolar radiofrequency (RF) and cryothermal energy devices[30]. In the last few years, surgical techniques have been developed, reducing the risk of surgical complications. The CM-IV procedure can be divided into right atrial and left atrial lesions. This procedure can be performed through a right mini-thoracotomy or median sternotomy approach (Figure 1) using specifically designed modern equipment (Figure 2) [25,31].

Atrial fibrillation is very often problem combined with cardiac procedures. Postoperative atrial fibrillation (POAF) is a frequent complication after cardiac surgery. Up to 30 - 50% of patients undergoing common mitral-valve surgery present atrial fibrillation, which is associated with reduced survival and high risk of stroke. Gillinov et al. showed lower AF

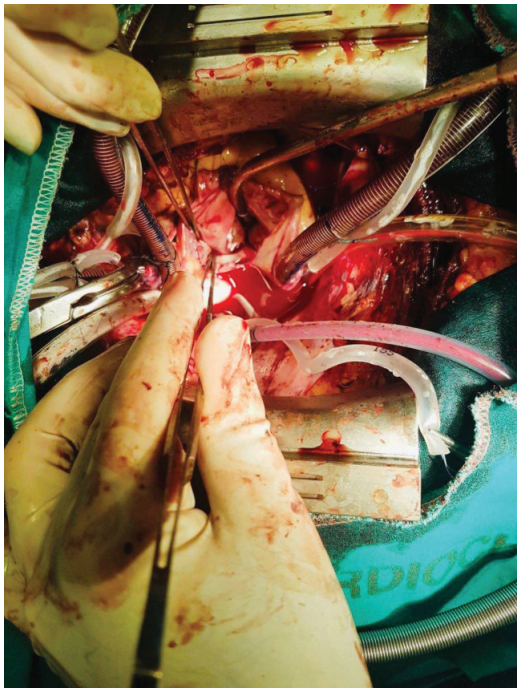

Fig. 1.
The Cox-Maze IV (CM-IV) procedure performed in patient with mitral-valve surgery

Fig. 2.
Medtronic Cardioblate 68000. Surgical Ablation System Generator

incidence in the ablation group comparing to the control group (no ablation performed) at both 6 and 12 months in patients undergoing mitral valve surgery (63.2% vs. 29.4%, P<0.001). Nevertheless the risk of implantation of a permanent pacemaker was also increased [34].

Radiofrequency catheter ablation (RFCA)

Radiofrequency (RF) energy is currently the most common and most dominant energy source for catheter ablation procedures. Flowing energy at high frequency causes thermal tissue damage. In the case of monopolar (unipolar) catheters used for RF energy ablation, the generated energy flows from the tip of the catheter (electrode) to the surface of the electrode, thus causing a proportional drop in the value of energy (heat) delivered to the deeper distal tissues. In the case of more popular bipolar catheters used for RF energy ablation, the flow of energy occurs between two opposite electrodes (rings mounted on a catheter), which causes a reduction of energy (heat) [35].

Cryothermal ablation

Cryothermal ablation is described as the most promising alternative to RFCA. The cryoablation catheter is equipped with a tip that can be cooled to -70 degrees Celsius or less, which is achieved by the argon nitrate infusion. In the case of the Maze III treatment, cryoablation is an integral aspect of the procedure and it is used in the area of coronary sinus. During cryoablation, the temperature of the heart muscle is reduced to a certain level with the subsequent extracellular and intracellular formation of ice crystals, which causes irreversible damage to the cells and eventually their necrosis [36]. Multiple cryoablation procedures can be used to achieve permanent cell damage. There were a big research describing and proving safety and effectiveness using a flexible cryablacial catheter based on the flow of argon during cardiac surgery performed for other reasons[37]. Another study compared 3 different sets of locations in the left atrium in which cryothermia was applied. Additional linear cryotherapy, compared with only cryo-isolation of pulmonary veins, was characterized by greater efficiency in the restoration of sinus rhythm with an effectiveness equal to 85% of the value achieved with anti-arrhythmic drugs, with the acceptance of the possibility of complete block of the heart. The abovementioned study showed the limitations of the cryoablation -65% of patients with additional linear applications develop complete heart block and in 71% of patients pulmonary veins isolation was achieved [38].

Comparison of the effectiveness of ablation using alternative energy sources and Cox-Maze III surgery

There were few studies [25] comparing the effectiveness of ablation procedures using alternative energy sources (RF current, microwave energy, cryothermia) with the classic surgical treatment of atrial fibrillation Cox-Maze III. The results of restoring the sinus rhythm in the postoperative period in the case of treatments using alternative energy sources was at the level of 78.3% against to 84.9% (p = 0.03) in the case of Maze III surgery [25]. However, after analyzing the data due to the type and duration of AF, as well as the presence and type of simultaneous cardiac surgery for other reasons, there were no statistical significance (p = 0.260) [25].

Surgical ablation of both atria compared to the left atrium ablation

The Cox Maze treatment has undergone many modifications. Currently, numerous studies are focused on determining the safest and most effective cut locations. There are few meta-analyses comparing the safety and efficacy of surgical procedures to eliminate atrial fibrillation: ablation procedures performed in

both atria compared to those performed only in the left atrium[39]. 69 studies with a total number of 5,885 patients and a 3-year follow-up were analyzed. In the group of patients who underwent any surgical AF ablation, the sinus rhythm was more likely to be restored (90.4–85.4%) than in the control group (47.2–60.9%) In analyzed time periods, patients who underwent ablation performed in both atria were characterized by more effective restoration and long-term maintenance of the sinus rhythm. (92.0–87.1%) in comparison with those who underwent ablation only in the left atrium (86.1–73.4%). The survival rate of patients was similar in both groups [34].

Conclusions

The understanding of AF pathophysiology and potential treatment has greatly increased over the past decades. The significant development of new surgical methods and procedures using alternative energy sources for ablation of atrial fibrillation has been made. The main goal of surgical ablation of atrial fibrillation is to achieve safe and effective control of arrhythmia and thus the need to take antiarrhythmic and anticoagulant drugs was eliminated.

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