

# The Maze that is Not Maze: It is Not Filling the Gap!

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## Abstract

When properly performed, the true Maze procedure is highly effective to eliminate any type of atrial fibrillation or flutter. Since non-paroxysmal atrial fibrillation is sustained by macro-reentrant circuits located anywhere in both atria, a full bi-atrial lesion pattern is the best way to approach all possible causes in one single step. As we move into less invasive surgical techniques, we must more clearly maintain the scope of the Maze procedure. Difficult approaches are oftentimes the source for incomplete, unsuccessful, and frustrated forms of the Maze. The two only alternative energy sources enabling full transmural lesions in the atrial myocardium are bipolar radiofrequency as well as cryothermia. Standardization of the Maze procedure as a full bi-atrial lesion pattern as well as the proper selection in the alternative energy source is the keystone to get the best outcome.

**Keywords:** Atria; Atrial fibrillation; Bipolar radiofrequency; Cryoablation; Maze procedure

## Introduction

On October 13, 1986, the formal initiation of surgery for Atrial fibrillation in a human took place [1]. Although it was not really a Maze procedure, as we know it today, this was the predecessor of the true Maze. However, the first Maze I procedure, recognized as such, it took place on September 25, 1987. Since then, the Maze procedure has evolved considerably. However, the secret for the Maze's success has consisted in knowing how to preserve its essence as a "full bi-atrial lesion pattern" [2]. We discuss in this paper the essence and basic aspects of the Atrial Fibrillation (AF), as well as the principles about how the Maze procedure works. This will enable us to get a general overview in order to understand the current approaches of the Maze procedure and how effective they are.

## Basic Considerations

AF is a reentry arrhythmia. Nevertheless, two basic and general conditions are necessary to produce AF. The first one is the triggers located mainly up to 90% of times into and around the Pulmonary Veins (PV), which are generating AF [3]. The second required condition is at least one macro re-entrant circuit sustaining the AF [3]. The first one leads the second one. Under normal conditions, when the atria are not electrically remodeled, the macro re-entrant circuit cannot be sustained for a long time. These circuits fade away by themselves. In this way, PV triggers can initiate a new macro re-entrant circuit over and over again. This intermittent behavior alternating with normal periods of sinus rhythm is the so-called "paroxysmal AF". On the contrary, once these macro re-entrant circuits persist in the atria for more than seven days, the atrial myocardium becomes electrically remodeled, and the circuits can stay for longer in a continuous way to the point that PV triggers are no needed anymore to produce AF. Now, the AF becomes self-sustained by means of these macro re-entrant circuits located anywhere in the both atria. This continuous arrhythmia is known as "non-paroxysmal AF" (persistent, long-standing persistent, or permanent AF) [3].

## Getting the hang of the maze procedure

One of the most important concepts discovered by Dr. Cox and his working group has been the minimum diameter size of the macro re-entrant circuit to produce AF of 6 cm or larger than this in the human atria. In such a way that if two separate incisions or burn lines are placed in parallel to less than 6 cm far away one from the other, so there will not be enough space for the development of the macro re-entrant circuits [4]. Moving from the theory into the practice, in the setting of the paroxysmal AF, PV isolation is highly effective to eliminate AF. Triggers located into and around the PV are isolated in 90% of times [5]. Nonetheless,

when approaching any form of non-paroxysmal AF (persistent, long-standing persistent) PV isolation is not enough to eliminate AF [6,7]. A much more complete procedure addressing not only the PV isolation but also all possible involved macro re-entrant circuits is required for this purpose. The Maze procedure provides an excellent option. This surgical procedure offers an outstanding solution thanks to its full bi-atrial lesion pattern approaching all possible macro re-entrant circuits in one-go, in one-single step [8].

### **The problem with the maze that is not a true maze**

In the light of the foregoing, we have to be very precise and extra cautious when selecting the lesion set pattern for surgical ablation of AF. All possible macro re-entrant circuits are located anywhere in both atria. They are not exclusive for the left atrium. Said that, in cases of non-paroxysmal AF, it is easy to understand that the only option to surgically treat this type of AF is by using a pattern as comprehensive as possible. If any incomplete procedure is utilized, effectiveness drops off dramatically. So, what does it happen when analyzing the meta-analyses and systematic reviews regarding the effectiveness of the maze procedure? Why does it seem not to be so effective? Well, to answer this question, we must tackle two extremely important issues. The first one is linked to the lack of standardization for the maze procedure [9,10]. There is actually a lack of standardization in the way of selecting the pattern for the maze procedure. From my view, according to the concept explained above, the best way to use the Maze procedure is as a full bi-atrial lesion pattern. This is the only possible way to break up all possible macro re-entrant circuits in both atria. The author has already made quite clear that the pulmonary vein and antrum isolation is not sufficient for this purpose.

In order to prove this hypothesis, the author isolated by surgical means the PV in one hundred patients in a way that no room for doubt about the transmurally of the isolation. In this series, only 30 % of patients remained in sinus rhythm after a 5-year follow-up [6]. The second one arises when gathering some articles meeting special criteria to be analyzed as part of a meta-analysis. It is quite frequent to fall into the error of accounting as Maze some cases that are not a true Maze. The less complete the maze, the worse the final outcome. It has given rise to the wrong perception that the Maze is not so effective when analyzing as a whole regardless of whether or not the procedure it is complete. By way of explanation, after analyzing all studies included in a meta-analysis about surgical ablation for AF, when analyzing the bi-atrial lesion set group, only one author out of eight (24 of 238 total patients) had correctly performed the bi-atrial Maze procedure. All other authors had used monopolar RF, electrocautery energy, incomplete PV box lesion set, or not so clear if monopolar or bipolar the procedure [11]. Another example is the meta-analysis by Li et al. [12]. They conclude that there is no difference in sinus rhythm conversion between left-sided or bi-atrial surgical ablation groups. However, it is worth stating out that when analyzing the normal sinus rhythm recovery beyond 1 year, for example, out of 7 studies matching criteria, in only 3 of them were correctly performed the Maze procedure.

A wide of variety of lesion sets as well as in the use of alternative energy sources other than bipolar RF or cryothermia are the most common errors. So, the final understanding must be the need of a real standardization to perform the Maze procedure. In one hand, the need of always using a full bi-atrial lesion pattern, regardless the underlying pathology originating the AF [9,10]. On the other hand, it is widely accepted that there are only two alternative energies to get a full and consistent transmural lesions on the atria, namely, cryolesion and bipolar radiofrequency ablation [13].

### **Less invasive techniques are not glittering at all**

In an attempt to make simpler the original maze procedure, some changes and adjustments have been made in order to achieve desired results. One of them, the main one, has been to replace the surgical incisions by burn lines using the aforementioned energies. This is the so-called Cox-maze IV procedure. This took place in 2002, by using monopolar RF as alternative energy source to surgically treat AF. Unfortunately, transmural lesions on the atrial myocardium are not consistent when using this type of energy. After FDA cleared the bipolar clamp for surgical ablation of AF in 2003, industry launched the widespread use of this device in 2004 [14]. It was quickly concluded that only cryolesion and bipolar radiofrequency caused effective transmural lesions on the atria [13]. Since then, the scope of the maze procedure has been worldwide extended. Despite the original Cox-maze III procedure remains as the gold standard [15], the Cox-maze IV procedure offers a reasonable option [16]. Still, great invasiveness has been indicated as the chief reason to be reluctant to use it.

The Maze procedure has moved toward less invasive techniques as mini-invasive approaches. In this setting, we can find three main groups, viz, the Cox-maze IV endocardial approach through a right mini-thoracotomy (on pump), the epicardial total thoracoscopic approach (off-pump), and the combined epicardial-endocardial approach, so-called hybrid Maze procedure (off-pump) [17]. The endocardial maze procedure has an effectiveness similar than the Cox-maze IV procedure because both of them are following the full bi-atrial lesion pattern by using just bipolar RF ablation as well as cryolesion over such a very critical areas (coronary sinus, mitral and tricuspid annuli) [16]. The epicardial approach is carried out by a bilateral thoracoscopy. It is an off-pump procedure. Nevertheless, bipolar RF has just a limited application, as the bipolar clamp is unable to reach all the necessary critical areas. A so-called transpolar pen is preferred to burn the mitral line, as well as the superior and inferior connecting lines at the box lesion in the left atrium [18]. Given the fact that the transpolar pen is not a true bipolar device, the penetration range of burn is wall-thickness dependent. In more than 6.7 mm of wall thickness, as often found, transmurally becomes incomplete [19]. But on the other hand, catheter-based techniques by electrophysiologists are highly effective to find some electric gaps on the burn lines. When combined epicardial and endocardial approaches (off-pump), the new hybrid maze procedure comes up [20]. Nonetheless, it is fairly worth highlighting this hybrid procedure can become as highly effective as the Cox-

maze IV procedure if adhered to the original full bi-atrial lesion pattern of the original maze procedure [20]. The major challenge has been the education in understanding the importance of using as much as possible the full bi-atrial lesion pattern in this kind of techniques. By way of explanation, the main source for failures after hybrid maze procedure has been the lack of completeness in the lesion pattern set [17,20]. However, when properly performed, the true hybrid maze IV procedure can become the gold standard for the stand-alone persistent AF once the catheter-based techniques have failed (class of recommendation IIA, level of evidence B) [21].

## Conclusion

In conclusion, most of the time, failures after the maze procedure are the result of technical errors in the selection of an incomplete lesion pattern, as well as in the selection and way of using the alternative energy sources. As a general rule, the more complete the lesion pattern, the higher the success after Maze procedure, irrespective the percutaneous or surgical approach. Special interest must be focused on performing the full bi-atrial lesion pattern as much as possible, regardless the underlying disease causing the AF.

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