Robotic-assisted biatrial Cox-maze ablation for atrial fibrillation

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Video clip is available online.

Surgical ablation of atrial fibrillation (AF) has received multisociety guideline-directed Class I recommendations on the basis of safety and longitudinal outcome.¹⁻³ The effectiveness of catheter-based ablation for persistent atrial fibrillation remains limited, often requiring multiple separate attempts for efficacy.³⁻⁵ Furthermore, recent epicardial minimally invasive surgical ablation techniques, particularly subxiphoid, are arrhythmically and anatomically incomplete and have potential major safety concerns.⁶⁻⁸

Despite the known effectiveness of the cut-and-sew Cox-maze III, there exists a reluctance on the part of patients, referring cardiologists, and surgeons to carry out a sternotomy for a stand-alone cut-and-sew surgical Cox-maze. Fortunately, the electrophysiologic principles of the Cox-maze III biatrial lesions can be identically and transmurally replicated with alternate power sources consisting of bipolar radiofrequency and/or cryothermia, as the Cox-maze IV procedure (Figure 1).^{9,10} Only surgical cryothermia has the ability to consistently construct all complete biatrial lesions as a sole power source.¹⁰

Minimally invasive platforms for the full biatrial Cox-maze using peripheral cardiopulmonary bypass (CPB) and a right mini-thoracotomy have been applied increasingly over the past several years.^{11,12} Since 2016, we have exclusively used the robotic platform to perform the complete biatrial Cox-maze lesions using cryothermic energy to apply the identical lesion set in more than 150 patients, and here we outline our technique. In conjunction with robotic

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CENTRAL MESSAGE

Robotic-assisted cryoablation can be performed safely as a standalone or concomitant single-incision and complete atrial fibrillation procedure with efficacy and outcomes that may rival alternatives.

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performance of surgical ablation, this versatile platform readily permits concomitant mitral repair or replacement, tricuspid valve repair or replacement, removal of intracardiac tumors, atrial septal defects, and, more recently, aortic valve replacement.

PREOPERATIVE PREPARATION

Once the presence of symptomatic AF has been confirmed and the patient has met guideline indications for surgical ablation, any patient without previous cardiac or right chest operation is considered for a robotic approach and preoperative anatomic imaging is performed. This includes coronary imaging for patients with significant risk factors for coronary artery disease performed by radial cardiac catheterization or coronary computed tomography angiography. Preoperative transthoracic echocardiography is often obtained should there be any concern for clot in the left atrial appendage (LAA) or the presence of moderate or greater structural valve pathology. Computed tomography angiography of the chest, abdomen, and pelvis is obtained to detect occult stenoses that could potentially elevate the risk of peripheral CPB.

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FIGURE 1. The biatrial Cox-maze lesion set, performed robotically-assisted.

OPERATIVE PREPARATION

Following informed consent, robotic-assisted biatrial Cox-maze is performed in the supine position via a 3-cm rib-sparing minimally invasive lateral thoracotomy at the level of the anterior axillary line that is facilitated by single lung ventilation. Patients receive a preinduction intrathecal injection of 0.5 mg of morphine sulfate whenever anatomically possible, in addition to surgically delivered intercostal injection of 0.25% bupivacaine to facilitate rapid postoperative recovery and timely extubation. All patients receive a double lumen endotracheal tube, left brachial arterial line, left internal jugular large-bore intravenous access, and external defibrillator pads. A bump of folded towels is placed under the right side below the tip of the scapula to facilitate a slight drop of the right shoulder and opening of the rib spaces.

The cardiac structures are accessed via the fourth intercostal space, viewing the right superior pulmonary vein under direct vision as the anatomic landmark to confirm correct thoracic entry. A soft-tissue wound retractor is placed to facilitate exposure (Alexis; Applied Medical Resources, Rancho Santa Margarita, Calif). The pericardium is opened from the IVC to the distal ascending aorta and gentle retraction sutures are placed to facilitate exposure of the heart and ascending aorta. The superior vena cava (SVC) is percutaneously cannulated with an 18- to 20-Fr cannula (FemFlex II; Edwards Lifesciences, Irvine, Calif) under transesophageal echocardiography guidance via the right internal jugular vein. The inferior vena cava (IVC) is cannulated via the right femoral vein with a 25-Fr multi-stage venous cannula that is posited in the right atrium (RA) (Bio-Medicus; Medtronic, Minneapolis, Minn). The right common femoral artery is cannulated with a 17-19 F arterial cannula (Bio-Medicus; Medtronic). A 5-Fr distal

perfusion catheter is placed in the right superficial femoral artery (Micro-Introducer; B. Braun, Bethlehem, Pa) in all cases. In cases in which femoral cannulation is not deemed safe, the right axillary artery may be used.

Robotic ports are inserted via stab incisions at the following locations: third intercostal space anterior axillary line for the left arm, fourth intercostal space midclavicular line for the dual blade left atrial retractor, and fifth intercostal space mid-axillary line for the right arm. A stab incision in the second intercostal space posterior axillary line is made for later passage of a transthoracic aortic crossclamp and one at the same level in the fifth intercostal space for later passage of a left ventricular (LV) vent. Following commencement of CPB, a cardioplegia cannula is inserted into the ascending aorta for the administration of antegrade cold cardioplegia (Antegrade 14F long MIS; Medtronic), and an LV vent is inserted via the right superior pulmonary vein (LV Vent 20F DLP; Medtronic). The Da Vinci Xi robotic system (Intuitive Surgical Inc, Mountain View, Calif) is then docked. The high-definition camera is positioned at the superior aspect of the working incision. The robotic instruments generally used are the DeBakey forceps in the left arm, the endowrist dual blade atrial retractor in third arm, and the needle driver or scissors in the right arm (Figure 2). Carbon dioxide is continuously infused via the third arm port. A previously positioned transthoracic aortic crossclamp is gently applied to the distal ascending aorta under full camera visualization. Intermittent antegrade cold blood 8:1 cardioplegia is delivered at 20-minute intervals to maintain optimal myocardial protection throughout the operative procedure.

Following robotically performed atriotomies, a nitrous oxide cryoprobe (AtriCure, Cincinnati, Ohio) is used to apply lesions in a prespecified consistent manner while visually confirming complete tissue contact without gaps (Figure 1). Left atrial lesions are each performed for

FIGURE 2. Robotic operative preparation with a 3-cm thoracic access incision.

VIDEO 1. Robotic-assisted biatrial Cox-maze surgical ablation for atrial fibrillation. Video available at: [https://www.jtcvs.org/article/S0022-5223\(21\)01408-2/fulltext](https://www.jtcvs.org/article/S0022-5223(21)01408-2/fulltext).

3 minutes, whereas each right atrial lesion is created for 2 minutes. Following completion of the lesions, the LAA is surgically obliterated in all cases (Video 1).

LEFT ATRIAL LESIONS

Following a robotically performed left atriotomy, the dual blade atrial retractor is inserted to provide exposure of the left atrium. The coronary sinus lesion is then epicardially performed via the oblique sinus (Figure 3) and the consequent endocardial ice ball in the left atrium is marked

with a surgical marking pen (Video 1). This mark assures that the eventual endocardial mitral isthmus line will be constructed at the same level as the coronary sinus lesion. Next, the inferior half of the pulmonary vein encircling, or “box,” lesion is created with the tip of the probe extending out along the length of the LAA (Figure 4). The superior box lesion is then completed with the roof line intersecting with, and overlapping, the inferior box lesion. Importantly, this superior box lesion is performed parallel to the right superior and left superior pulmonary veins to avoid inadvertent electrical interruption of Bachman’s bundle. Finally, the endocardial mitral isthmus lesion is made to the posterior mitral annulus, often at the level of the P3 mitral scallop. To avoid perimitral atrial flutter recurrence, this line is at the exact level as the epicardial ablation of the coronary sinus, covering the previously placed surgical mark.^{9,10}

RIGHT ATRIAL LESIONS

The right-sided lesions are performed following a vertical right atriotomy placed in the caudal third of the RA to purposely avoid any anatomical interruption of the SA nodal complex of the mid RA body, a potential cause for postoperative sinus node dysfunction or junctional rhythm. Vacuum-assisted venous drainage to control caval inflow makes snaring unnecessary. Cryothermic ablation lines

FIGURE 3. Left atrial cryothermic Cox-maze Lesions. A, Robotic-assisted placement of the epicardial coronary sinus lesion. B, Inferior box lesion extending into the left atrial appendage. C, Superior box lesion overlapping with the inferior box lesion. D, Mitral isthmus line crossing the previously location of the coronary sinus lesion.

FIGURE 4. Right atrial cryothermic Cox-maze lesions. A, Following vertical atriotomy in caudal third of right atrium, a tricuspid completion line to the tricuspid annulus is performed. B, Superior vena cava line placed posterolaterally to avoid the sinoatrial nodal complex and mid right atrial body. C, Inferior vena cava line. D, The right atrial appendage line into the tip of the appendage placed at the most anterior aspect of the atrium from the edge of the vertical atriotomy in a parallel course to the superior vena cava line, thus completely avoiding the mid right atrial body.

are created to the anterior tricuspid annulus, the SVC, the IVC, and the right atrial appendage. This latter lesion has been specifically modified from a tangential cryo-lesion¹³ to one that is parallel to the SVC lesion and perpendicular to the vertical right atriotomy so that the mid RA body is completely avoided.⁹ Additionally, when constructing the SVC line, it is also important to stay posterior to the SVC-RA junction to avoid the sinoatrial node complex during ablation. During formation of the line to the SVC and IVC, care must be taken to ensure that the probe does not come in contact with the adjacent pericardium and the subjacent but protected right phrenic nerve. When performing the line to the tip of the right atrial appendage, the probe is positioned within 5 mm of the atrioventricular groove to avoid injuring the paranodal region.¹⁴ If these technical principles of RA lesions are followed, junctional rhythm following surgical ablation, and the potential lesion-based etiology to pacemaker requirement may be readily avoided.^{10,14}

LEFT ATRIAL APPENDAGE OBLITERATION

Obliterating the LAA can directly impact stroke and long-term survival.¹⁵⁻¹⁷ Exclusion of the appendage can be performed by left atrial clipping, suture closure, or epicardial stapling. When performing open and robotic

Cox-maze operations, we prefer an important modification of direct suture closure.¹⁷ It is essential to note that this is not a purse-string or single layer closure that is known to be prone to reopening. Performed with polytetrafluoroethylene suture, this is a 2-layer deep closure that incorporates the entire body of the LAA to achieve complete and durable obliteration.¹⁴ The first suture line at the os of the LAA also incorporates the entire body of the LAA that is intussuscepted so as to collapse and obliterate it. The second suture line imbricates the first with a running Lembert suture that further plicates the LA wall and eliminates tension on the suture line (Video 1). This leaves a homogeneous smooth endoatrial surface of complete obliteration at least 1 to 2 cm away from the mitral annulus. Both right and left atriotomies are then closed robotically with a running 4-0 polytetrafluoroethylene suture followed by robotic placement of epicardial RA and right ventricular temporary pacer wires before cardioplegic reanimation and crossclamp removal.

POSTOPERATIVE CARE AND FOLLOW-UP

The patient is separated from CPB and the pericardium is primarily closed after placement of a single soft silicone-based chest drain. Patients who were not previously loaded with amiodarone are given an intravenous amiodarone

infusion at the commencement of CPB. All patients are most often in normal sinus rhythm or atrially paced at the completion of the operative procedure. In our experience, no patient is in AF nor in need of cardioversion from an AF rhythm at the conclusion of the procedure. Following incision closure and completion of pharmacologic anesthetic reversal, the patient is most commonly extubated in the operating room and transferred to the intensive care unit. The intraoperative infusion is transitioned to oral dosing starting on postoperative day 1, which is continued for 90 days. For the rare patient known to be previously intolerant to amiodarone, no amiodarone is administered during the procedure and sotalol is started on postoperative day 1.

Once supplemental oxygen is weaned and the chest tubes are removed, patients are ready for discharge, often by the third or fourth postoperative day. Any rare patient to develop early postoperative AF is electrically cardioverted. No patients are discharged in AF. All patients receive guideline-directed follow-up at 1, 3, 6, 9, 12, 18, and 24 months, with a 24-hour Holter continuous monitor before every visit after 6 months.¹⁷ Yearly visits with Holter monitoring are obtained thereafter. Unless there are specific indications (mechanical or bioprosthetic replacements, clotting diathesis, depressed left ventricular function), patients are not routinely anticoagulated.^{3,17}

SUMMARY

Catheter-based ablation for persistent AF has limited effectiveness, often requiring multiple subsequent ablations.³⁻⁵ Epicardial attempts at minimally invasive ablation, particularly subxiphoid or transdiaphragmatic is often incomplete, does not address the LAA, and may expose to a unique increased set of complications.⁶⁻⁸ Robotic-assisted biatrial surgical ablation can be safely performed as a standalone or concomitant procedure and offers the ability to perform the full Cox-maze III/IV as well as direct LAA obliteration.^{9,17} The safety profile and outcomes of robotic surgical ablation may mimic those obtained with sternotomy Cox-maze operations while providing a single-stage, single-incision, minimally invasive procedure to rival alternatives.

Conflict of Interest Statement

The author reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict

of interest. The editors and reviewers of this article have no conflicts of interest.

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