



How to Correctly Perform the Cox-Maze IV Procedure: From the Theory into the Practice. Part I. Surgical Technique

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Abstract

The Cox-maze procedure has been designed to eliminate any type of atrial fibrillation or flutter. When correctly performed, success rate freedom from atrial fibrillation after operation may reach up to 90% at 5-year follow-up. Considering that the atrial fibrillation is a reentrant arrhythmia, it is sustained by macro reentrant circuits located anywhere in both atria. The key point is to break down all possible macro reentrant circuits by means of placing some surgical incisions or burn lines on both atria. Hence, the more complete the lesion pattern, the higher the success rate. A full biatrial lesion pattern is of utmost importance. One of the most common mistakes for failure is performing the procedure as a partial one. In this article we explain step by step how to perform in a correct way the full and true Cox-maze IV procedure.

Keywords

Atria; Atrial fibrillation; Bipolar radiofrequency; Cox-maze procedure; Cryoablation

Introduction

The Cox-maze procedure has been designed to eliminate any type of atrial fibrillation (AF) or flutter. Since AF is a reentrant arrhythmia which is self-sustained by means of macro reentrant circuits located anywhere in both atria, this surgical procedure is based upon breaking down all possible macro reentrant circuits sustaining the AF. The final goal is to construct a "labyrinth" or "maze" based on limiting the amount of atrial tissue available to fibrillate. Maze-like complete transmural lines are used for this purpose. Considering that fibrocyte is the worst electric conductive cell in the nature, these lines are basically composed of fibrosis. Fibrosis can be achieved by "cut-and-sew" as well as coagulative necrosis from hot or cold energy. From its inception in 1987 as Cox-maze I and II [1], it quickly evolved towards the classic standard Cox-maze III procedure in 1992 [2]. Since then, only a few little iterations have been done basically to move into some other easier and faster ways of performing. Bipolar radiofrequency (RF) (hot energy) or cryotherm (cold energy) are the only alternative energy sources, which can produce transmural and consistent lesions. Thus, by replacing surgical incisions with burn lines, the so-called Cox-Maze IV procedure has been used since in 2002 [3].

When correctly performed, the Cox-maze procedure can achieve a success rate for freedom from AF up to 90% in a long-term 5-year follow-up [4].

However, one of the major problems that the surgical world has been experiencing all over the years with the Cox-maze procedure is a lack of standardization of the surgical technique as well as in selecting the proper alternative energies source. The way of applying these energies as a full biatrial lesion pattern is crucial to get the best outcomes [5]. The more complete the lesion pattern (full biatrial lesion pattern), the better the outcome after the Cox-Maze procedure.

Off-pump Step

That said, we proceed to explain how to perform the Cox-maze IV procedure using a bipolar RF clamp (**Figure 1**). This is an open chest surgery, approaching through a median sternotomy routinely performed on cardiopulmonary bypass. After standard ascending aorta and bicaval cannulation have been done, the first step is to release both vena cavae from all the tissue around. At the same time, retroaortic space is dissected well behind up to be free all the way from the right atrial roof up to the left atrial appendage (LAA). The right pulmonary veins (PVs) are surrounded and released from both vena cava and the posterior pericardium. An 18-22Fr (6-7 mm in diameter) Foley catheter instead of a conventional rubber band is used to surround them.

The following step is to do the right atrial (RA) lesions. A transversal imaginary line is drawn on the anterior aspect of the RA just at the level where lower third meets with the

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Figure 1: Bipolar radiofrequency clamp utilized to perform the Cox-maze IV procedure.

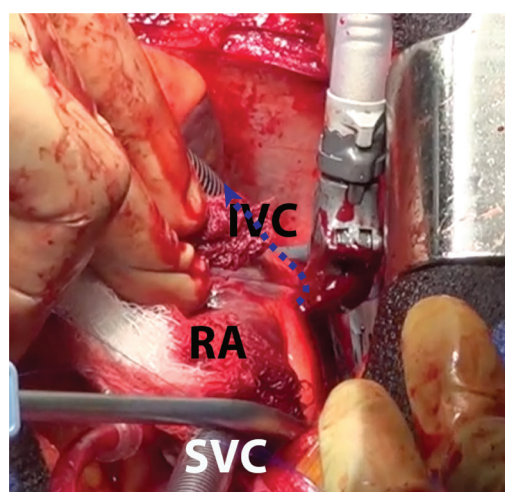


Figure 3: Inferior extreme of the intercaval line (dotted arrow-line in blue color). The clamp is directed towards the inferior vena cava. IVC: inferior vena cava, RA: right atrium, SVC: superior vena cava.

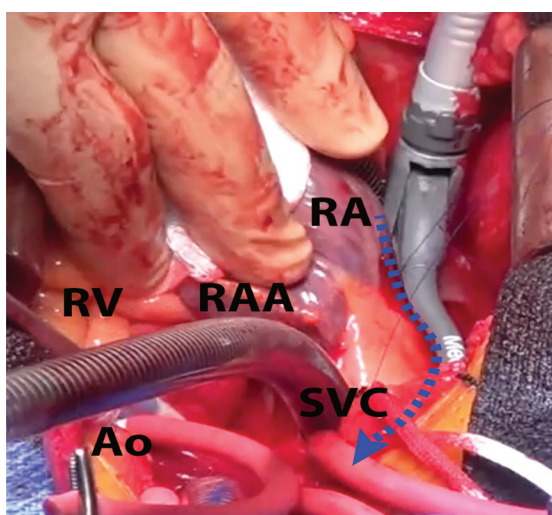


Figure 2: Superior extreme of the intercaval line (dotted arrow-line in blue color). The clamp is approaching the superior vena cava. Ao: ascending aorta, RA: right atrium, RAA: right atrial appendage, RV: right ventricle, SVC: superior vena cava. Dotted arrow-line in blue color

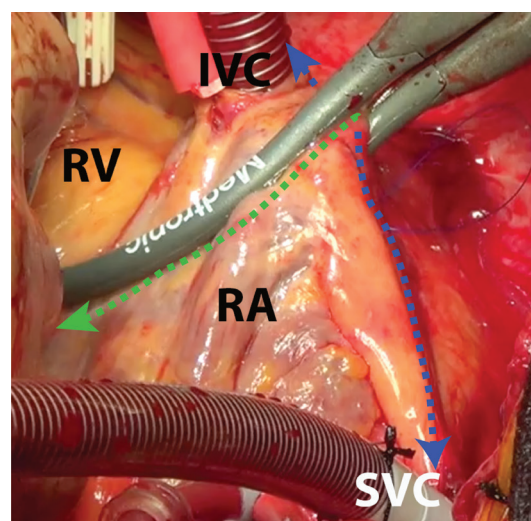


Figure 4: Transversal line in the right atrium. Dotted line in blue color: intercaval line. Dotted line in green color: transversal line in the right atrium. Of note, all the two burn lines are perfectly anchored at the site where the purse string is placed. IVC: inferior vena cava; RA: right atrium, RV: right ventricle; SVC: superior vena cava.

two superior thirds. A perpendicular line is now extended between both vena cavae. A strategic purse-string using 3-0 polipropylene is placed exactly where both lines intersect with each other. Using the bipolar RF clamp through the same purse-string, the superior vena cava is addressed. All effort must be done to reach the venous wall beyond the muscular zone of the RA (**Figure2**). Then, the same maneuver is done, but now going on the inferior vena cava (**Figure3**). A complete intercaval line is obtained. A burn line now supplies the aforementioned transverse line on the RA by placing the clamp through the purse-string on the RA towards the right atrio-ventricular (AV) groove (**Figure4**). Special care is taken to avoid reaching this groove. Otherwise, the generated heat wave could damage the right coronary artery. At the end, both transversal and perpendicular lines are forming together a "T" (**Figure5**).

The latest step before going on pump is to isolate the right PV. For this purpose, the bipolar clamp is placed surrounding the PV. Since the entire pedicle containing the right PVs must be fully included between both arms of the clamp, some special maneuvers must be taken into account. One of the arms of the clamp is incorporated inside one of the extreme of the Foley catheter surrounding the right

PVs. Now the clamp can be properly placed around the right PVs just by pulling the Foley catheter. The catheter is retired and the clamp closed. RF ablation is applied through the clamp. Two or three in-a-row overlapped applications are delivered. This maneuver increases the likelihood of success in getting a full transmural burn line around the right PVs (**Figure 6**).

On-pump Step

Now, the cardiopulmonary bypass is started. Ascending aorta is cross-clamped and cardioplegia solution administered. After the arrest of the heart, the best way to expose the left PVs and the left atrial appendage (LAA) is by pulling up and twisting the heart towards the right side. This dislodging maneuver fully exposes all this left-sided structures. Particular emphasis must be placed on the involvement of the ligament of Marshall. This anatomic structure must be completely divided by two reasons. Firstly, it is located above and in front of the left PVs. Therefore, after division the exposure of the left PVs becomes much easier. Secondly, it is a well-known fact that this ligament

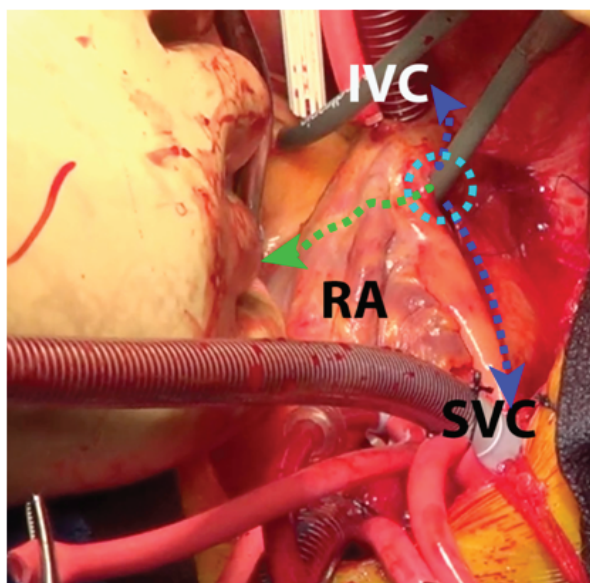


Figure 5: Both transversal and perpendicular lines are forming together a 'T' shape, represented by a light blue discontinued circle. Dotted line in blue color: intercaval line. Dotted line in green color: transversal line in the right atrium. IVC: inferior vena cava, RA: rightatrium, SVC: superior vena cava.

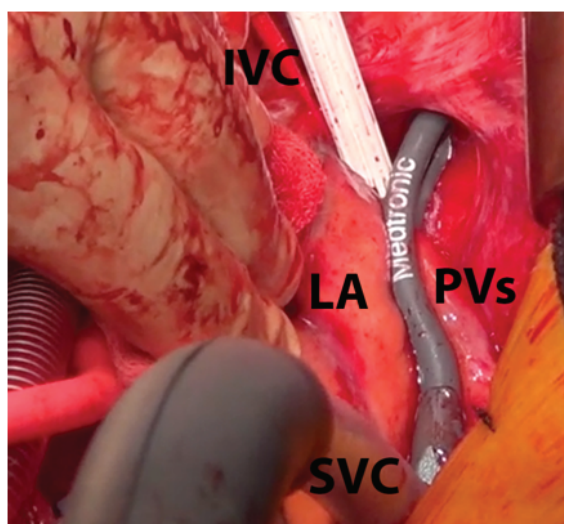


Figure 6: Right pulmonary veins isolated by using the bipolar clamp. IVC: inferior vena cava, LA: leftatrium, RA: rightatrium, SVC: superior vena cava.

may contain triggers initiating AF. Once the ligament is divided by electrocautery (**Figure7**), dissection of the left PVs is carried on. Scissors and a right angle clamp are used to cut and release all surrounding tissue around the left PVs. If the surgeon feels insecure to make this sharp dissection, a blunt dissection can be achieved by circling the vein pedicle with the thumb and index finger of the right hand until all the tissue has been removed. As in the right PVs, a Foley catheter is placed around and bipolar RF clamp is then applied several times (**Figure8**). Keeping the same anatomic exposure, the LAA is now approached. I always resect the LAA, regardless the case. Resection of the LAA from outside the heart is performed. With the heart dislocated from the pericardium, the exposure of the LAA is relatively easy. The LAA is fully exposed by pulling up with forceps. Then, it is cut with scissors just leaving no more than 1.5 cm in height in order to avoid leaving any remnant of the sac (**Figure9**). Thrombus formation may take place here when done in a wrong way. Now, introducing the clamp through the hole of the LAA performs a

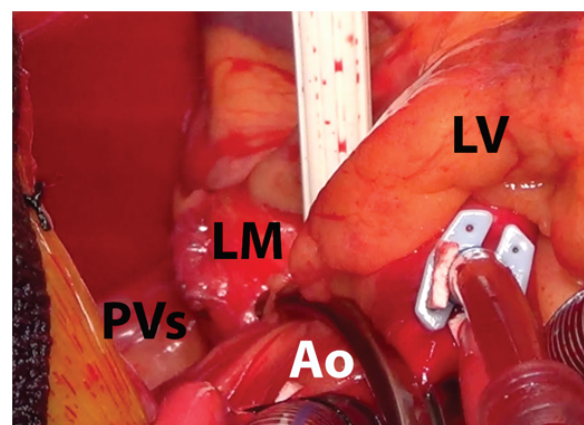


Figure 7: Sectioned ligament of Marshall. Ao: ascending aorta, LM: ligament of Marshall, LV: left ventricle, PVs: left pulmonary vein

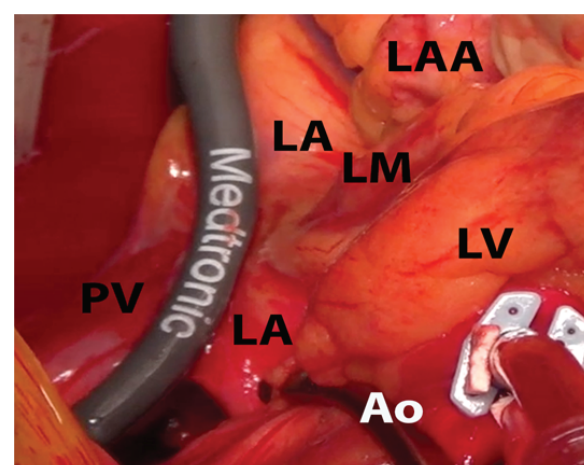


Figure 8: Isolation of the left pulmonary veins. The bipolar radiofrequency clamp is placed around the left pulmonary veins. Ao: Ascending aorta; LA: left atrium, LAA: left atrial appendage; LM: ligament of Marshall, LV: left ventricle, PVs: left pulmonary veins

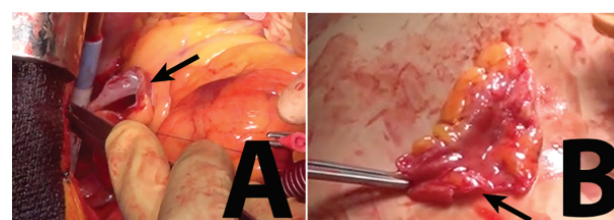


Figure 9: A: Arrow indicating the base of the left atrial appendage once resected. B: Resected left atrial appendage. The arrow is indicating the base of the left atrial appendage

communicating line between left PVs and the LAA. Since the tissue wall of the LA (left atrium) is very thin in this area, just one RF application is usually sufficient to get full transmural. One must be sure both burn lines from the LAA and the left PVs are overlapping in a T-shape(**Figure10**). After the bipolar RF clamp has been removed, the base of the LAA is closed using a 3/0 polipropylene double running suture. Preferably, teflon felt mattresses are highly recommended on both ends of the suture line. Care must be taken to avoid placing all these suture bites not so deep because the circumflex artery runs nearby. The heart is left into place. The LA is opened vertically from the right side in front of the right PVs as usually done for conventional mitral surgery. Knife must incise over the previous burn line. Then, the incision is well extended upwards and downwards through the

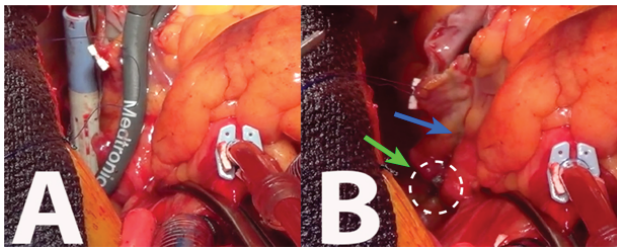


Figure 10: A: Connecting line between the base of the left atrial appendage and the left pulmonary veins applying the bipolar radiofrequency clamp. B: Both burn lines (blue arrow: connecting line, green arrow: left pulmonary veins burn line) well anchored forming a "T" shape (Circle with white interrupted line).

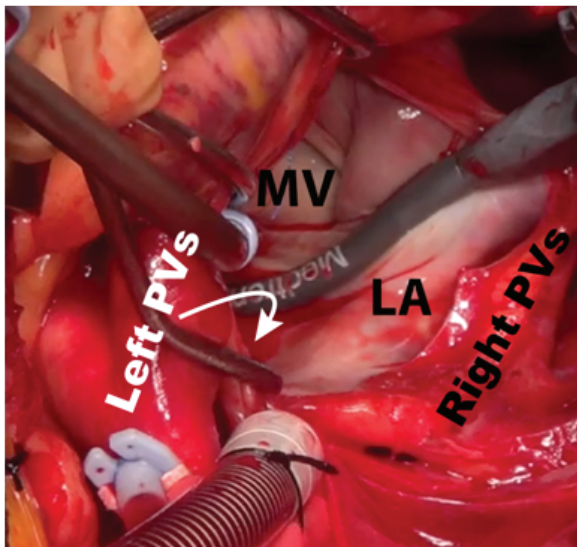


Figure 11: Left atrial box lesion set. Inferior connecting line between right and left pulmonary veins

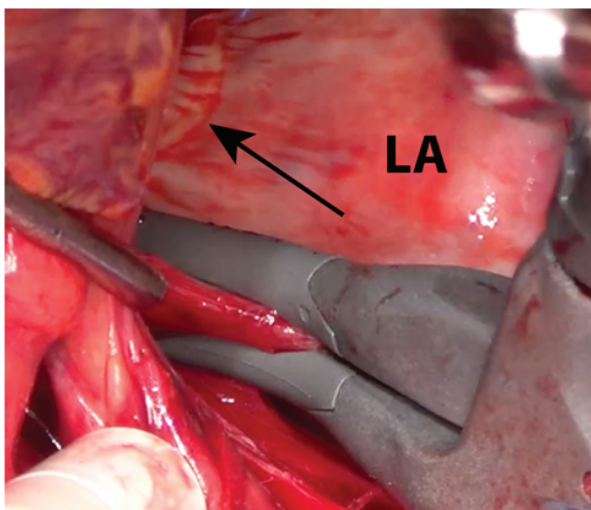


Figure 12: Left atrial box lesion set. Superior connecting line between right and left pulmonary veins. The arrow is pointing the burn line on the left pulmonary veins. LA: left atrium

anterior surface of the LA in front of the right PVs to easily expose all inside the LA. Special retraction of the LA is necessary to fully expose the four PVs. A conventional Deaver retractor is inserted. A technical point is, perhaps, worth mentioning here. The retractor is placed slightly differently than usual for conventional mitral valve

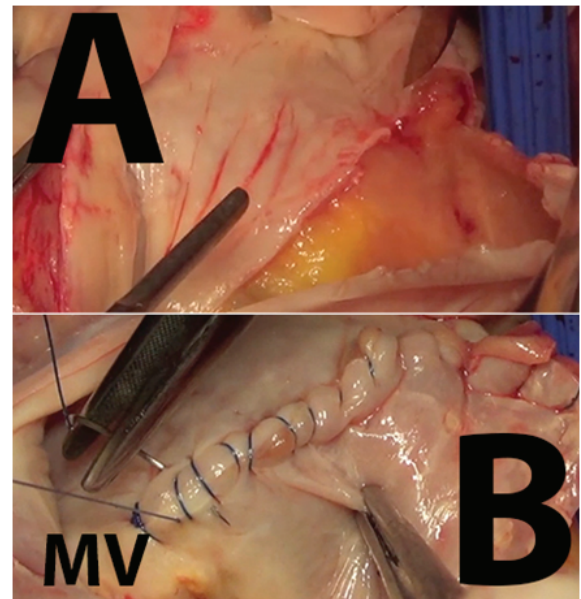


Figure 13: Mitral line located at the mitral isthmus. A: epicardial fat of the left ventricle is the limit to stop the left atrial myocardial dissection. B: Closure of the incision in the mitral line. The ending is anchored to the mitral annulus. MV: mitral valve

surgery. The entire mitral valve is included in the widest Deaver retractor that can be inserted in the LA. Gentle traction is applied, so the four PVs are now completely exposed. The PVs box lesion set is next. Placing the clamp in such a way that both right and left PVs burn lines performs the inferior connecting line (**Figure 11**). It is worth emphasizing that a perfect tailoring of the LA is extremely necessary in order to avoid any failure. A very common mistake at this step is that some tissue plications by imperfect tailoring may go unnoticed. Thus, this can result in some unburned and non-consistent areas. My best advice in order to avoid this kind of failure is to tighten the atrial tissue with forceps. In addition, several in-a-row overlapping RF application (two or three) may be eventually required. The same procedure is made now for the superior connecting line (**Figure 12**). At this point, since the ascending aorta is bulging over the LA roof, previous retroaortic dissection make easier the correct placement of the clamp up to reaching the left PVs burn line. The PVs box lesion set is now complete. The best way to make sure that burn lines are correctly anchored is by overlapping each other.

Next step is one of the most demanding all along the procedure. Also, it is one of the most common sources for errors. Therefore, it deserves our full attention. The so-called "mitral line" goes from the PVs box lesion and continues straight ahead to reach the native mitral valve annulus. At first glance, placing the bipolar RF clamp to get a transmural burn line seems to be quite reasonable. However, one should act with the utmost care. Three important facts should be highlighted here. The first one is the fact that the left ventricle is superimposed over the LA. The left ventricle covers approximately one third of the extension of the free posterior LA wall. The hinge point is where both anatomic structures meet each other with the native mitral annulus altogether. This anatomic complex is called left AV groove. As a consequence, this site acquires a considerable thickness, being mainly formed by fatty tissue. Thus, if the bipolar clamp is applied, the RF cannot be totally transmural. The second fact is that, given the fact about the anatomical implicit intricacy of the area, the true mitral valve annulus remains more than unattainable when using the clamp. And thirdly, special care needs to be taken to prevent any damage to the circumflex coronary artery and its branches. RF ablation may damage the coronary arteries and any effort must be done so as not to put in any way endanger them. A general overview can get by pulling up the apex of the left ventricle. The dominant

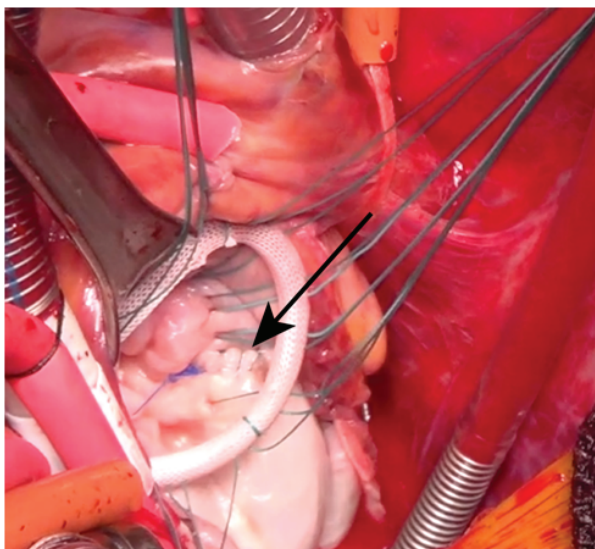


Figure 14: Mitral valve repair using a prosthetic annuloplasty ring. The arrow indicates the mitral line

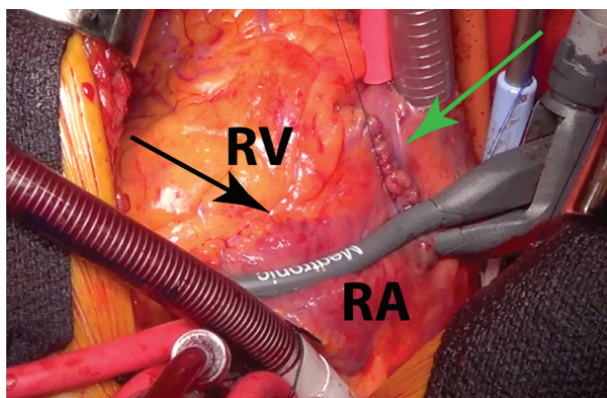


Figure 15: Perpendicular line on the anterior right atrial wall. The black arrow is showing the right atrioventricular groove. The green arrow is indicating the transversal incision on the right atrium. RA: right atrium, RV: right ventricle

coronary pattern can be observed, and we might be able to track the path of the coronary artery branches. However, the risk of coronary lesion is always present as we approach the left AV groove. After all this explanation above, it is easy to understand that there are only two possible ways to correctly perform the mitral line. Firstly, by means of the traditional “cut-and-sew” technique, or secondly, by applying cryoablation. When we decide to use “cut-and-sew”, the LA opening line is extended up to reach the mitral annulus. The cut is performed from inside the LA. The knife is carefully handled to cut bit by bit all muscular layers of the LA. The stopping point is reached when epicardial fat of the left ventricle appears (**Figure 13A**). A very useful and handy tip is placing a traction suture between P2-P3 at the level of the mitral annulus. This simple maneuver makes easier the cut over the mitral line. Special care is taken with the coronary sinus (CS). This must be practically clean-shaven exclusively with the knife. The incision is extended to the mitral annulus. Starting at the mitral pole of the incision, this is carefully closed by means of a 4/0 polipropylene double running suture. Additional measures are taken to burn with cryoablation on the external surface of the CS. External muscle fibers crossing-over the CS may allow the electric impulse to travel between both atria. Hence, when the coronary sinus is not burned out directly at its external surface, the risk for failure can be as high as 15-0%. The second way of performing the mitral line is by applying directly cryoablation from inside (mitral line) and outside (CS)

the heart. If any additional mitral valve procedure is indicated, it can be performed at this stage (**Figure 14**). The LA incision is closed with 3/0 polipropylene simple running suture. And the aortic cross-clamp is removed.

On beating heart with both cavae cannulae well snugged, a transversal incision preferably over the previous RA burn line is done. This incision is extended from inside the RA through and over the right AV groove until meeting the tricuspid annulus at 2 o'clock. This is the tricuspid counterlesion. The same principles we have stated out about the left AV groove can be applied to this anatomic area, but now on the right AV groove and the tricuspid valve. “Cut-and-sew” or cryoablation can be used to perform this tricuspid counterlesion. Special attention is drawn to include the tricuspid annulus as a part of this lesion. Once it is done, we can proceed with the direct closure of the counterlesion. Total depth stitches but without taking the right ventricle fat are placed as a single running suture. This same suture line is extended beyond the right AV groove for just 1-1.5 cm into the RA surface. Now, the bipolar RF clamp is placed from this point until reaching the tip of the RA appendage. The exact placement of the clamp is just parallel to the AV groove 1-1.5 cm outwards (**Figure 15**). No need for any other else tricuspid counterlesion at this level. Just one sole clamp application is commonly used to get full transmuralty in this area. Clamp is withdrawn and the transversal RA incision can be totally closed. Direct 4/0 polipropylene simple running suture is often utilized.

The patient is weaned from the cardiopulmonary bypass, and the rest of the procedure is carried out as usual. I only use one or two epicardial temporary wires on the anterior surface of the right ventricle before closing the chest. Full management based on antiarrhythmic, anticoagulant and diuretic therapies is according to our protocol. An integral evaluation about the cardiac rhythm is preferable made after the third postoperative month. If no arrhythmia is observed, amiodarone can be withdrawn after 3 months and oral anticoagulation after 4 months of operation, respectively.

References

1. Cox JL. The surgical treatment of atrial fibrillation. IV. Surgical technique. *J Thorac Cardiovasc Surg.* 1991 Apr;101(4):584-592.
2. Cox JL, Jaquiss RD, Schuessler RB, Boineau JP. Modification of the maze procedure for atrial flutter and atrial fibrillation. II. Surgical technique of the maze III procedure. *J Thorac Cardiovasc Surg.* 1995 Aug;110(2):485-95.
3. Damiano RJ Jr, Schwartz FH, Bailey MS, Maniar HS, Munfakh NA, et al. The Cox maze IV procedure: predictors of late recurrence. *J Thorac Cardiovasc Surg.* 2011 Jan;141(1):113-121.
4. Cox JL, Schuessler RB, Lappas DG, Boineau JP. An 8 1/2-year clinical experience with surgery for atrial fibrillation. *Ann Surg.* 1996 Sep;224(3):267-75.
5. García-Villarreal OA. Standardization in maze procedure: a step towards a better future. *J Thorac Dis.* 2018 Nov;10(Suppl 33):S3887-S3889.