Techniques for Percutaneous Left Ventricular Apical Access

What you need to know.

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Percutaneous left ventricular (LV) apical access was first reported in 1956 by Brock et al.[1] For many years, it was the standard method to obtain ventricular pressure measurements. Once transvascular left heart catheterization became available, the need for the transapical approach decreased but remained an option in patients with mechanical aortic and mitral valve prostheses.[2,3] Apical access has received renewed attention lately by facilitating alternative access for complex cardiac structural interventions, including closure of ventricular septal defects (VSDs),[4,5] LV pseudoaneurysm repair and paravalvular leak (PVL) closure,[6-9] and most recently, to externalize the guidewire to provide a coaxial rail for support during transseptal transcatheter mitral valve implantation.[10,11] Percutaneous LV apical access is also utilized by electrophysiologists during ventricular tachycardia ablation procedures in patients with aortic and mitral mechanical valve prostheses[12] or with aortic mechanical valves when previous transseptal attempts were not successful due to inadequate catheter contact with the basal septum (Table 1).[13]

It is clear that the role of percutaneous LV apical access is expanding in the current era of transcatheter structural and electrophysiology interventions. However, one needs to be aware of both the advantages and the risks associated with this procedure.

TABLE 1. POTENTIAL APPLICATIONS OF PERCUTANEOUS LV APICAL ACCESS IN THE CURRENT ERA

- Diagnostic hemodynamic evaluation in patients with mechanical aortic and mitral valve prostheses
- Percutaneous closure of VSD
- Percutaneous closure of PVL
- Percutaneous LV pseudoaneurysm repair
- To externalize guidewire during transeptal mitral valve implantation to provide coaxiality during valve deployment
- Ventricular tachycardia ablation procedures in patients with mechanical aortic and mitral valve prostheses

THE DATA BEHIND APICAL ACCESS

The main advantages of direct apical access include the close proximity to both the mitral and aortic valves, a favorable approach angle for valve implantation or PVL closure, and an alternative to retrograde LV access via the two transvascular approaches (ie, retrograde from the aorta or antegrade from the transseptal route). These transvascular accesses make device manipulation more difficult due to the long catheter length from the access point to the point of intervention, the lack of a coaxial approach angle for procedures, and the tendency of stored tension that limits tactile feedback and fine catheter adjustment. Percutaneous apical access is not without its challenges, but these can be greatly alleviated with imaging.

Complications have been reported in several series, which often did not have the same preprocedural imaging used for planning as what is currently recommended today. In a series of cases from the Massachusetts General Hospital reported by Walters et al, 38 patients with aortic and mitral mechanical prosthetic valves underwent percutaneous LV access for hemodynamic evaluation between 1989 and 2000.[3] During the procedure, the LV apex was identified by palpation or echocardiography. A 5.5-F X 20.5-cm-long One-Stem fluid drainage assembly system (Electro-Catheter Corp.) was used for LV access. This system consists of a trocar, needle, and pigtail catheter. The procedures were performed under fluoroscopic guidance, and echocardiographic guidance was not consistently used. Device closure of the apical puncture was not used. Intravenous heparin infusion without bolus was resumed 4 to 6 hours after the procedure. Three patients (8%) had LV access-related complications, including local hematoma, puncture site repair,

hemopericardium, hemothorax, thoracotomy and decortication, and ventricular fibrillation.

Pitta et al reported the complications seen in a series of 32 patients undergoing percutaneous LV access between 2002 and 2009 for diagnostic hemodynamic evaluation or PVL closure at the Mayo Clinic.[6] These procedures were performed under fluoroscopic and echocardiographic guidance. In this series, an 18- or 21-gauge Angiocath catheter system (Becton, Dickinson and Company) was used. The sheath size ranged between 4 and 6 F, and no closure devices were used for hemostasis after the procedure, but anticoagulation was reversed. A higher complication rate was found when LV access was used for interventions compared with diagnostic procedures (25% vs 12.5%), despite reversing anticoagulation. This finding was probably related to the larger size sheath required for interventions. Hemothorax was the most frequent serious complication (19%), requiring intervention in most patients (16%).[6]

A more recent report by Jelnin et al described the outcomes of 32 procedures utilizing percutaneous LV access in 28 patients undergoing mitral PVL closure or LV pseudoaneurysm repair between 2008 and 2010.[8] In addition to echocardiography and fluoroscopy, CT angiography was used for preprocedural planning and, subsequently, for intraprocedural guidance using the HeartNavigator software (Philips Healthcare). The sheath size ranged from 5 to 12 F. Closure devices were used to achieve hemostasis in all procedures utilizing 6-F or larger sheaths. Closure was achieved with an Amplatzer muscular VSD occluder (St. Jude Medical, Inc.) in one patient and a 6- X 4-mm Amplatzer duct occluder (St. Jude Medical, Inc.) in the remaining patients (off-label use of devices). Surgiflo hemostatic matrix (Ethicon, a Johnson & Johnson company) was injected though the delivery sheath to fill the track from the epicardium to the skin at the end of the procedure. There were no complications in the four patients who underwent the procedure with a 5-F sheath despite no closure device being used. When a closure device was used, successful LV apical access closure was achieved in all patients. However, one pericardial effusion was documented by echocardiography, but this did not require drainage. There was one procedure-related death in a patient with suprasystemic pulmonary hypertension, who developed pulseless electrical activity cardiac arrest after successful PVL closure and transapical puncture closure. No evidence of pericardial effusion was found by echocardiography and emergency thoracotomy. There were no other LV access-related complications.[8]

The results of this series are encouraging, as they show that the addition of CT angiography to procedural planning and the use of closure devices in the contemporary era add safety to the procedure. The technique and equipment has also improved over time, particularly the use of a 21-gauge micropuncture needle kit instead of the traditional

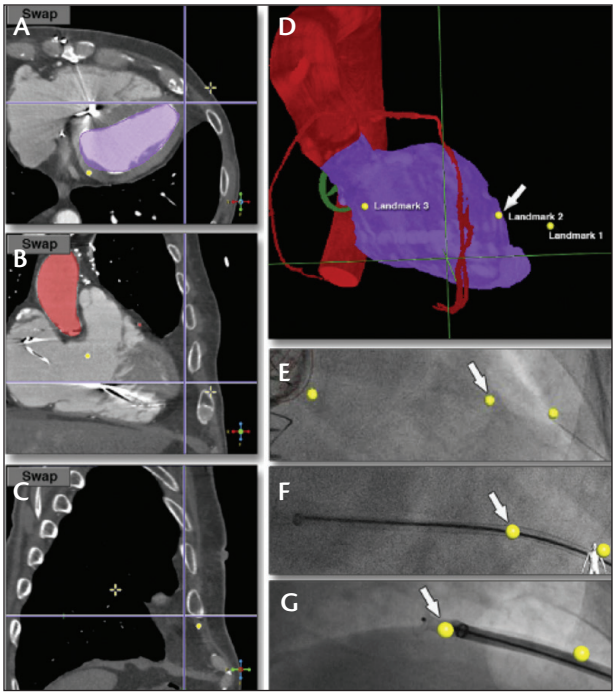

Figure 1. CT angiography and fluoroscopy fusion to guide percutaneous LV apical access. Axial (A), coronal (B), and sagittal (C) images of CT angiography were three-dimensionally rendered and segmented using the HeartNavigator software (Philips Healthcare). The aorta and coronary arteries are shown in red and the left ventricle in purple (D). Yellow dots were placed and utilized as landmarks to identify skin entry and epicardial left ventricle entry (D, arrow). The CT angiographic images were then coregistered and overlaid onto live fluoroscopy to guide percutaneous LV access (E-G). Reprinted from J Am Coll Cardiol Imag, Vol. 7, Kliger C, Jelnin V, Sharma S, et al, CT angiography-fluoroscopy fusion imaging for percutaneous transapical access, pp. 169-177, 2014, with permission from Elsevier.[15]

18-gauge needles used in the past, which might contribute to lower complication rates as well.

ROLE OF IMAGING

The role of imaging in procedural planning is crucial to achieving success and minimizing complications. In the initial experience, imaging was primarily limited to fluoroscopy. The LV apex was identified externally on the chest wall by palpation only. Eventually, echocardiography was utilized, initially with M-mode[14] as it was the only form available, and later with two-dimensional imaging. More recently, the use of high-resolution CT has been a major breakthrough in preprocedural planning. CT can help identify the intercostal space that will allow entry into the desired target in the LV, identify the structures to avoid, (eg, lung tissue and coronary arteries, particularly the left ante-

rior descending [LAD] artery), and even project an angle of entry to reach the structural target (ie, prosthetic mitral annular paravalvular leak).[8]

CT analysis and planning can be done manually or with the use of software. Kliger et al described the use of the HeartNavigator software to provide CT angiography-fluoroscopy fusion imaging to guide these procedures.[15] This method allows the operator to fuse CT images obtained before the procedure with live fluoroscopy. Markers can be placed based on CT analysis and are projected in the live fluoroscopic screen to help identify cardiac structures, such as the target entry into the LV (Figure 1). Kliger et al reported a series of 20 consecutive patients undergoing percutaneous LV apical access for mitral PVL closure (70%), mitral PVL closure and valve-in-valve implantation (20%), LV pseudoaneurysm closure (5%), and aortic PVL and Gerbode defect closure (5%) utilizing this technique. Markers were placed to identify the desired site of LV entry, as well as the lung tissue and the LAD artery to identify their location during LV puncture. Successful percutaneous transapical access was achieved in 100% of the patients, and no LV access-related complications were seen. These results are encouraging; however, not every center has this software. Fortunately, operators may obtain similar information with alternative methods. In addition, all of the patients in this study had undergone previous cardiac surgery. It is possible that a previous cardiac surgery may have protected them against significant pericardial effusion due to pericardial adhesions. It is unknown if similar outcomes can be achieved in patients without previous cardiac surgery undergoing apical puncture for an intervention (ie, transcatheter valve implantation in a native calcified mitral valve).

TECHNIQUE

We recommend the use of multi-image modality integrating information obtained by echocardiography, CT angiography, and fluoroscopy. Even though the HeartNavigator software can help in the preprocedural planning and intraprocedural guidance, not every operator has access to this software. In the absence of this tool, operators may obtain very valuable information with manual analysis of the CT images. Three-dimensional volume rendering can help identify the desired point of LV apical entry, thereby avoiding the LAD artery or other coronary vessels and lung tissue, as well as identifying the appropriate intercostal space for needle entry (Figure 2).

Percutaneous LV apical access as part of a structural intervention is usually performed under general anesthesia. Once the patient is on the hybrid cath lab/operating room table and under anesthesia, the operators can use palpation to locate the apical impulse. Later, two-dimensional echocardiography can be used to confirm that the intercostal space selected by CT analysis will provide the correct angle

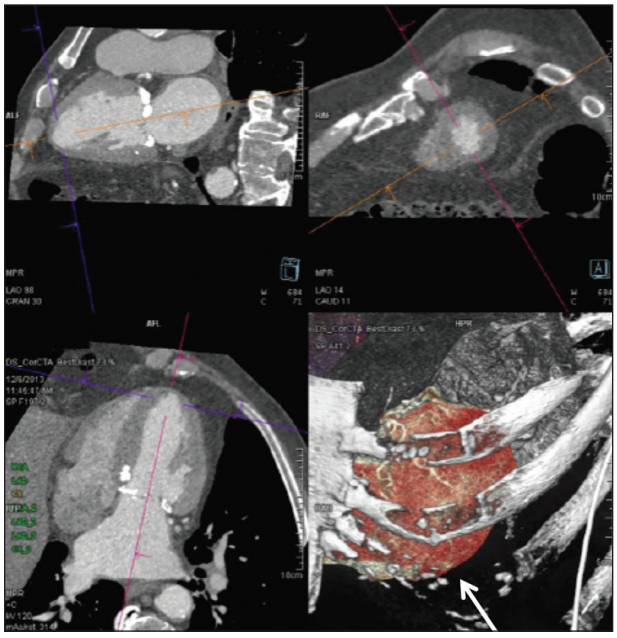

Figure 2. Three-dimensional reconstruction of CT angiography allows for identification of the target apical entry and delineation of a safety window (arrow), avoiding the LAD artery and lung tissue and determining the intercostal space for needle entry.

of entry into the desired "window of safety," which is the lateral segment of the apex away from the LAD artery and lung tissue. Two-dimensional echocardiography can also be used to confirm the correct angle to approach the target for structural intervention (ie, location of PVL).

One should scan the chest with echocardiography and place a radiopaque marker, such as a hemostat, to confirm the position and intended entry trajectory with fluoroscopy. The operators should take into consideration the respiratory cycle and observe fluoroscopic landmarks on both inspiration and expiration. It is best to make the puncture at the end of expiration, with the ventilator paused, to decrease the risk of lung injury. The decision regarding which intercostal space to use should be made during expiration as well to avoid entering too high in the lateral wall. Once the site entry site is determined, the skin is marked with a marker, and the patient is prepared and draped in the usual sterile fashion for the procedure. The chest should be prepared for emergent pericardiocentesis or cardiac surgery if needed to treat complications.

The use of a micropuncture system (ie, the 21-gauge X 15-cm-long micropuncture needle with 4-F Stiffen micro-introducer, Galt Medical Corporation) to enter the LV instead of a large 18-gauge needle is believed to be valuable in minimizing complications. Operators must take into consideration the neurovascular bundle located below the inferior border of the ribs and introduce the needle right on

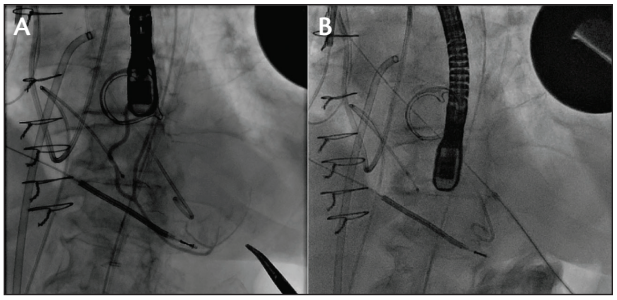

Figure 3. Angiography of the left internal mammary graft to the left anterior descending in left anterior oblique view. Important landmarks were identified in this view with surrogate markers including an automatic implantable cardioverter defibrillator and temporary pacer lead in the RV apex and pigtail catheter in the LV apex. The hemostat indicates the desired level of apical entry (A). A radiopaque-tip sheath was introduced in the left ventricle after achieving access with a micropuncture needle (B).

the superior border to avoid damage to the bundle, as well as the primary risk of either arterial or venous bleeding from the intercostal vessels. In the absence of HeartNavigator software, other surrogate fluoroscopic landmarks can be used to define the location of the right ventricle (RV) (ie, pre-existing pacer lead in the RV apex or new temporary transvenous pacer if needed for intervention, as in transcatheter mitral valve implantation), the location of the LV (a pigtail catheter can be positioned in the LV apex, and contrast injections can be performed to further delineate the apex), and the left coronary artery (selective coronary angiography can be performed either through the left coronary or bypass graft to the LAD artery if no flow through the native LAD artery exists). The left anterior oblique cranial view is useful when advancing the needle in the LV because it allows for visualization of all the structures mentioned, including the RV, LV, and LAD (Figure 3).

It is helpful to hold ventilation in expiration during needle entry to prevent lung injury. The needle is advanced while applying negative suction with a syringe to achieve blood return when entering the LV (the operator might notice premature ventricular contractions while entering the LV myocardium). Once blood return is achieved, the syringe is disconnected, and a 0.018-inch guidewire is introduced into the LV (either the 60-cm, 0.018-inch wire in the micropuncture kit or a longer wire). When the needle is removed and the soft wire is in the LV, ventilation can be resumed. This step should not take more than several seconds, and it is best not to have respiratory movement during this critical portion of the procedure.

Once the wire is in the LV and the patient is breathing, the micropuncture catheter is introduced into the LV cavity, and the wire is removed. It is helpful to measure the pressure through the micropuncture catheter to confirm positioning in the LV (and not the RV) prior to exchanging for a larger sheath. If the RV is inadvertently entered, the micropuncture wire or the micropuncture sheath (if placed) may be removed without requiring a closure device, or it may be left in the RV temporarily as a marker during a second attempt at LV entry to avoid re-entering the RV.

The pressure measurement may be obtained with the help of a Touhy-Borst adaptor without losing wire position. Once position in the LV is confirmed, a 0.035-inch guidewire is introduced into the LV through the larger element of the micropuncture sheath and, if possible, across the aortic or mitral valve to gain a more distal position of the wire in order to facilitate sheath insertion. The micropuncture catheter is then exchanged for the sheath required for intervention. It is beneficial to use a sheath with a radiopaque marker at the tip to visualize its location at all times and to consider a 23-cm length. Once access is achieved, standard anticoagulation is recommended. Sheath exchanges should be avoided during the procedure because the LV entry site might bleed. When the intervention is complete, the LV apical access may be closed with the off-label use of an Amplatzer AGA closure device (St. Jude Medical, Inc.). Multiple devices have been successfully used to achieve closure, including the Amplatzer muscular VSD occluder, Amplatzer vascular plug II, Amplatzer duct occluder, and Amplatzer duct occluder II (St. Jude Medical, Inc.). The use of these devices has not been systematically evaluated, and there are no established guidelines regarding device type and size selection. The 6-mm to 4-mm Amplatzer duct occluder and the 4-mm to 6-mm Amplatzer duct occluder II have been the most frequently used. The use of a 0.014-inch safety wire or "buddy wire" is recommended as it may facilitate repeat entry into the LV through the apical tract if needed in case the closure device dislodges or pulls through the LV wall during deployment. The use of the smaller-profile AGA delivery cable facilitates this maneuver without having to upsize the sheath to make room for the safety wire. Depending on the sheath size used, the space for a safety wire may be limited. In some instances, it is best to first introduce the closure device and deploy both discs in the LV cavity and then introduce the wire through the sheath next to the AGA delivery cable.

Once the safety wire is in the LV, the proximal disc of the closure device may be recaptured into the sheath to proceed with deployment in the apical wall under fluoroscopic and transesophageal echocardiographic guidance. The presence of a pigtail catheter in the LV apex to provide contrast injections is helpful during this crucial step. Similarly, small manual contrast injections through the sheath in the LV may assist in determining the location of the closure device in relationship with the LV wall. When the distal disc is against the LV wall and some tension is applied, the operator may release the rest of the device under fluoroscopic

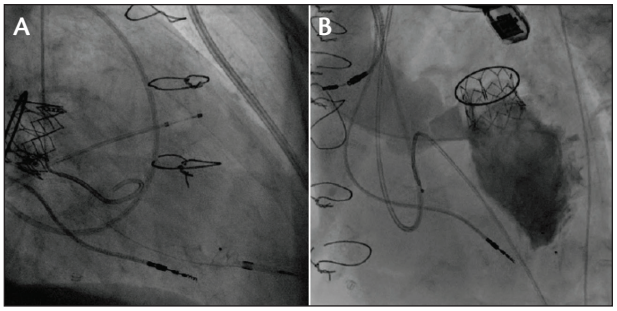

Figure 4. A 6- X 4-mm Amplatzer duct occluder II closure device was deployed in the LV access site. A 0.014-inch wire was in the LV as a safety wire (A). Left ventriculography demonstrated the closure device in the LV wall near the apex without evidence of extravasation (B).

and transesophageal echocardiographic guidance, leaving the safety wire in place. After confirming adequate positioning of the device and lack of bleeding, as demonstrated by left ventriculography (using the standard injector settings and the pigtail placed in the distal third of the LV), the device can be released and the safety wire removed (Figure 4). Anticoagulation is reversed with protamine. The subcutaneous tract may be sealed with an injection of Surgiflo hemostatic matrix through the sheath while it is being removed. There should be contrast in the sheath to visualize the Surgiflo as it exits the sheath and enters the tract. Manual pressure may be applied after sheath removal, but it is usually not needed. A final postprocedure echocardiogram is recommended to document lack of pericardial effusion. If a new or worsening pericardial effusion is demonstrated, careful clinical and echocardiographic evaluation is recommended to rule out tamponade physiology. Rarely, pericardiocentesis might be needed to treat significant pericardial effusion. This can be achieved using a standard subxyphoid approach or through the sheath in the LV prior to complete removal (a wire may be introduced in the pericardial space through the sheath as it reenters the pericardial space while being pulled back from the LV. Once a wire is in the space, and proper position is confirmed by fluoroscopy, a pericardial drain catheter may be introduced over the guidewire).

The patients are usually observed overnight in the cardiac intensive care unit. A follow-up echocardiogram is obtained the next morning, and if absence of significant pericardial effusion is demonstrated, the patients may be discharged or transferred to a nonintensive care unit if they are stable. Although no established guidelines exist regarding endocarditis prophylaxis, one could consider the use of periprocedural antibiotics, as in ASD or VSD closure procedures and antibiotic prophylaxis prior to dental work for 6 months. To our knowledge, the role of this practice has not been evaluated.

CONCLUSION

Percutaneous LV apical access has an important role in complex structural and electrophysiology interventions. Operators need to be aware of the technique as well as the associated risks, and make efforts to prevent complications and be prepared to treat those that arise. Complications may be decreased with multimodality imaging for preprocedural planning and intraprocedural guidance, as well as with the use of closure devices. ■

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