Europace (2012) **14**, ii13–ii18
doi:10.1093/europace/eus214

Epicardial access for the treatment of cardiac arrhythmias

Andre d'Avila*, Jacob S. Koruth, Srinivas Dukkipati, and Vivek Y. Reddy

Helmsley Cardiac Arrhythmia Service—Mount Sinai Medical Center, One Gustave L. Levy Place, Box 1030, New York, NY 10029, USA

Since the introduction of percutaneous epicardial access for the purpose of mapping and ablation of cardiac arrhythmias, this technique has become an important adjunct and at times the preferred approach to treat certain cardiac arrhythmias. In addition, this approach is currently also being considered for a number of other cardiovascular applications such as epicardial pacing, left atrial appendage ligature occlusion, etc. The focus of this review is to discuss relevant aspects of pericardial anatomy, and various methods of epicardial access.

Keywords Percutaneous • Epicardial • Pericardial • Anatomy, Access, Subxiphoid mapping • Ablation

Introduction

Since the introduction of percutaneous epicardial access for the purpose of mapping and ablation of cardiac arrhythmias,[1–4] this technique has become an important adjunct and at times the preferred approach to eliminate certain cardiac arrhythmias. Over the last decade, the presence of epicardial substrates responsible for harbouring arrhythmias such as supra-ventricular tachycardia,[5] atrial fibrillation,[6] idiopathic ventricular tachycardia (VT), and scar-related VT[7] has been increasingly demonstrated. In addition, this approach is currently also being considered for a number of other cardiovascular applications such as epicardial pacing, left atrial appendage ligature occlusion, etc. The focus of this first of a two-part review will be (i) relevant pericardial anatomy, (ii) various methods of epicardial access, and (iii) epicardial mapping.

Pericardial anatomy

The normal pericardium is a double-layered fibroserous sac which is made up of an outer parietal and an inner visceral layer that is invaginated by the heart. The inner layer or visceral pericardium remains adherent to the epicardium, before reflecting back upon itself as the outer parietal pericardium. The pericardial cavity exists as a continuous virtual space that lies between these two layers.[8] It is to be noted that the parietal pericardium is attached to the diaphragm's central tendon by loose tissue, except over a small area of the central tendon of the diaphragm and is also attached to the posterior sternal surface by small ligaments that anchor and help to maintain the position of the heart within the thorax.

Atrial surface

Although most of the pericardial cavity can be easily mapped using standard mapping catheters, mapping the posterior wall of the left atrium (LA) can be challenging given the complex pericardial reflections that form the pulmonary vein (PV) recesses and the two major sinuses (*Figure 1*).

Transverse sinus

This sinus exists posterior to the great arteries, bounded superiorly by the right pulmonary artery and inferiorly by the roof of the LA. Catheter exploration of the sinus allows access to the anterior portion of the LA, the area of Bachman's bundle, and via the inferior aortic recess, the non-coronary cusp. Access to this sinus may also allow passage from the left to the right half of the epicardial surface. However, this is exceedingly difficult during percutaneous epicardial catheter mapping and virtually impossible after open-heart surgery. The easiest access to the left and right sides of the epicardial surface is to manoeuvre the catheter anterior to the great vessels.

Oblique sinus

The oblique sinus is limited to the posterior wall of the LA and extends only behind the atria, particularly the LA in the region between the four PVs. It is bounded on the right side by the inferior vena cava and to the left by the pericardial reflection connecting the two left PVs. Its shape varies according to the anatomy of the pulmonary recesses, but its opening inferiorly is always bounded by the two inferior PVs and its depth is defined by the distance between this region and its superior boundary at the level of the transverse sinus. Of note, the Marshall's ligament projects obliquely to the lateral and posterior aspect of the LA,

* Corresponding author. Tel: +212 241 7114; fax: +646 537 9691. Email: andre.d'avila@mountsinai.org

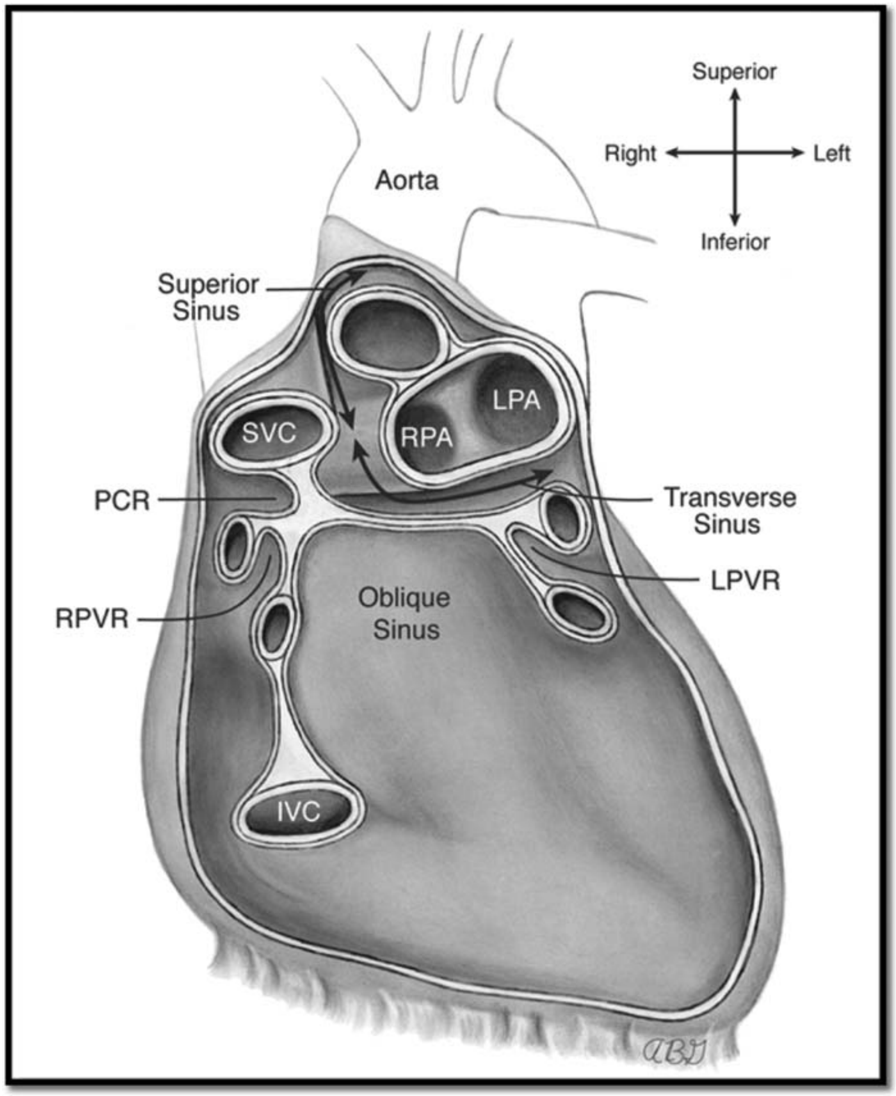

Figure 1 The anatomy of the pericardium space and its reflections along the great vessels, sinuses, and recesses is shown in an anterior view after removal of the heart. The transverse sinus is limited by a pericardial reflection between the superior pulmonary veins. The oblique sinus is confined by the pericardial reflections around the pulmonary veins and the inferior vena cava. PCR, post-caval recess; RPA, right pulmonary vein; RPVR and LPVR, right and left pulmonary vein recesses; LPA, left pulmonary artery.

running laterally towards the left inferior PVs, and reaching the superior-lateral portion of the pulmonary veno-atrial junction outside the oblique sinus. The details of this complex anatomy are relevant only if the epicardial route is used for atrial ablation for arrhythmias such as atrial tachycardias and fibrillation.

Ventricular surface

The epicardial surfaces of both ventricles are free of reflections and in the absence of prior severe pericarditis or cardiac surgery. This allows for easy manipulation of the mapping/ablation catheter during ventricular epicardial ablation. The inferior and anterior approach taken during percutaneous epicardial access allows for easier access to the respective surfaces of the heart.

Epicardial fat

The presence of epicardial adipose tissue and coronary arteries creates a unique milieu that has safety and efficacy implications during radiofrequency catheter ablation. The presence of epicardial fat interposed between the ablation catheter and the epicardium of the heart can be a significant hindrance in procedural success as it can decrease the effectiveness of ablation. In a recent study,[9] we assessed *in vivo* epicardial fat distribution and thickness in 59 patients undergoing multi-detector computed tomography for coronary artery assessment using a 16-slice computed tomography scanner. The results indicate that the mean epicardial fat thickness was 5.3 ± 1.6 mm. The mean total epicardial fat in patient's $\geq$65 years was 22% greater than in younger patients, with 36, 57, and

38% increments, respectively, along the right ventricular (RV) anterior free wall, RV diaphragmatic wall, and the left ventricular (LV) lateral wall. Women overall averaged 17% more total epicardial fat when compared with men.

Percutaneous epicardial access

Conceptually, entering the pericardial space is straightforward as draining pericardial effusions.[1] However, in the absence of an effusion, epicardial access can be daunting since there is little room for error. The normal pericardial cavity contains only 20–25 cc of physiologic fluid with only virtual space. Thus, there is an increased risk of perforating the RV wall and/or of damaging epicardial vessels when attempts are made to access the space percutaneously with a regular pericardiocentesis needle. In a series of ~200 patients, Sosa and Scanavacca[10] reported a bleeding rate of 10% and 'dry' RV puncture rate of 4.5% but with a reduction with experience.

Accordingly, a blunt-tipped epidural needle (Tuohy) designed to enter virtual spaces was initially used and has since been routinely employed.[1] The needle is advanced gently at an angle (depending on whether an anterior or inferior approach is required) aiming for the left scapula within the patient in the supine position (*Figure 2*). The preferred entry point is 2–3 cm below a line that joins the xiphoid process and the costal margin, left of the midline. A skin incision is often made to allow easy entry of the needle into the deeper tissues and this also helps in transmitting the tactile sensation of various structures encountered on the way, especially the contracting walls of the heart. Under fluoroscopic guidance, the needle is continually advanced until the operator can feel cardiac motion. X-ray can be deceiving especially in one view. Often as one reaches the border of the heart small injections of contrast are made to delineate proximity to the pericardium. In our lab we perform percutaneous access after induction of general anaesthesia and this allow us to puncture during apnea, allowing for a more controlled puncture. Other centres use only sedation to maximize the chance of VT induction. A small amount of contrast may be then injected to demonstrate entry of the needle into pericardial space. Occasionally, the parietal pericardium can be stained and tenting of the pericardium can be seen before the needle suddenly enters the space. The appearance of layering of the contrast medium within the pericardial space indicates that the needle is correctly positioned within the pericardial cavity. This transition into virtual space is usually accompanied by a sensation of 'give' which is noted with experience.

Once within the pericardial space, a guidewire is passed through the needle. This step again allows for confirmation of entry within pericardial space. Occasionally, in some patients cardiac motion and/or the sensation of 'give' is difficult to perceive and direct

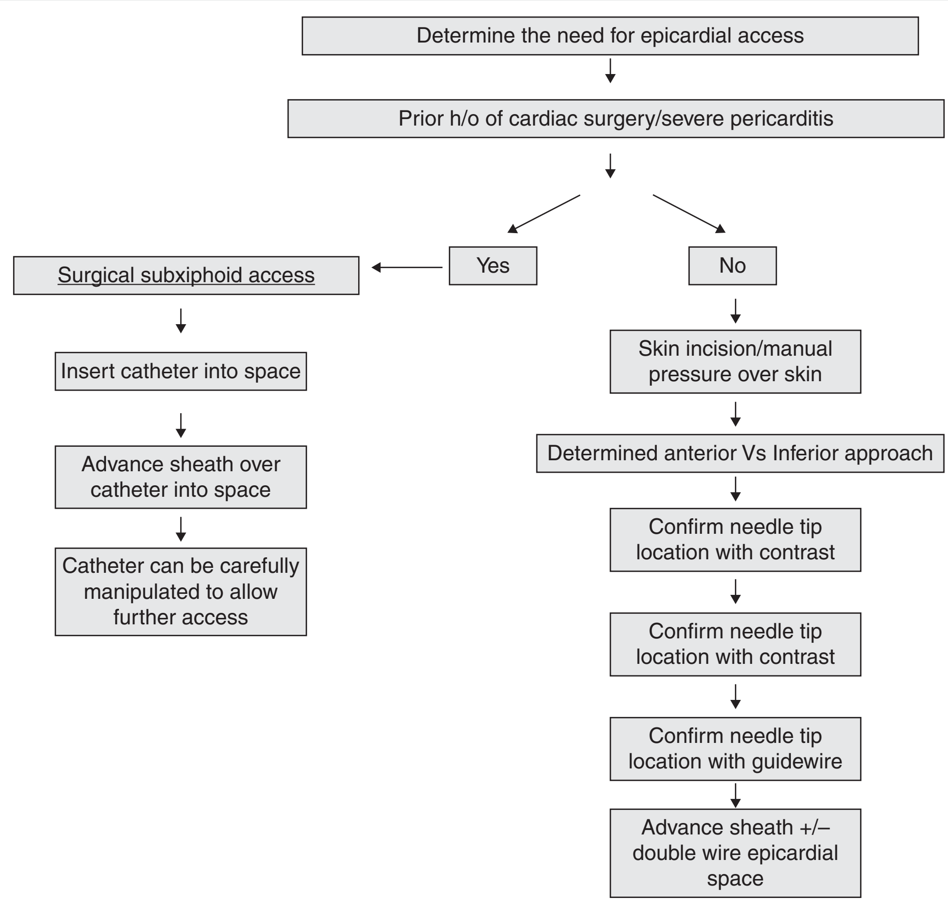

Figure 2 Transthoracic epicardial access: stepwise access to epicardial access.

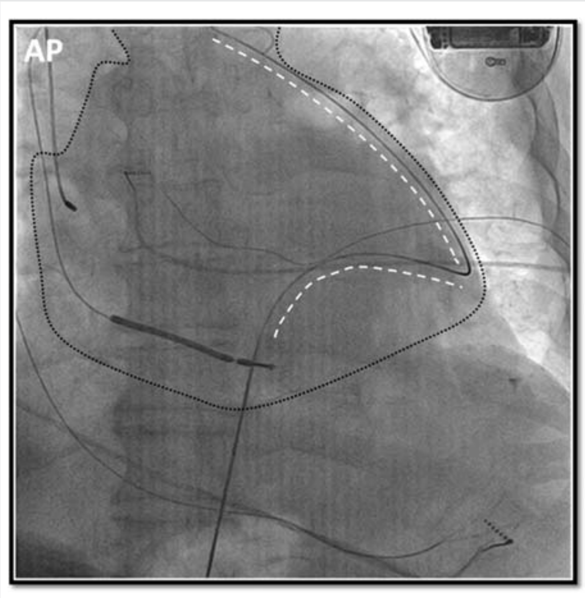

Figure 3 Antero-posterior (AP) view of guidewire through the epicardial needle during an anterior approach forming a large loop (white dashed line) that lies along the cardiac silhouette suggesting pericardial location.

entry into the RV cavity may occur inadvertently. In such cases, aspiration of blood or passage of the guidewire into the RV/right ventricular outflow tract accompanied by salvoes of premature ventricular contractions indicates entry into the RV cavity. If this occurs, the needle should be slowly withdrawn a few millimetres and the guidewire pulled back into the needle tip and readvanced. This can be repeated until one gains entry into the pericardial space as opposed to withdrawing the needle entirely.

As a general rule, as the guidewire is advanced, it should slide unimpeded over the epicardial surface until it outlines the fluoroscopic left heart border. This is usually achieved and confirmed in the left anterior oblique (LAO) view by advancing the guidewire, forcing it into a loop and observing the loop glide across the various chambers until it outlines the cardiac silhouette. Once the wire position within the pericardial space is confirmed beyond any doubt, the introducer and sheath are advanced over the wire under fluoroscopy maintaining adequate length of guidewire distal to the sheath tip. The introducer/guidewire is then removed and a standard ablation/pig-tail catheter is advanced through the sheath and manipulated into the pericardial space (*Figure 3*). Double wiring of the epicardial space to avoid inadvertent loss of pericardial access during sheath manipulation is often helpful. The pig-tail catheter is particularly useful to accurately assess the presence of haemopericardium as it has implications for subsequent heparinization.

Special care should be taken when excessive contrast is injected as it can obscure relevant fluoroscopy details if too much contrast is used. In this situation, the operator should consider waiting until the contrast dissipates allowing for clear visualization of the cardiac silhouette before attempting another puncture. Some operators try not to use contrast since if no contrast is used the views are preserved. However, it can be difficult to confirm the correct access without contrast using current tools.

Anterior vs. inferior approach

Depending on the indication and/or the location of the potential ablation target, either an inferior or an anterior approach to pericardial puncture may be chosen. Typically, an inferior puncture (*Figure 4*, upper panel) allows for better mapping and ablation of the infero-lateral wall of the ventricles and the posterior wall of the LA or for epicardial LV lead placement. Conversely, an anterior puncture may be preferable when the anterior walls of the heart, such as the anterior RV or the left and right atrial appendages are the target regions. When needle access is attempted with prior cardiac surgery, posterior access maybe attempted.

In order to enter at the inferior surface of the pericardium, the puncture can be performed in 40° LAO projection because it gives the operator a better view of the inferior wall of the heart. When an anterior puncture is chosen (*Figure 4*, lower panel), the entering point should be 3–4 cm below the junction of the xiphoid appendage and the costal bone and the needle should advanced in a slightly shallow approach angle, often with gentle downward pressure to keep the left lobe of the liver away from the needle path. In this situation, the antero-posterior (AP) projection may facilitate visualization of the free wall of the right ventricle.

Advancing the guidewire and sheath

The guidewire is always advanced under fluoroscopy typically in the AP/LAO projection. When the AP projection is chosen, it is difficult to discriminate whether the guidewire is actually in the pericardium along the lateral surface of the LV, or is instead being advanced into a dilated RV and pulmonary artery. The operator can only be sure that the guidewire is wrapping around the heart in the LAO projection. When it does occur, inadvertent RV puncture with the epidural needle or the guidewire does not cause severe complications. However, if the sheath is inadvertently advanced into the RV, surgical repair may be required to control the resulting haemopericardium. Thus, until the location of the guidewire is confirmed by fluoroscopic visualization in an LAO projection, the sheath should not be placed.

Percutaneous access in patients with a history of cardiac surgery

Postoperative pericardial adhesions were initially thought to be contraindications to percutaneous epicardial access. However, it is possible to perform percutaneous access in these patients albeit with caution. In this situation, an inferior approach should be used because of the higher density of the adhesions anteriorly, where the pericardial sac is typically opened during cardiac surgery. As in patients without prior cardiac surgery, contrast should be used to verify the location of the needle tip as it is advanced. However, instead of the typical appearance of a 'sluggish' layering of the contrast medium around the heart, the contrast tends to pool along the inferior aspect of the heart.[11]

In the authors' experience, it is possible to perform an inferior puncture in up to a third of the patients after cardiac surgery.

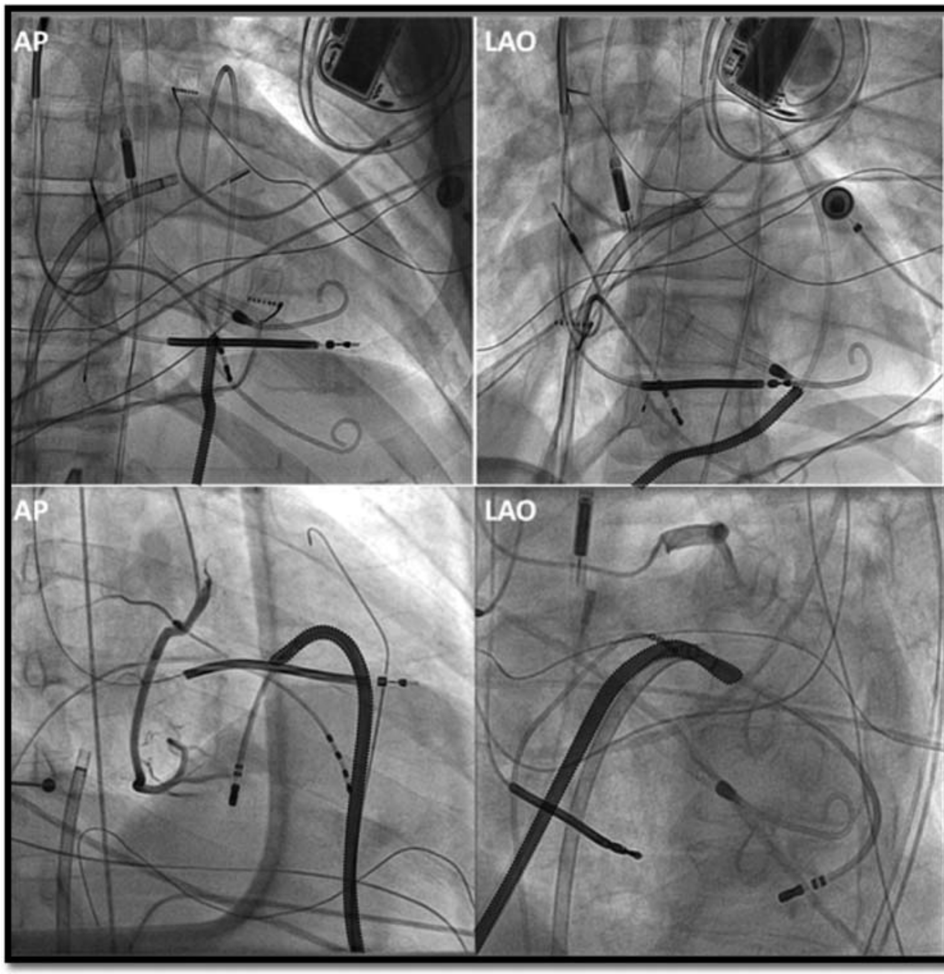

Figure 4 Upper panel: antero-posterior (AP) and left anterior oblique (LAO) view of a case demonstrating route taken by the sheath in a case where an inferior approach to epicardial access was pursued. A pig-tail catheter is shown exiting the sheath into the pericardial space. Note how the sheath enters inferiorly. Lower panel: right anterior oblique and LAO view of a case demonstrating route taken by the sheath in a case where an anterior approach to epicardial access was pursued in a patient with right ventricular dysplasia. An ablation catheter is shown exiting the sheath into the pericardial space. Note how the sheath enters anteriorly over the right ventricular surface. It is clear that the position of the guidewire inside the pericardial space can only be fully appreciated in the LAO projection. In right anterior oblique and right lateral, one cannot be sure whether the guidewire is being advanced inside the RV and pulmonary artery instead of the free pericardial space.

The amount of exposure to the epicardial surface is often limited using this technique typically along the infero-lateral region. Multiple attempts are often needed and the incidence of complications is usually higher and is best reserved for extreme situations where open surgical access is not an option.

Subxiphoid surgical approach in patients with a history of cardiac surgery

As proposed by Soejima *et al.*,[12] a limited surgical approach to gain epicardial access in patients with prior cardiac surgery is feasible and fairly safe. The cardiac surgeon typically makes a 3 in. vertical incision in the midline in the epigastrium but veering to the left of the xiphoid process. The pericardium is subsequently opened horizontally, parallel to the diaphragmatic reflection and the incision is extended to improve visualization of the ventricle. This is followed by blunt dissection of pre-existing adhesions inferiorly so as to expose the maximal possible epicardial surface without either excessive bleeding risk or damage to the bypass grafts. After the ablation procedure, the incision is closed and a pericardial drain is placed overnight and removed the next morning if appropriate. This approach is usually well tolerated by patients.

Breaking pericardial adhesions with the ablation catheter or guidewire

Despite the surgical window or successful posterior needle access, the ability to map the epicardial surface may often be confined to a small area along the infero-lateral wall of the left ventricle. In this situation, the operator can with caution, force the curve of the deflected ablation catheter or the guidewire against the pericardial adhesions in an attempt to gently disrupt them. Often this successfully disrupts the pre-existing adhesions and allows improved access to the epicardial surface. The same approach can be useful when unanticipated epicardial adhesions are found in patients without previous cardiac surgery (due perhaps to prior pericarditis).

Percutaneous access in patients with a history of pericarditis/prior epicardial access

The vast majority of patients in this group can undergo percutaneous access with unimpeded access to the entire epicardial surface. Moreover, in the absence of severe pericarditis this can be performed repeatedly.[13] Animal data exist[14] to support the use of epicardial steroids to minimize post-procedure pericarditis and this can allow for easier access by limiting adhesion formation. Human data have not been produced.

Epicardial mapping

With the catheter in pericardial space, the operator can easily map the entire epicardial surface of both the right and left ventricles as well as parts of the atria. The limits of this surface are marked by pericardial reflections. The lateral and inferior/posterior walls of the ventricles are easier to map as compared with the anterior wall due to difficulty in generating good contact force anteriorly. Compared with endocardial mapping, catheter stability in the pericardial space is better due to the relatively constant apposition of the catheter against the epicardial surface of the heart unless an effusion is not drained. This stability is obtained by the constant apposition of the two layers of the pericardium by the negative pressure found within the pericardial space.

Use of special sheaths during epicardial mapping and ablation

Although contact between ablation catheter and the epicardium is good in most situations, certain locations along the epicardial surface (depending on the approach used for percutaneous access) contact forces can be suboptimal leading to ineffective lesion generation. Although soft tip long vascular sheaths (e.g. Brite-tip®, Johnson & Johnson) are often adequate in most situations, deflectable sheaths (Agilis™ EPI steerable sheath, St Jude Medical) can be used to enhance contact. An important measure when using sheaths is to ensure that the lumen of the sheath is always occupied either with an ablation catheter or a pig-tail catheter so as to prevent the distal edge of the sheath from causing local trauma.

Conclusions

Epicardial catheter mapping and ablation is frequently useful and sometimes an essential approach for the treatment of certain cardiac arrhythmias. This technique can be safely performed in most patients but there is a risk of RV perforation especially in less experienced hands. Adequate understanding of the relevant anatomy, different approaches to epicardial access, mapping techniques, and knowledge of different complications is important to ensure successful and safe use of this technique.

Conflict of interest: none declared.

References

1. Sosa E, Scanavacca M, d'Avila A, Pilleggi F. A new technique to perform epicardial mapping in the electrophysiology laboratory. *J Cardiovasc Electrophysiol* 1996;**7**:531–6.
2. Sosa E, Scanavacca M, d'Avila A, Piccioni J, Sanchez O, Velarde JL *et al.* Endocardial and epicardial ablation guided by nonsurgical transthoracic epicardial mapping to treat recurrent ventricular tachycardia. *J Cardiovasc Electrophysiol* 1998;**9**:229–39.
3. Sosa E, Scanavacca M, d'Avila A, Oliveira F, Ramires JA. Nonsurgical transthoracic epicardial catheter ablation to treat recurrent ventricular tachycardia occurring late after myocardial infarction. *J Am Coll Cardiol* 2000;**35**:1442–9.
4. d'Avila A, Scanavacca M, Sosa E. Transthoracic epicardial catheter ablation of ventricular tachycardia. *Heart Rhythm* 2006;**3**:1110–1.
5. Schweikert RA, Saliba WI, Tomassoni G, Marrouche NF, Cole CR, Dresing TJ *et al.* Percutaneous pericardial instrumentation for endo-epicardial mapping of previously failed ablations. *Circulation* 2003;**108**:1329–35.
6. Reddy VY, Neuzil P, Ruskin JN. Extra-ostial pulmonary venous isolation: use of epicardial ablation to eliminate a point of conduction breakthrough. *J Cardiovasc Electrophysiol* 2003;**14**:663–6.
7. Soejima K, Stevenson WG, Sapp JL, Selwyn AP, Couper G, Epstein LM. Endocardial and epicardial radiofrequency ablation of ventricular tachycardia associated with dilated cardiomyopathy: the importance of low-voltage scars. *J Am Coll Cardiol* 2004;**43**:1834–42.
8. d'Avila A, Scanavacca M, Sosa E, Ruskin JN, Reddy VY. Pericardial anatomy for the interventional electrophysiologist. *J Cardiovasc Electrophysiol* 2003;**14**:422–30.
9. Abbara S, Desai JC, Cury RC, Butler J, Nieman K, Reddy V. Mapping epicardial fat with multi-detector computed tomography to facilitate percutaneous transepicardial arrhythmia ablation. *Eur J Radiol* 2006;**57**:417–22.
10. Sosa E, Scanavacca M. Epicardial mapping and ablation techniques to control ventricular tachycardia. *J Cardiovasc Electrophysiol* 2005;**16**:449–52.
11. Sosa E, Scanavacca M, D'Avila A, Antônio J, Ramires F. Nonsurgical transthoracic epicardial approach in patients with ventricular tachycardia and previous cardiac surgery. *J Interv Card Electrophysiol* 2004;**10**:281–8.
12. Soejima K, Couper G, Cooper JM, Sapp JL, Epstein LM, Stevenson WG. Subxiphoid surgical approach for epicardial catheter-based mapping and ablation in patients with prior cardiac surgery or difficult pericardial access. *Circulation* 2004;**110**:1197–201.
13. Sacher F, Roberts-Thomson K, Maury P, Tedrow U, Nault I, Steven D *et al.* Epicardial ventricular tachycardia ablation a multicenter safety study. *J Am Coll Cardiol* 2010;**55**:2366–72.
14. d'Avila A, Neuzil P, Thiagalingam A, Gutierrez P, Aleong R, Ruskin JN *et al.* Experimental efficacy of pericardial instillation of anti-inflammatory agents during percutaneous epicardial catheter ablation to prevent postprocedure pericarditis. *J Cardiovasc Electrophysiol* 2007;**18**:1178–83.