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Epicardial Radiofrequency Ablation: Who, When, and How?

Chin-Yu Lin

Abstract

In the past decades, it has been known that reentry circuits for ventricular tachycardia or focal triggers of premature ventricular complexes are not limited to the subendocardial myocardium. Rather, intramural or subepicardial substrates may also give rise to ventricular tachycardia, particularly in those with non-ischemic cardiomyopathy. Besides, some of the idiopathic ventricular tachycardia might be originated from epicardial foci. Percutaneous epicardial mapping and ablation have been successfully introduced to treat this sub-epicardiac ventricular tachycardia. Herein, this chapter reviews the indications for epicardial ablation and the identification of epicardial ventricular tachycardia by disease entity, electrocardiography and imaging modalities. This chapter also described the optimal technique for epicardial access and the potential complication.

Keywords: epicardial, ventricular tachycardia, ablation, non-ischemic cardiomyopathy, idiopathic

1. Introduction

The pericardium is a two-layer membrane surrounding the heart and vital vessels. The two-layer structure included a serous visceral membrane inside and a fibrous membrane (parietal pericardium) outside. The fibrous membrane is adhered to the diaphragm, posterior part of sternum by the tissue and ligament to fix the heart. The pericardium encloses the heart and pericardial fluid, which provides lubrication for the myocardium [1]. Pericardial puncture is a standard and useful therapeutic procedure for the treatment of diagnosis of tamponade or symptomatic pericardial effusion [1]. In 1996, Sosa et al. first described the use of pericardial puncture in an electrophysiological laboratory for epicardial ablation in ventricular arrhythmia, [2] the use of pericardial puncture to map and ablate ventricular arrhythmia started to expand in other diseases [3].

Before to the era of catheter ablation with epicardial approach, patients with ventricular tachycardia (VT) refractory to catheter ablation from the endocardium often required surgical approach. The technique became well-developed and skilled in high-volume center recently. Many centers reported the successful application of the epicardial ablation in a diverse range of cardiac arrhythmia. Therefore, the indication for the epicardial approach has extended. The potential indication included substrate/ idiopathic VTs, accessory pathways, and miscellaneous supraventricular tachycardias [4]. Since Sosa et al. first introduced the application of epicardial ablation for the ventricular arrhythmias (VAs) in Chagas disease, [2] the use of this technique through a percutaneous method has been applied to other diseases [3].

In the patients with ischemic cardiomyopathy due to prior myocardial infarction (MI) and VT, the involved circuit mostly involved the inner part of the heart [5]. In the previous report, part of the ischemic VT circuit may involve areas within the subepicardial area [6]. The advantage of the epicardial approach was demonstrated by clinical study. An approach with combined endo-epicardial mapping/ablation has been reported to show a better outcome selected patients with non-ischemic cardiomyopathy (NICM) VT ischemic VT [7–10]. Furthermore, the percutaneous technique for epicardial access have been proven to improve outcomes with an acceptable risk of peri-operative adverse event in experienced operator or high-volume centers [11]. However, there were many surrounding epicardial vascular structures or nerves in the tract of epicardial puncture. The unskilled operators may encounter serious and detrimental complications. Prior studies have reported the incidence rate of major complications around 4.1-8.8%, including adverse event of a hemopericardium, intra-abdominal bleeding, and arterial/venous/nerve injuries [11–14]. This chapter was aimed to discuss the clinical implication, patient selection, and detailed procedure for the epicardial ablation in the patients with VA.

2. Who should be considered to perform the epicardial approach?

2.1 Contraindication for endocardial approach

Generally, the endocardial approach was contraindicated in the following condition

1. Endocardial mural thrombus was presented.
2. Coexisted mechanical valves were presented in the mitral and aortic valve

In the patient with the presence of newly-identified mural thrombus, the strategy of endocardial ablation should be postponed. Previous report described the results of endocardial VT ablation in 8 patients with identified old thrombus [15]. Intracardiac echocardiography (ICE) seems to be more sensitive for the detection of LV thrombi compared to transthoracic echocardiography (TTE) and is helpful in real-time navigation of the mapping / ablation catheter. No procedural or periprocedural complications were observed in this retrospective study [15].

Mechanical prosthetic aortic and mitral valves preclude either a retrograde aortic or transseptal approach to the left ventricle (LV) endocardium. Several operators have reported previously on the use of unconventional techniques during VT ablation such as transventricular septal puncture, [16, 17] epicardial approach, [18] transmechanical valve approach, [19] transc coronary venous approach, [20] or transapical approach [21].

2.2 Contraindication for percutaneous epicardial approach

Intrapericardial access is usually obtained through a subxiphoidal pericardial puncture. This approach might not be possible in patients with pericardial adhesions caused by prior cardiac surgery, pericarditis, or prior epicardial ablation. (**Figures 1 and 2**) In such cases, a hybrid procedure involving surgical access to

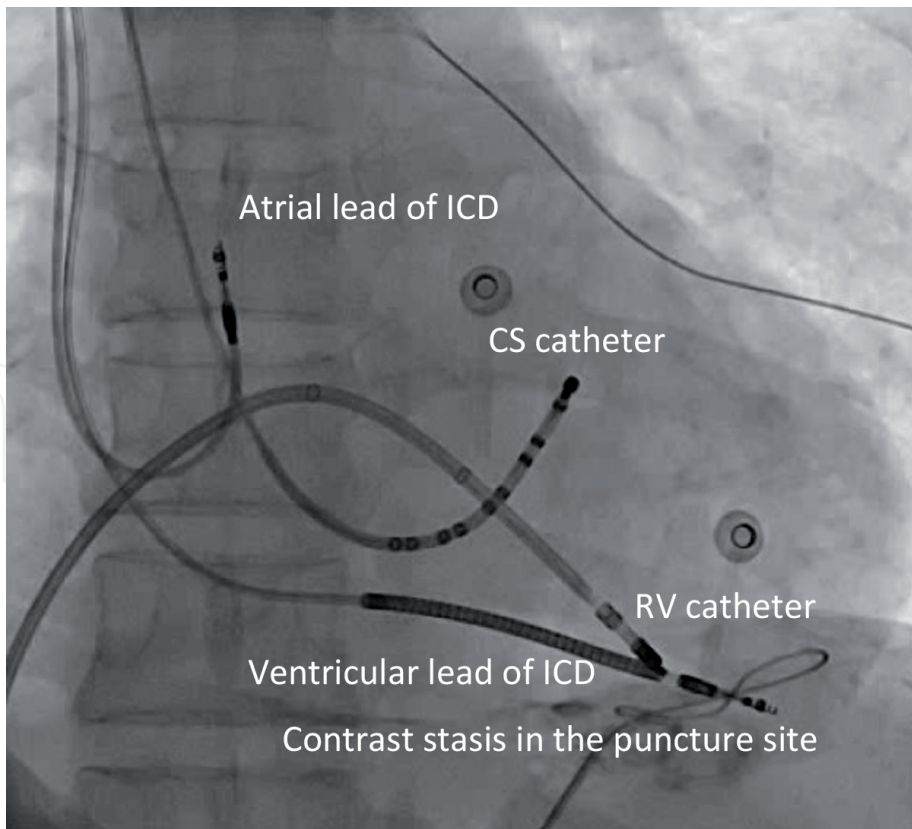


Figure 1.
Epicardial puncture in a patient with prior epicardial ablation. The figure showed the anterior–posterior view during epicardial puncture. The fluoroscopic view demonstrated the contrast stasis in the bottom of the epicardium due to prior ablation and severe adhesion. The wire could not advance further in the localized epicardial space.

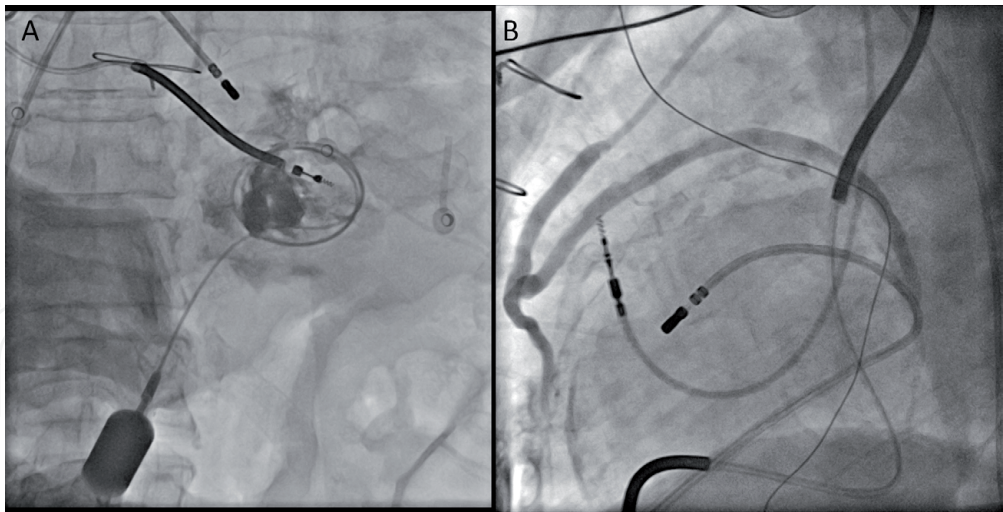


Figure 2.
Epicardial puncture in a patient with prior coronary artery bypass grafting. The figure showed the anterior–posterior view during after an initial puncture. The fluoroscopic view demonstrated the contrast stasis in the bottom of the epicardium due to prior cardiac surgery severe adhesion. The wire could not advance further in the localized epicardial space (panel A). After several attempts, the ablation catheter was advanced to the limited epicardial space. Coronary angiography was done before the ablation to avoid coronary injury through the graft (panel B).

a subxiphoid pericardial window or lateral thoracotomy might be a feasible and safe method of performing epicardial catheter ablation in the electrophysiology laboratory [4].

2.3 Endocardial approaches were more favorable than epicardial approach

2.3.1 Myocardial infarction related VT

The previous study showed a good response with subendocardial resection to treat the subendocardial location of the VT substrate from surgical experience, which indicated the endocardial VT circuits [22]. Furthermore, the endocardial catheter ablation with mappable VT demonstrated good acute procedural success rate. However, the long-term outcome was unsatisfied [23]. A prior study examined all ischemic cardiomyopathy (ICM) VT cases with endocardial and/or epicardial mapping/ablation. Epicardial approach was applied in 14% of patients, and application of ablation in the epicardium was done in 8.5% patients. Part of the patient (0.5%) did not undergo epicardial ablation because of proximity to an epicardial coronary artery to the of identifying epicardial substrate [24]. In an Asian study from Taiwan, the epicardial approach for the ICM-related VT was rarely reported [14]. This may be related to the highest quality and convenience of Taiwan's public health system. A recent non-randomized study provided evidence of epicardial-endocardial approach in these patients [25]. Generally, the region of myocardial infarction does not appear to be predictive of epicardial involvement. On the other hand, imaging, such as cardiac magnetic resonance imaging (MRI), cardiac computed tomography, or nuclear scintigraphy suggesting transmural infarction may identify patients more likely to have epicardial substrate [26].

2.3.2 Idiopathic ventricular arrhythmia

The recent review article summarized most common idiopathic VT arising from the right and left ventricle: (1) outflow tract VT, (2) fascicular VT, (3) intracavitary VT, (4) perivalvular VT, and (5) epicardial VT [27]. Around 1. 8–9. 2% of idiopathic VT were raised from the epicardium. In the prior study, the electrocardiography is a useful parameter for predicting the successful ablation sites of VT originating from the continuum between the aortic sinus of Valsalva (ASV) and the left ventricle (LV) summit [28]. In the results, aVL/aVR Q-wave ratio is useful in the prediction of successful ablation sites. A coronary venous approach / pericardial access might be required with a cutoff value of 1.536-1.740 and > 1.740 respectively.

2.4 Epicardial approaches were more favorable than endocardial approach

2.4.1 Brugada syndrome catheter ablation

Brugada syndrome (BrS) is one of the main causes of sudden cardiac arrest in young population [29]. The efficacy and adverse effects of anti-arrhythmic drugs on BrS was disappointing. Catheter ablation emerged and offers an alternative therapeutic strategy for these patients with repeat recurrent implantable cardioverter defibrillator (ICD) shock after the ICD implantation. Nademanee et al. first demonstrated the effectiveness and safety of ablating the arrhythmogenic electrogram at the epicardium of right ventricular outflow tract (RVOT) to decrease the VT/VF burden [30]. Further study on the post-mortem heart demonstrated interstitial fibrosis and reduced gap junction expression in the epicardium of RVOT in BrS patients. The abnormal fibrosis resulted in arrhythmogenic potentials. Eliminating the arrhythmogenic potentials by using ablation could abolish the BrS ECG pattern and reduce VT/VF burden. In the clinical practice, the operator may perform



Figure 3.
 Local fractionated potential in the epicardial right ventricular outflow tract of a patient with Brugada syndrome. The left panel demonstrated local abnormal signal and delayed electrogram, which was localized in the epicardial right ventricular outflow tract. (red arrow, right panel) this patient was diagnosed as Brugada syndrome and survived from an episode of sudden cardiac death due to ventricular fibrillation.

epicardial mapping and identified the slow conduction zone and abnormal electrogram in the RV epicardially. (**Figure 3**) The electrophysiological group in Taipei Veterans General Hospital first introduced the warm water instillation, which would enhance the phenotype and functional substrate in the patient with BrS. Ablation by targeting the triggers and abnormal epicardial substrates provided an effective strategy for preventing ventricular tachyarrhythmia recurrences in BrS [31].

2.4.2 Arrhythmogenic right ventricular cardiomyopathy

Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a heritable desmosome disorder. The clinical manifestations vary from asymptomatic concealed stage, electrical abnormality with ventricular arrhythmias (VAs), to progressive heart failure [32, 33]. Catheter ablation is emerging as an alternative therapy for drug-refractory VAs in patients with ARVC. Although the catheter ablation could result in acute procedural success with VT termination, the high incidence of recurrence limited the role of ablation in ARVC initially [34, 35]. The application of epicardial and endocardial ablation of VT in the patients with ARVC had been proposed with good effects acute and long-term outcome and VAs-freedom [36, 37]. Recent studies also demonstrated that 45 ~ 84. 6% patients were free from VA recurrences or ICD therapy through the combination of endocardial and epicardial ablation [38, 39]. Epicardial approach is required in more than one third ARVC patients for achieving non-inducibility in the prior reports [40]. The number of fulfilled SAECG criteria was correlated to the extent of diseased epicardial substrate and could be a potential surrogate marker to predict the requirement of epicardial ablation in ARVC with drug-refractory VA [40].

2.4.3 Non-ischemic cardiomyopathy

In contrast to ischemic cardiomyopathy, non-ischemic cardiomyopathy (NICM) consists of a heterogeneous group of diseases [41] affecting the myocardium. Despite the progress and improvement in the pharmacological medication of heart failure in recent decades have significantly decreased the disease progression and mortality in NICM patients, anti-arrhythmic medications and ICD implantations remain the most important treatment for patients carrying a high risk of VT/VF or who have experienced aborted SCD due to fatal VT/VF [42]. Owing to the improvement in electro-anatomic mapping and ablation catheter, catheter ablation of VT in NICM patients has been recognized as an upcoming issue [43]. A prior study proven the promising results that a successful catheter ablation could reduce VT recurrences and improve the survival in NICM patients regardless of the functional class status or left ventricular function [44]. NICM VTs in different disease entities could result from non-uniform arrhythmogenic substrates, which can lead to different ablation outcomes.

With the exception of ARVC and BrS, the arrhythmogenic substrates in NICM that could be identified by electroanatomic mapping, are mostly located in the base or perivalvular region of the LV, which is distinct from the substrate ICM [45]. The arrhythmogenic potentials could be identified from the endocardial/epicardial aspect in the patients with NICM [46]. These arrhythmogenic substrates frequently associate fibrosis tissue that leads to conduction disturbance and fractionated electrograms [47]. Aside from the electroanatomic substrate mapping with bipolar/unipolar voltage, cardiac MR can provide additional information to unmask the scar distribution as a non-invasive manner [48–50]. Additionally, patients with scar involving the inferolateral aspect of the LV, which frequently requires an epicardial approach, usually have a better prognosis than those with anteroseptal scar [51].

A comprehensive investigation of patients with NICM and VT includes cardiac imaging and genetic testing. These information might enable recognition of undiagnosed diseases, such as isolated and active cardiac sarcoidosis or inherited cardiomyopathies. An accurate diagnosis could improve patient selection for ablation and early consideration of individualized treatments [52].

3. When should be considered to perform the epicardial approach?

An epicardial approach could performed for patients with refractory ablation from an endocardial approach. The clinical documentation of surface ECG could provide specific electrocardiographies evidence supporting an epicardial origin [28, 53, 54]. In cases with a disease entity favoring an epicardial substrate, or those with electroanatomic mapping supporting the existence of a diseased epicardial substrate, an epicardial approach could be considered [30, 55, 56].

Before preparing for epicardial approach, the first step is to localize the VT origin and identify the potential regions of arrhythmogenic substrates. The surface ECG morphologies provide the information about the origin and the potential need for an epicardial approach [53]. Standardized echocardiography or intracardiac could delineate the valvular structure, area of hypokinesia or akinesia, and excluding any intracardiac thrombus [57]. Computed tomography (CT) and cardiac MRI with a late gadolinium enhancement, could localize the regions of abnormal tissue in specific protocol [48–50]. The distribution and extent of the scar is useful for deciding the ablation strategy, such as an epicardial approach, transcoronary venous ablation,

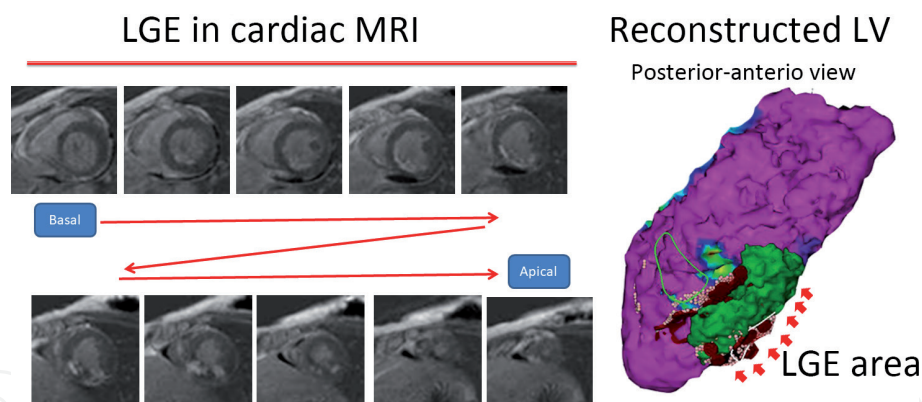


Figure 4. Cardiac magnetic resonance imaging (CMRI) and three-dimensional reconstruction in a patient with non-ischemic myocardial infarction. The CMRI demonstrated a late gadolinium enhancement (LGE) in the mid posterior wall. The three-dimensional reconstruction was performed to guide the catheter ablation.

alcohol ablation, or simultaneous bipolar ablation. The integration of the reconstructed images obtained from CT and MRI and 3-D navigation, mapping systems (**Figure 4**) can aid in the illustration of the structural complexity and avoidance of damage to the critical regions, in terms of vascular or nervous structures.

4. How to perform the epicardial approach?

4.1 Traditional method (posterior approach)

After obtaining informed consent, the procedure would be performed with the patients in a fasting state under general anesthesia. Pre-procedure subxiphoid echocardiography was recommended to perform routinely. In some cases, the echocardiography could help the operator avoid liver or gastric injuries. A subxiphoid puncture was performed to penetrate the pericardium in the inferior aspect of the heart according to the technique described by Sosa et al [2]. Access to the pericardium was achieved by using an 18 G Tuohy Needle (Arrow International, Inc., Reading, PA, USA) in the laboratory of Taipei Veterans General Hospital through the subxiphoid process. The anteroposterior projection was usually used to direct the access in the anterior/posterior plane, while the left anterior oblique (LAO) 60° projection was used to guide the needle leftward tangentially to the cardiac border. **Figure 5** demonstrated the adjacent structure with these two views by reconstruction of the CT. After passing through the diaphragm, 1-2 cm³ of contrast could be injected between the diaphragm and pericardium to observe tenting of the pericardium. After entering the posterior side of pericardium, a 0.032 guidewire would be advanced to the left heart border in the LAO projection, and 10 cm³ of contrast could be injected into the pericardial space through a 5F dilator or the side hole of a 5Fr sheath to allow for visualization of any adhesions. (**Figure 6**) An 8-Fr Sheath or flexible long Sheath would be exchanged by using the guide wire. The ablation/mapping catheter would be inserted through the sheath after obtain the access to avoid injury by the edge of the sheath. Angiography would be performed while locating the catheter in the interested area to avoid coronary injury. (**Figure 7**) After the procedure, the epicardial sheath was exchanged for a pigtail. Pericardial injections of hydrocortisone 100 mg and ketorolac tromethamine 30 mg were routinely given immediately and 24 hours after the epicardial procedure to prevent any future epicardial adhesions or pericarditis.



Figure 5.
The anatomy with anterior-posterior view (left panel) and LAO view (right panel). The green arrow indicated the anterior approach and the red arrow indicated the posterior approach.

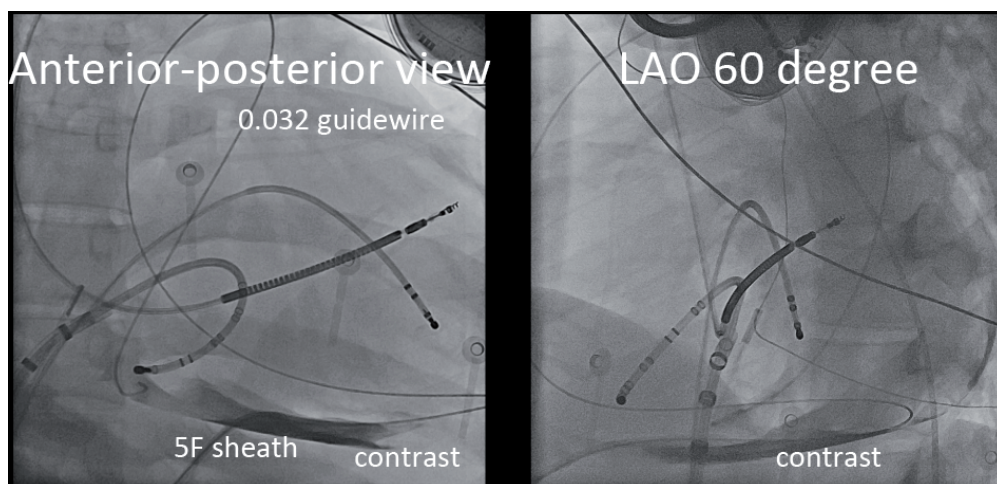


Figure 6. *Epicardial puncture in a patient with arrhythmogenic right ventricular cardiomyopathy. The anterior–posterior view (left panel) and LAO view (right panel) showed the wire in the epicardial space surrounding the whole heart and the contrast in the epicardial space without adhesion.*

4.2 Needle-in-needle method

A ‘needle-in-needle’ technique for epicardial access has been described by Kumar et al [58]. In this approach, a 7-cm 18-gauge needle is inserted beneath the sternum. The purpose of this short needle is to provide stability and tactile feedback for a long (15- or 20-cm) micropuncture 21-gauge needle, which is inserted through the 18-gauge needle. Once the 21-gauge needle is inserted into the pericardial space, along 0.018-inch guidewire with a floppy tip is advanced into the pericardial space. Upon fluoroscopic confirmation that the guide wire has been inserted into the pericardium both needles are then removed. Micropuncture dilators are then used to upsize the guide wire to a 0.35-inch wire and ultimately, an 8-Fr sheath is introduced into the pericardial space. The ‘needle-in-needle’ approach was compared to the traditional methods. Successful epicardial access was achieved in 100% of the ‘needle-in-needle’ cases, as compared to 94% with the Sosa technique. Failure of epicardial access in the traditional method were due to prior cardiac surgery [13] or

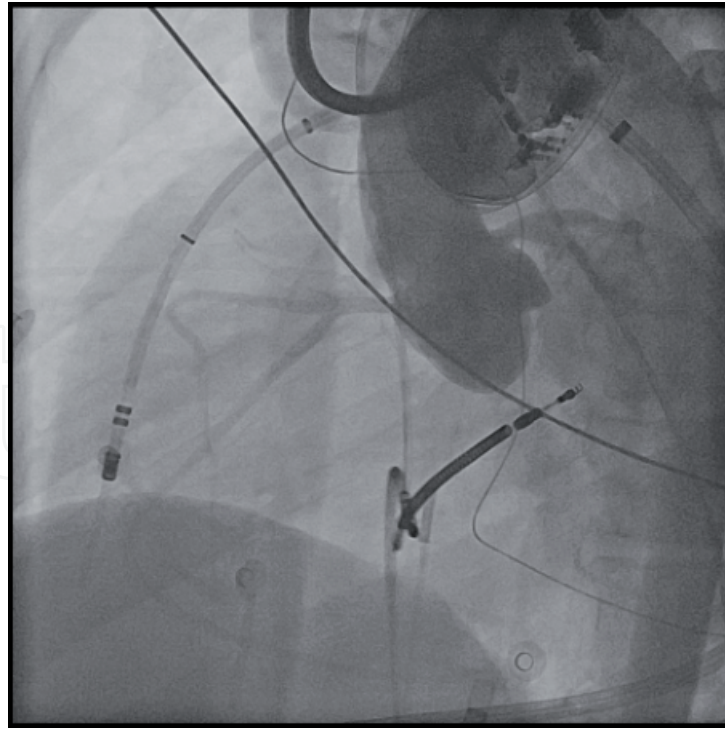


Figure 7.
Angiography before epicardial ablation. After a successful epicardial puncture through posterior approach, the angiography was performed before the ablation to avoid coronary injury.

adhesions from prior epicardial mapping/ablation or episodes of pericarditis [7]. Major pericardial bleeding was similar between both techniques [58].

4.3 Anterior approach vs. posterior approach

In anatomic, there is a potential space below the sternum and xyphoid process. While puncturing below the xyphoid process, the needle might directly pass through the fibrous pericardium avoiding the puncture through the diaphragm [59]. The term of “anterior approach” was used for the epicardial approach via this potential space (**Figure 8**). This approach was based on the previous finding that an increased fluid in the anterior part of the heart during supine position [60, 61]. Theoretically, the density of myocardium is heavier than and pericardial fluid. During supine position, the heart might force the pericardial fluid to the anterior part within the pericardium. Keramati et al. reported the anterior approach was successfully performed in 100% of patients in their study cohort [62]. The success rate was similar between the anterior approach and the needle in needle approach. On the other hand, the success rate of the anterior approach was higher than the traditional approach. In the report, there were no major pericardial hemorrhage and even the PV puncture. **Figure 9** demonstrated the illustration of the anterior approach and posterior approach.

4.4 Fluoroscopic approach with carbon dioxide insufflation

The technique of carbon dioxide insufflation was first reported with right atrial exit in human study by Greenbaum et al [63]. A modified approach with exit from the coronary sinus was reported by Silberbauer et al [64]. The pericardial space was insufflated with carbon dioxide after creating the exit, which allowing visualization of the pericardial membrane and separated membrane to the myocardium. The epicardial space with carbon dioxide allowed safe epicardial puncture and minimized the risk of RV perforation. A multi-center registry was conducted with

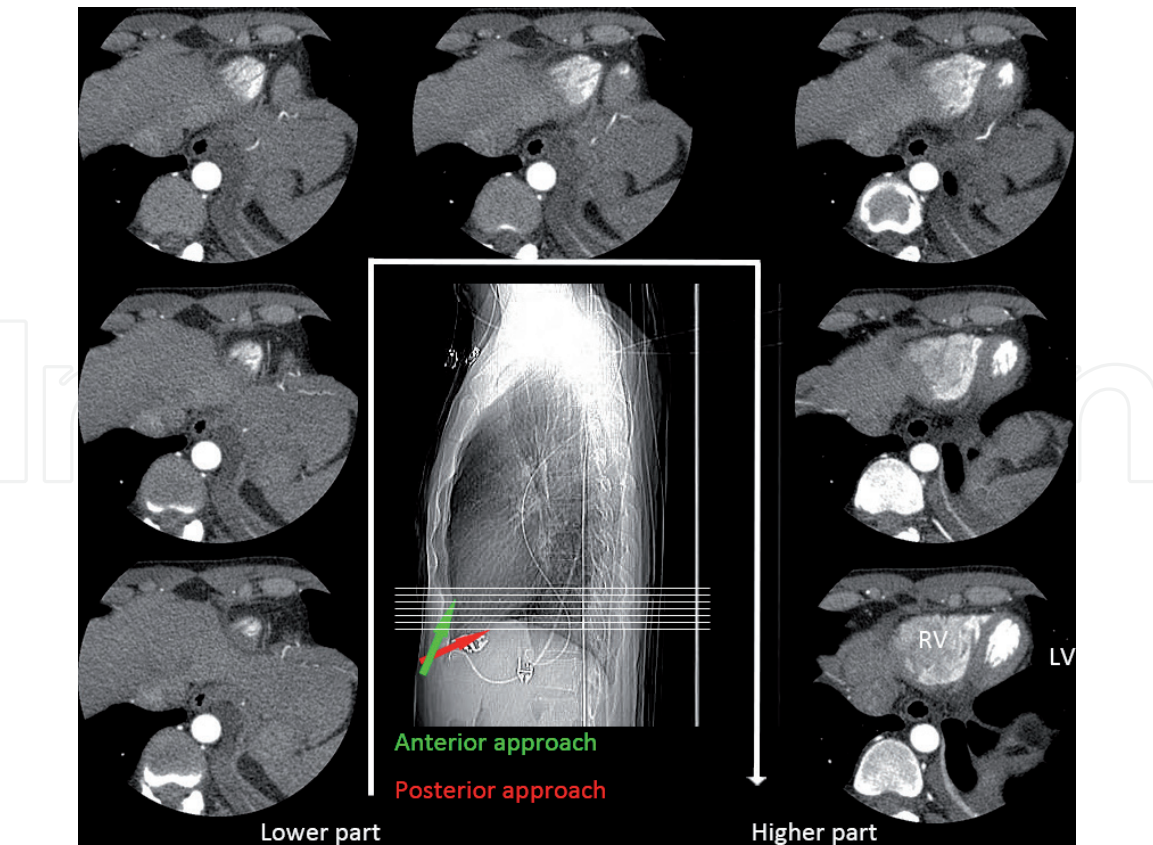


Figure 8.
An illustration of anterior and posterior approach. The figure showed the X-ray from the lateral view. The green arrow indicated the anterior approach and the red arrow indicated the posterior approach. The horizontal cut of the heart from lower caudal part of the cranial part. The white arrow indicates the sequence from the lower part of the higher part. Each cut was corresponding to the horizontal white line in the X-ray.

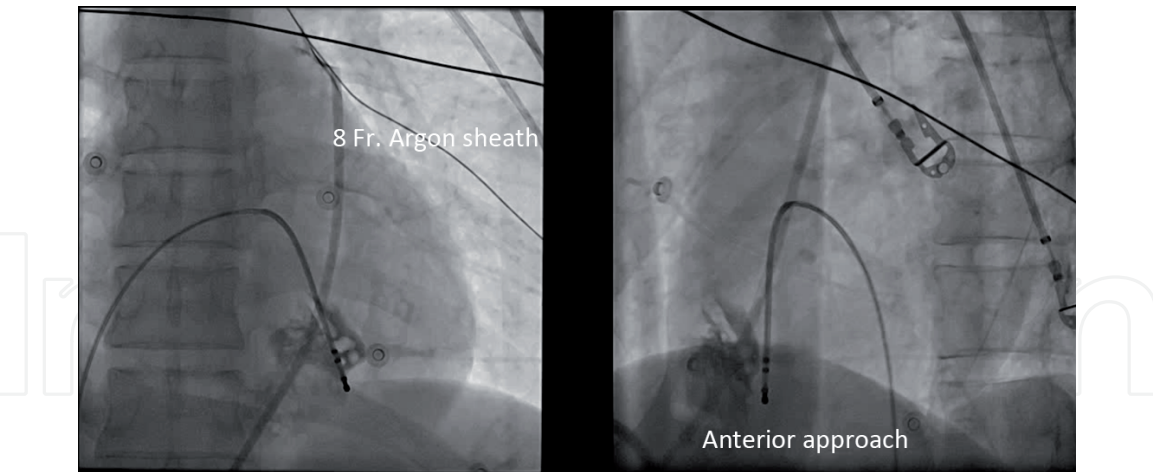


Figure 9.
Example of anterior approach. Anterior approach was performed successfully. The guide wire was exchanged with an 8 Fr sheath after confirming the location.

this modified approach. There was no patient complicated with the RV puncture of coronary artery injury [65]. However, the operator needs to take care of the potential risk of bleeding from the exit site.

4.5 Wire-guided puncture

This approach was first described by Long et al [64] in 2019. This approach was different from traditional approach using the contrast-filled syringe to the needle.

In the wire-guided approach, a J-tipped guide wire is within the needle during puncture. After advancing the needle the adjacent area of the pericardium, the wire was advanced. The wire would curve back if it reached the parietal pericardium, and the operator could feel the heart pulsations. The wire was dragged back to the needle's tip at this point. The wire and needle were both pressed again at the same time. While the needle was traveling through the epicardium, the wire would fall into the pericardial region. The study found that this method was safe and that the success rate was comparable to that of the traditional method.

4.6 Surgical access

Pericardial window provides clear visualization of the epicardial myocardium and manipulation of the mapping catheter and Realtime feedback for the location of the mapping catheter cooperating with the 3-D anatomic mapping system. The operator might not be able to perform percutaneous subxiphoid access in patients with pericardial adhesions. In these patients, a surgical window may be required to gain access to the pericardium. This technique involves a subxiphoid incision, followed by manual lysis of adhesions to visualize the epicardial surface. A sheath was then placed into the pericardial space after opening a small window in the pericardium [66]. This technique should be considered in patients with a prior history of cardiac surgery with dense pericardial adhesions [67].

5. Periprocedural complications of an epicardial approach

In the prior report, the incidence of major complications was 10.0%, and that for minor complications was 17.5% [14]. Prior single and multicenter studies also reported similar findings [11, 12]. However, it is important to keep in mind that these complication rates were obtained from arrhythmia centers with an experience of epicardial approach. The surgical backup was required for potential major complications. Major complications of intra-abdominal bleeding due to vessel damage and MI owing to ablation in the adjacent area were reported [68]. Another possible cause of intra-abdominal bleeding is the liver puncture or perforation. The operator should also take care for the location of the coronary sinus. Coronary sinus puncture might occur if the puncture site is close to the base of the heart. Thus, detailed preoperative evaluations by ECG, echocardiography, and peri-operative image, especially for patients with hepatomegaly or a congested liver, may prevent the occurrence of any life-threatening complications.

RV puncture was not uncommon and it has been reported to be a minor complication with an incidence of 4.5 ~ 7.5% [13, 14, 68]. The RV puncture could be reduced after a learning curve. Post-procedural pericarditis was common. Prolonged and intolerable chest pain due to pericarditis might be improved by the administration of intrapericardial steroids and non-steroidal anti-inflammatory drugs. Phrenic nerve injuries and coronary artery damage could be avoided by phrenic nerve pacing and pre-ablation angiography [69, 70].

5.1 Patients with anticoagulant

In the patient with anticoagulant, the epicardial access could be performed according to the guideline. After excluding the potential risk of adhesion, history of epicardial surgery, and complex anatomy, the procedure might be classified as a minor risk procedure in an experienced operator [71]. Therefore, the procedure could be performed at NOAC through level (12 or 24 hours after the first intake)

and resume after the procedure or latest next day without active bleeding. Beside, the procedure should be better performed by experienced operator and avoid repeated RV puncture. Antidote or blood transfusion should be available in the hospital.

6. Conclusion

The need for an epicardial approach for VA ablation displayed a gradually increasing trend. The disease entity, prior surgery or ablation, electrocardiography, image study, and other diagnostic test should be carefully reviewed before the decision making. The prior studies demonstrate the effectiveness of epicardial catheter ablation with acceptable safety in experienced referral center.

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Conflict of interest

The author declares no conflict of interest.

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