Off Pump Microwave Ablation of Atrial Fibrillation during Mitral Valve Surgery

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The off pump technique demonstrated here for the AFx Flex 4™ microwave antenna is applicable for any energy source that uses a narrow flexible ablation probe that is shielded on its outside surface. Microwave, diode laser, and high-intensity focused ultrasound are examples of such tools either now available or under development.

Left atrial appendage (LAA) thrombus must be excluded before epicardial ablation. Transesophageal echo (TEE) excludes obvious thrombi, but even when negative, a gentle surface echocardiogram of the appendage is still performed using an epiaortic ultrasound probe which is a more sensitive examination. All patients with an appendage thrombus undergo endocardial ablation via atriotomy with open removal of the thrombus. Left atrial diameter is measured in all patients on TEE, primarily for prognostic value regarding success.
The Tri-ring lesion pattern was developed specifically to treat atrial fibrillation (AF) associated with mitral valve disease.\textsuperscript{1,2} The lesions are based on evidence of triggers arising from the pulmonary vein muscle sleeves as well as the left atrial appendage. The connecting lesions in this pattern are safely applied without risk of coronary artery injury. The appendage is removed in the modified Tri-ring pattern shown here to avoid trying to ablate the sometimes thick appendage base which has a trabeculated inner surface.

The creation of transmural lesions during off-pump epicardial ablation is harder to achieve than during endocardial ablation in the empty opened left atrium. Transmurality requires that heat delivered to atrial tissue by the probe overcomes the cooling effect of circulating left atrial blood.\textsuperscript{3} The Flex 4\textsuperscript{TM} antenna is therefore set at a power of 65 W and the timer at 90 seconds. This compares to the settings of 65 W and 45 seconds used during endocardial ablation in the open atrium. The antenna must be held steady during lesion delivery to achieve narrow deep lesions rather than wide superficial lesions.
The right atrium must be peeled back from the left atrium to expose the anterior junction of the right pulmonary vein trunk with the left atrium. Failure to do this may result in a lesion that is shallow due to the fat pad and the absorption of the energy by the overhanging right atrium.

Three pericardial reflections are also opened. The first lies between the superior vena cava (SVC) and left atrium just below the level of the right pulmonary artery. The second consists of thin tissue separating the oblique and transverse sinuses. This reflection is best approached by first opening the fat pad on the left atrial dome, between the SVC and aorta. Retraction of the aorta with the handle of a Metzenbaum scissors aids visualization. As the fat is peeled away, blunt dissection establishes a plane leading posterior to the underside of the left atrium. A large curved clamp then passes around the dome gently as the tip of the clamp is felt by the surgeon’s right hand which is placed into the oblique sinus under the heart. The clamp can then be safely passed through the reflection, which is easy to penetrate. The third pericardial reflection that is opened lies between the inferior vena cava (IVC) and right inferior pulmonary vein.
Patients are heparinized before ablation. Ablation lesions are made on the left atrium rather than on the pulmonary vein muscle sleeve to electrically isolate the entire muscle sleeve without risk of pulmonary vein stenosis. Wherever possible, the lesions are placed 1 cm away from the pulmonary vein junction.

Four lesions are usually needed to encircle the right pulmonary vein trunk. If a standard atriotomy for mitral valve exposure is anticipated, this can substitute for the anterior lesion. The lesions are placed with 5-mm overlap to avoid gaps. (A) The probe is passed from lateral to medial under the SVC, and posteriorly around the back of the left atrium, with good contact against the left atrial wall. The probe must be visualized during ablation to ensure it does not ride up onto the sinoatrial node region of the right atrium. Touch-up lesions to achieve transmurality are most common along the dome of the atrium. (B and C) Since the posterior lesions are hidden from view, overlap is best achieved in this location by crossing of the lesions at a slight angle. The black line indicates the inactive side of the probe and must be visualized as the probe is placed behind the atrium to prevent collateral tissue damage to the underlying esophagus.
Pulmonary vein electrograms are used to assess transmurality and absence of gaps after each pulmonary vein trunk has been circled with lesions. The electrograms measure epicardial muscle sleeve electrical activity that is conducted from the left atrium to the pulmonary vein, and can be interpreted by the surgeon. Ideally, pulmonary vein electrograms are read on a multichannel recorder that simultaneously records the surface electrocardiogram (ECG) to recognize far field QRS interference. The amplitude of the signals is similar to those of intracardiac atrial electrograms recorded by pacemaker leads.

A reliable method that uses readily available materials feeds the signal from the two distal electrodes of an electrophysiology (EP) recording catheter into the atrial socket of a discarded reusable dual chamber pacemaker that is then telemetered to an internal cardioverter defibrillator (ICD) programmer with attached limb leads. We have found that the Guidant ICD programmer gives a clean signal free of artifact. The complete absence of electrical activity postablation is an endpoint that can be printed on chart paper to document successful pulmonary vein isolation. (A) The pericardium and underlying fat must be peeled away to expose the muscle sleeve for proper recording. The bipolar recording probe is placed lateral to the intended line of ablation to obtain a baseline recording. On occasion, no baseline signal is obtained because of an absent or very short muscle sleeve, most commonly on the left inferior pulmonary vein. (B) A recording of the right superior pulmonary vein (PV) electrogram of a patient in sinus rhythm showing a large conducted muscle sleeve depolarization preablation which essentially coincides with the p wave on the limb lead. This depolarization is eliminated postablation. (C) Typical pre- and postablation PV electrograms from a patient in atrial fibrillation.
The left atrial appendage and left pulmonary veins are best viewed by retraction of the heart toward the right using a strap made from a moist vaginal pack cut to a length of four Metzenbaum scissors. (A) The strap is sutured to the pericardium in the oblique sinus to the right of midline so that the left inferior pulmonary vein is not obscured by the strap itself.
Continued. The straps are positioned so that the superior one holds the base of the sometimes dilated left ventricle out of the line of vision. (B) The right diaphragmatic attachment of the pericardium is released to within 1 cm. of the phrenic nerve. This allows the heart to enter the right chest without kinking the SVC. Trendelenberg position and low dose dobutamine may be necessary in patients with cardiomyopathy; on pump ablation is preferable in cases where exposure compromises hemodynamics.
Three or four lesions are required to isolate the left pulmonary vein trunk. Although greater cardiac retraction is necessary to ablate around the left pulmonary veins, the dissection required to surround the veins is fortunately minimal. (A) The pericardial reflection separating the transverse and oblique sinuses is thin and easily penetrated with a blunt curved clamp. There is a thin fat pad that covers a recess between the left superior pulmonary vein and the base of the appendage, which is opened to peel the two structures apart. A thicker fat pad covering the dome of the left atrium is peeled away to allow the probe to contact directly on the left atrial muscle.
Continued. (B) The probe is held against the posterior left atrium during ablation to maintain good contact. The circumflex artery is easily avoided during delivery of anterior lesions by avoiding probe slippage. Touch-up lesions are applied if pulmonary vein electrograms are not silent after the trunk has been encircled. The left atrial dome fat pad is the usual location for nontransmurality or gaps.
A connecting lesion is made from the left superior pulmonary vein across the lateral left atrial appendage. The lesion goes sufficiently far onto the appendage so that it crosses the subsequent line of excision. Dry gauze is placed under the appendage to prevent the microwave energy from injuring the underlying left ventricle. Two applications of ablative energy are made without moving the probe to improve transmurality. An effort is made to not compress the lateral and medial walls of the appendage together to minimize thermal coagulum from forming near the tip of the appendage. The appendage is not manipulated until excision after placing this lesion.
A connecting lesion is placed between the left and right pulmonary vein encircling lesions at the level of the inferior pulmonary veins; the posterior left atrium is thin in this location, which favors transmurality. Two lesions are required to span the distance. There should be a 1 cm overlap of these two lesions, which are at a slight angle to each other, to avoid a gap. 

(A) The ventricle is lifted cephalad briefly to place the Flex 4™, then let down with a hand holding the probe against the left atrium to steady the smooth faced probe. The vaginal pack straps are usually not helpful for this lesion. The heel of the probe slightly crosses the line of ablation around the left inferior pulmonary vein.
Continued. (B) The IVC prevents visualization of the right PV trunk in the oblique sinus; therefore, the second lesion is placed with the handle of the probe lateral to the IVC and the antenna under the IVC against the left atrium. The right inferior pulmonary vein and its encircling lesion can now be seen to ensure it is intersected by the connecting lesion.
The left atrial appendage is removed after placement of the connecting lesions. (A) After application of a small straight vascular clamp oriented perpendicular to the left pulmonary vein trunk, the appendage is excised. The line of excision should cross the connecting microwave lesion on the lateral appendage. Strips of native pericardium are used to reinforce a double suture line of 4-0 prolene.
Continued. (B) A 45-mm Endo-GIA stapler with 4.8-mm staples and dry Peristrips can also be used to remove the left atrial appendage. The stapler is oriented similar to the vascular clamp. A 4-0 prolene mattress stitch is sometimes necessary to close the posterior end of the staple line if the appendage has a large base.

The morphology of the LAA varies and occasionally a residual cul-de-sac remains after excision. In this case the LAA opening must also be oversewn endocardially during the valve procedure to avoid postoperative thrombus formation. A running double layer of 3-0 prolene is used.

The appendage can be friable and thin in the elderly. In these patients, and those with left atrial distension due to valvular insufficiency, it is easier to excise if the left atrial pressure is temporarily reduced either with Trendelenberg position or a vasodilator. In some patients, if a difficult appendectomy is anticipated, it is preferable to cannulate and initiate cardiopulmonary bypass immediately before performing appendectomy.
POSTOPERATIVE CARE

Before closure, temporary electrodes are placed on the lateral right atrial wall in all patients to allow postoperative atrial electrograms for diagnosis of atrial dysrhythmias, and for overdrive pacing of postoperative atrial flutter. Virtually all patients leave the OR with p waves but early return of atrial fibrillation occurs in over half of patients. Beta blockers are given routinely as tolerated. Amiodarone is loaded and continued at 200 mg orally daily for 3 months; it is continued for up to 6 months if the patient has not yet converted to sinus rhythm.

Coumadin is given for 6 weeks and continued while the patient has postoperative atrial dysrhythmias. Patients with a suspected incomplete left atrial appendectomy should be treated with anticoagulation as though appendectomy was not performed.

COMMENTS

The technique described here does not treat typical right atrial flutter, a condition that can coexist with atrial fibrillation. We now apply endocardial lesions in the right atrium in patients with mitral valve associated atrial fibrillation that either have a history of atrial flutter, or who require a right atriectomy for tricuspid valve repair or closure of patent foramen ovale (PFO).

The classic cavotricuspid lesion to cure typical right atrial flutter extends from the tricuspid annulus at the posterior leaflet attachment to the medial inferior vena cava, running just anterior to the coronary sinus. This lesion is delivered at 65 W for 45 s using the Flex 4™. A lesion from the right atriotomy to the lateral IVC, avoiding the phrenic nerve, is also given because atypical flutter can arise from the atriectomy itself. Finally, a lesion is made from the fossa ovalis to the cavitricuspid lesion if a PFO or atrial septal defect has been repaired.

A total of 59% of patients have tolerated this procedure off pump. In general, two types of patients require cardiopulmonary bypass to accomplish epicardial ablation: 1) patients who present with chronically enlarged right atria, in which the inferior vena cava can be quite foreshortened, dilated and thin walled; and 2) patients who have both aortic and mitral insufficiency. Valvular insufficiency tends to increase when the heart is rotated to the right to expose the left pulmonary veins; this maneuver may be difficult for these patients to tolerate, even for brief periods of time.

The procedure described here has been used not only in mitral valve-associated atrial fibrillation but also in patients undergoing sternotomy for other cardiac conditions. It is particularly suitable for patients undergoing off-pump coronary artery bypass (OPCAB) who have continuous atrial fibrillation. These patients, unlike those with paroxysmal AF, usually need a more comprehensive lesion pattern than simple bilateral pulmonary vein isolation. Exposure of the left pulmonary veins tends to be better tolerated. In patients with significant ischemia, bypass grafting is performed before ablation. The left internal mammary artery graft (IMA) graft is made longer than usual to avoid stretching when the heart retracts into the right chest.

Epicardial microwave ablation using the Tri-ring pattern has been applied in 27 patients. Table 1 shows a comparison in efficacy between off pump and on pump ablation during the first year of follow-up. Freedom from atrial fibrillation and flutter improves over time, and is somewhat higher in the on-pump group. We compared the ability to achieve silent electrograms between the two groups, and lesion transmurality using the Flex 4™ was clearly superior when lesions are delivered on-pump (Table 2). We now restrict off-pump ablation with the Flex 4™ to older and sicker patients who have a compelling reason to limit bypass time. Newer energy sources such as bipolar radiofrequency are able to achieve the Tri-ring pattern with excellent transmurality and are a reasonable alternative to on-pump microwave ablation if right atrial flutter lesions are not required.

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REFERENCES


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Table 1. Comparison of Results On Pump versus Off Pump

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<th>Percentage Freedom from AF or AFL (N) Anniversary Dates</th>
<th>1 Month</th>
<th>3 Months</th>
<th>6 Months</th>
<th>1 Year</th>
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<tr>
<td>On Pump</td>
<td>63.6% (11)</td>
<td>77.8% (9)</td>
<td>77.8% (9)</td>
<td>100% (6)</td>
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<td>Off Pump</td>
<td>62.5% (16)</td>
<td>55.8% (13)</td>
<td>69.2% (13)</td>
<td>88.9% (9)</td>
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<td>Total</td>
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<td>63.6% (22)</td>
<td>72.7% (22)</td>
<td>93.3% (15)</td>
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Table 2. Postablation Pulmonary Vein Electrogram Silence

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<th>All 4</th>
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<th>2 Non-silent</th>
<th>3 Non-silent</th>
<th>4 Non-silent</th>
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<td>On Pump</td>
<td></td>
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<td>N = 7</td>
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<td>3</td>
<td>2</td>
<td>1</td>
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