

Transthoracic Epicardial Catheter Ablation
– Indications, Techniques, and Complications –

Takumi Yamada, MD, PhD

Transthoracic epicardial catheter ablation is a useful supplemental or even preferred strategy to eliminate cardiac tachyarrhythmias in the electrophysiology laboratory. The indication for this technique has extended to a diverse range of cardiac arrhythmias, including scar-related ventricular tachycardia (VT), idiopathic VTs, accessory pathways, atrial tachycardias, inappropriate sinus tachycardia, and atrial fibrillation, as the epicardial substrates of these tachyarrhythmias have become increasingly recognized. When endocardial ablation and epicardial ablation through the cardiac veins are unsuccessful, transthoracic epicardial ablation should be the next option. Intrapericardial access is usually obtained through a subxiphoid pericardial puncture. This approach might not be possible in patients with pericardial adhesions caused by prior cardiac surgery or pericarditis. In such cases, a hybrid procedure involving surgical access with a subxiphoid pericardial window and limited anterior or lateral thoracotomy might be a feasible and safe method of performing epicardial catheter ablation in the electrophysiology laboratory. Potential complications associated with this technique include bleeding and collateral damage to the coronary artery and phrenic nerve. Although the risk of these complications is low, electrophysiologists who attempt epicardial catheter ablation should know the complications associated with this technique, how to minimize their occurrence, and how to rapidly recognize and treat the complications that they encounter. This review discusses the indications, techniques, and complications of transthoracic epicardial catheter ablation. (Circ J 2013; 77: 1672–1680)

Key Words: Epicardial catheter ablation; Tachyarrhythmias; Transthoracic approach; Ventricular tachycardias

Catheter ablation is an effective treatment that can cure tachyarrhythmias. The techniques and technologies of catheter ablation have been progressively advancing to treat more challenging tachyarrhythmias. A decade ago, transseptal catheterization was not a routine technique for most practicing electrophysiologists. However, once ablation of atrial fibrillation (AF) emerged, electrophysiologists learned to perform transseptal punctures, and tools were subsequently developed so that they could do it routinely. The same thing is now about to occur with pericardial access and interventions. Epicardial ablation has been performed for many years within the cardiac veins or above the semilunar valves to treat accessory pathways (APs) or focal origins of ventricular tachycardia (VT). However, most practicing electrophysiologists do not perform epicardial interventions with a transpericardial approach because the pericardial space has long evoked a sense of trepidation for them. The pioneering work of transcoracic epicardial catheter ablation by a transpericardial approach to treat VT was first reported by Sosa and his colleagues in 1996. Since then, the epicardial substrates of tachyarrhythmias have been increasingly recognized and transthoracic epicardial mapping and catheter ablation have been proven to enhance the success rate of catheter ablation and help patients avoid a surgical procedure. This review discusses the indications, techniques, and complications of transthoracic epicardial catheter ablation.

Techniques

Percutaneous Access to the Pericardial Space

Intrapericardial access is obtained through a subxiphoid pericardial puncture, with an 18-gauge epidural introducer needle angled at 20–30 degrees advanced into the pericardial space aiming toward the left midclavicle at the cardiac border under fluoroscopic guidance (Figure 1). The angle entry may need to be adjusted according to whether an anterior or posterior approach is preferred. Puncturing below the cartilage of the ribs usually does not encounter strong resistance until the stronger resistance of the diaphragm is felt. The cardiac contraction can be felt through the needle itself. Crossing this relatively thin zone that is directly attached to the strong texture of the fibrous pericardium should be performed under constant negative pressure. When entering the pericardial space, a small volume (2–3 ml) of pericardial fluid can be aspirated. Subsequently, contrast medium is injected to demonstrate the position of the needle tip, and a J-tipped, floppy guidewire is then introduced through the needle until its tip is free within the pericardial space. A long sheath is advanced into the pericar-
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required to facilitate better access and contact of the ablation catheter at the presumable target region.

An irrigated radiofrequency ablation catheter is used for epicardial sites accessed via the pericardial approach. Current is delivered with the electrode in the power-control mode, with a maximum power output of 30–50 W for 1–2 min at each ablation site. An irrigation flow rate of 15–30 ml/min is used and care is taken to limit the electrode temperature to <41°C. Irrigation enables radiofrequency energy to be delivered to locations where little or no convective cooling of the ablation electrode by blood flow occurs. Irrigated radiofrequency ablation is more effective than non-irrigated radiofrequency ablation in generating epicardial lesions in the presence of epicardial fat interposed between the ablation electrode and target site in the myocardium.

The efficacy of transthoracic epicardial radiofrequency ablation can be limited by inaccessibility of the myocardial site of origin, close proximity to the coronary artery, or an epicardial location that lies beneath a fat pad (ie, near the atrioventricular groove). Cryothermal ablation might be a viable alternative to radiofrequency ablation in patients with a high impedance over a thick fat pad, or a VT origin close to a coronary artery, because it is not limited by the impedance and is safer than radiofrequency ablation because of a lower risk of damage to the vessel and thrombus formation.

Absence of
dial space over the guidewire to enable aspiration of pericardial fluid and delivery of the ablation catheter to the epicardial surface of the atrium and ventricle.

The percutaneous subxiphoidal intrapericardial approach might not be possible in patients with pericardial adhesions caused by prior cardiac surgery or pericarditis. Because pericardial adhesions are anticipated to be denser in the anterior wall, the nonsurgical transthoracic epicardial puncture may have to be directed to the inferior wall of the left ventricle (LV), allowing for ablation of the inferolateral LV. Accumulation of contrast medium in the inferior wall instead of spreading around the cardiac silhouette during the epicardial puncture procedure may suggest pericardial adhesions (Figure 2). The catheter can be used to gently lyse adhesions manually, by vibration, or by applications of radiofrequency energy. In individuals with pericardial adhesions, a hybrid procedure involving surgical access with a subxiphoid pericardial window and limited anterior or lateral thoracotomy might be a feasible and safe method of performing epicardial catheter ablation in the electrophysiology laboratory (Figure 2).³

Epicardial Mapping and Catheter Ablation

Once the mapping catheter is introduced through the sheath into the pericardial space, it can usually move around without difficulty. However, a deflectable sheath may sometimes be
Electrocardiographic Recognition of Epicardial VT

The 12-lead ECG tracings are very helpful for determining the likely epicardial VT origin prior to the electrophysiological study. In human hearts, the Purkinje network is located only at the subendocardium. This anatomical background means ventricular activation from the epicardial origin takes more time to return to the Purkinje network, which results in a slow onset of the QRS during epicardial VTs. Based on this mechanism, several parameters predicting epicardial VT origins have been proposed: a “pseudo-delta” wave duration >34 ms, QRS complex duration >200 ms, delayed intrinsicoid deflection of >85 ms, RS complex duration >121 ms, and maximum deflection index (calculated by dividing the shortest time from the QRS onset to the maximum deflection in any of the precordial leads by the total QRS duration) >0.54.

When the ventricular activation propagates from the epicardial origin at the LV free wall or ventricular posterior wall, the total activation vector should go from the lateral toward the medial or from the inferior toward the superior, resulting in a QS pattern in lead I or lead aVF. On the other hand, when the ventricular activation propagates from an endocardial origin on the LV free wall or posterior ventricular wall, part of the activation vector should go toward the lateral or inferior, which reflects the activation conducting through the ventricular muscle wall toward the epicardium, resulting in the presence of an initial R wave in lead I or lead aVf. Therefore, a QS pattern in lead I or lead aVf suggests an epicardial origin in the LV free wall or posterior ventricular wall, respectively (Figure 3).

Indications for Transthoracic Epicardial Ablation

The indications for transthoracic epicardial ablation have extended to a diverse range of cardiac arrhythmias, including scar-related VT,10-12 idiopathic VTs,12,13 APs,14,15 atrial tachycardias (ATs),16 and AF.17,18 Electrophysiologists should make their decision on the indication of transthoracic epicardial mapping and ablation based on the electrocardiographic and electrophysiological findings at any time during the procedure.
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Cardiac ablation should be considered. The activation time and pace map in the cardiac veins are a helpful reference during transpericardial mapping. Catheter ablation in the LV summit and crux has the potential risk of damage to the coronary arteries. Therefore, coronary angiography is mandatory to prevent this complication during catheter ablation in these regions.

Scar-Related VT

The mechanism of scar-related VTs is predominantly based on macro reentry. A critical site of such a reentrant circuit as a presumable ablation target is indicated by a mid-diastolic potential during monomorphic, hemodynamically stable VT, areas of low voltage in the local ventricular electrograms, and sites responsible for isolated diastolic potentials and late potentials, which are identified by substrate mapping during sinus rhythm or constant ventricular pacing. When endocardial mapping fails to identify the area of interest or endocardial ablation fails, transthoracic epicardial mapping should be performed.

An epicardial VT substrate is common in patients with non-ischemic cardiomyopathy (NICM) or Chagas disease, but less likely (up to approximately 1/3) to be present in patients with ischemic heart disease. In patients with arrhythmogenic right ventricular cardiomyopathy, an epicardial substrate might be eliminated by endocardial ablation because the wall of the right ventricle (RV) is not thick. However, the necessity
of performing epicardial ablation is increasingly being recognized in these patients. In patients with NICM, it is not uncommon that the endocardial bipolar voltage map is normal. In such a setting, unipolar endocardial voltage mapping might be able to predict the sites of epicardial scar (an area with a local endocardial unipolar voltage <5.5 mV in the RV and 8.3 mV in the LV seems to correlate with epicardial scar) and thus localize the area of interest for bipolar epicardial mapping (Figure 6). In ischemic VTs, epicardial reentry circuits, in general, are more frequent in the inferior, as opposed to anterior, wall.

**Supraventricular Tachycardia**

There are particular APs that are not uncommonly epicardial and may be ablated by an epicardial approach, such as certain posteroseptal and left posterior pathways, and right atrial appendage to right ventricular pathways. However, in general, when endocardial and transvenous epicardial ablation...
Complications that are encountered. Therefore, these procedures should be done by experienced personnel at well-resourced, high volume heart rhythm centers.

Complications Related to Pericardial Access
Most of the critical complications can occur during pericardial access. During transthoracic epicardial access, inadvertent puncture of a cardiac vessel or chamber may sometimes occur as a “dry” puncture with only a few milliliters of pericardial fluid. Careful preparation and detailed knowledge of the underlying anatomy is the key to preventing such complications. The subxiphoid approach involves blindly passing a needle from the skin through the subcutaneous fat, rectus muscle, and usually the diaphragm. In patients with congestive heart failure, the left lobe of an enlarged liver may also be punctured. Arterial vessels in any of these structures may be punctured. In order to minimize these complications, systemic anticoagulation with heparin should not be administered or must be reversed if already administered before the epicardial access. Inadvertent puncture of the RV is relatively common. However, in patients who are not anticoagulated, RV perforations are usually benign if only the needle or guidewire enters the chamber. Therefore, it is important to recognize RV perforation before introducing the pericardial sheath. RV perforations may be easily recognized with a contrast injection. If the needle is within the RV, it should be slightly retracted until contrast is seen surrounding the heart within the pericardial space. At this point, an attempt to feed the guidewire into the pericardial space may be made, rather than withdrawing the needle.

![Image](image-url)
completely and starting anew. However, even with this precaution the guidewire may still be introduced into the RV through the needle. The first sign of this may be arrhythmia, and is usually a run of premature ventricular contractions coming from the RV outflow tract while the guidewire is advancing through it (Figure 1). The second sign may be the lack of the typical appearance of the guidewire in the pericardial space on the fluoroscopic images as more guidewire is advanced. It is essential to observe the guidewire in the left anterior oblique projection, and that it hangs the cardiac silhouette, crosses more than 1 chamber, and is circumferential to both the right and left heart (Figure 1). Observation in the right anterior oblique or anteroposterior projection alone can be misleading.

With the transthoracic pericardial approach, approximately 10–30% of patients experience some degree of pericardial bleeding that can be managed with percutaneous drainage from the pericardial catheter. It is not uncommon to aspirate 10–30 ml of bloody drainage from the pericardial catheter early in the procedure. However, if a large amount of blood is present in the pericardial space, it can be autotransfused through a venous sheath. Generally, bleeding ceases within 5–10 min and is self-limiting. If hemostasis cannot be obtained in this way, surgical repair should be considered without delay. In the case of the sheath being introduced into the RV by mistake, a second attempt to obtain the correct pericardial access leaving the first sheath in place should be performed. The sheath may be surgically removed after the epicardial catheter ablation has been completed.

Infrequently (0.5% in 1 case series), intra-abdominal bleeding may occur during the pericardial puncture, resulting in a hemoperitoneum that may require a blood transfusion and surgical hemostasis. Bleeding within the liver may occur when the needle penetrates an enlarged liver obstructing the course of the puncture needle in heart failure patients. Abdominal pain, and Blumberg’s sign may lead to the diagnosis of this complication. Therefore, conscious sedation may be preferred so that this finding can be detected early.

When positioning the pericardial sheath and introducing a mapping catheter through the sheath, air may be inadvertently aspirated into the pericardial space (Figure 8). Aspirated pericardial air in the apex may be easily recognized on the fluoroscopic images. Pericardial air may rarely cause cardiac tamponade, but it may elevate the defibrillation threshold for a transthoracic defibrillator, especially because the air is likely to stay in an apical site, which is most anteriorly located when the patient is supine (Figure 8).

Complications During Mapping and Ablation

Pericardial Effusion

Use of lower external irrigation flow rates, such as 1 ml/min during mapping and 10–17 ml/min during ablation, may help to control fluid accumulation in the pericardial space where thrombus formation does not pose a risk of embolization.

Damage to Epicardial Vessels

Epicardial mapping and
ablation may damage the epicardial vessels, coronary artery or coronary venous system. Such damage includes laceration of vessels, acute coronary artery spasm and coronary artery occlusions.

The susceptibility of coronary arteries to damage by radiofrequency ablation is inversely proportional to the proximity of the ablating electrode and the vessel size. It is important to maintain a distance of more than 5 mm between the coronary artery and the distal electrode of the ablating catheter at any point in the cardiac cycle in order to reduce the risk of coronary artery damage during the ablation. Prior coronary angiography must be done to determine the safest area for the radiofrequency ablation. Because the base and the anterior and posterior septal areas are considered the more dangerous zones, coronary angiography should be performed before and during radiofrequency ablation being performed in these areas. Chronic damage can occur to coronary arteries despite the absence of acute effects. When the target ablation site is located adjacent to the coronary arteries, cryothermal ablation may be an alternative.

Phrenic Nerve Injury Injury to the phrenic nerve and consequent diaphragmatic paralysis is a well-recognized complication of epicardial ablation. In particular, a limitation of epicardial ablation for NICM VT is the potential proximity of the left phrenic nerve to the VT substrate. The course of the left phrenic nerve is in the vicinity of the left atrial appendage and the high and posterolateral LV wall at the level of the mitral valve annulus and variable along the basal border of the LV. The phrenic nerve is vulnerable to heat as well as cold, and cryothermal ablation seems unlikely to prevent this complication.

Pacing maneuvers can assist in identifying the phrenic nerve course, as well as ensuring an apparent safe distance for ablation. Prior to the epicardial ablation in the dangerous areas as described, pacing is usually performed at a high output of 20 mA at a pulse width of 2 ms to ensure lack of phrenic nerve capture. If patients are paralyzed under general anesthesia, diaphragmatic motion with phrenic nerve stimulation during pacing may not occur to warn of the proximity. Therefore, conscious sedation may be a better choice during epicardial pacing may not occur to warn of the proximity. Therefore, conscious sedation may be a better choice during epicardial ablation with an expected risk of phrenic nerve injury.

When catheter ablation has to be performed adjacent to the phrenic nerve, injury may be avoided by interposing a sheath, balloon, or even air and saline in the pericardium between the ablation site and the nerve. Air and/or saline should be gradually injected via a hemostatic sheath into the pericardium until loss of phrenic nerve capture with careful monitoring of blood pressure to prevent any iatrogenic cardiac tamponade. In the technique using a balloon catheter in the pericardial space to mechanically separate the phrenic nerve from the ablation catheter, a steerable outer sheath may be helpful for guiding balloon placement and providing additional support and stability.

Damage to the Esophagus, Vagus Nerve and Lungs During epicardial ablation, there is also a potential risk of collateral damage to structures that surround the heart such as the esophagus, vagus nerve and lungs. Ablation of the left atrial posterior wall may damage the esophagus and left branch of the vagus nerve, which runs along the esophageal anterior wall toward the stomach, resulting in critical complications such as atrioesophageal fistula or delayed gastric emptying. Real-time visualization of the esophagus with barium or a radio-opaque marker, esophageal temperature monitoring and avoidance of ablation over the esophagus, may help to eliminate inadvertent injury around the esophagus. Although small pulmonary lesions can be anticipated, no clinical significance has been reported.

Postprocedural Complications

Pericarditis Symptomatic pericarditis is a common complication of epicardial ablation. The clinical sign suggesting this complication may be precordial distress and a pericardial friction rub. This complication is usually mild, of limited duration, and often responds well to oral nonsteroidal antiinflammatory medications. However, the intensity of the pericardial inflammatory reaction varies considerably. In general, the longer the procedure and the larger the number of epicardial applications, the more severe the epicardial inflammatory reaction. In order to prevent pericarditis, several measures are recommended. First, all pericardial sheaths should be removed at the end of the procedure unless there is continued bleeding. Second, 0.5–1 mg/kg of methylprednisolone or 2 mg/kg of an intermediate-acting corticosteroid (triamicinolone) should be injected intrapericardially. This treatment may prevent postprocedural inflammatory adhesion formation, especially if a repeat procedure is necessary.

Pleuritis Symptomatic pleuritis may occur after the procedure. The clinical signs suggesting this complication may be dyspnea and a pleural friction rub. This complication may be similar in its clinical course to pericarditis and responds well to oral nonsteroidal antiinflammatory medications.

Conclusions

Transthoracic epicardial catheter ablation is a useful supplemental or even preferable strategy to eliminate cardiac arrhythmias in the electrophysiology laboratory. The indications of this technique have extended to a diverse range of cardiac arrhythmias. If potential complications associated with this technique are well understood and managed, transthoracic epicardial catheter ablation can be safely performed and enhances the success rate of catheter ablation.

Disclosures

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References
