ASE POSITION PAPER

Guidelines for Performing a Comprehensive Epicardial Echocardiography Examination: Recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists

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During the last few decades, the utility of intraoperative echocardiography has become increasingly evident as anesthesiologists, cardiologists, and surgeons continue to appreciate its potential application as an invaluable tool for monitoring cardiac performance and diagnosing pathology in patients undergoing cardiac surgery.[1,2] The essential information provided by intraoperative echocardiography regarding hemodynamic management, cardiac valve function, congenital heart lesions, and great vessel pathology has contributed to its widespread popularity. In fact, perioperative echocardiography has been shown to influence cardiac anesthetic and surgical management in as many as 50% of cases.[3] The publication of guidelines describing the indications for performing intraoperative echocardiography based on reviews of the literature and expert opinion of task force members from the Society of Cardiovascular Anesthesiologists (SCA), American Society of Anesthesiologists, and American Society of Echocardiography (ASE) has also facilitated the growth of this important diagnostic tool.[4,5]

Despite its overwhelming popularity and favorable influence on perioperative clinical decision-making and outcomes,[1,2,6] the transesophageal echocardiographic (TEE) approach to a comprehensive echocardiographic examination has some limitations. For example, TEE imaging of the distal ascending aorta and aortic arch may be impaired by the interposition of the trachea and main bronchi.[7-9] In addition, a TEE probe may occasionally be difficult or impossible to advance into the esophagus or, in patients with significant gastroesophageal pathology, TEE probe placement may even be contraindicated.[10] Furthermore, TEE may be rarely associated with perioperative morbidity from oropharyngeal and gastroesophageal injury (eg, dysphagia, gastrointestinal hemorrhage, gastroesophageal rupture).[10,11] Thus, an experienced echocardiographer must be familiar with other imaging approaches to conduct a comprehensive perioperative echocardiographic examination.

More than a decade before the introduction of TEE, epicardial echocardiography was already in use as a diagnostic imaging modality to assist cardiac surgeons, anesthesiologists, and cardiologists with clinical decision-making.[12] A comprehensive epicardial echocardiographic examination can be performed efficiently and safely,[13] and may be the most practical intraoperative imaging technique when a TEE probe cannot be inserted or when probe placement is contraindicated. Epicardial echocardiography may be superior to TEE because it can provide optimal image resolution when using higher frequency probes.[14] In addition, epicardial echocardiography may offer better windows for imaging anterior cardiac structures including the aorta, aortic valve (AV), pulmonic valve, and pulmonary arteries, and, therefore, may have a favorable influence on perioperative surgical decision-making.[15,16] However, epicardial imaging requires direct access to the anterior surface of the heart, and consequently cannot be performed without a sternotomy. Furthermore, the epicardial approach does not permit continuous monitoring, and requires interruption of the surgical procedure for imaging.

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The most recent recommendations by the ASE and SCA Task Force Guidelines for Training in Perioperative Echocardiography include epicardial and epiaortic imaging as core components of advanced training.[5] Thus, the following guidelines for performing a comprehensive epicardial echocardiographic examination have been developed by the ASE Council for Intraoperative Echocardiography to establish requirements for training, and to standardize a comprehensive epicardial examination using a set of 7 reliably obtained views.

TRAINING GUIDELINES

The epicardial approach is unique among the readily used echocardiographic imaging windows in that it requires a collaborative effort with the cardiac surgeon to either allow the echocardiographer to guide them in obtaining images, or alternatively permit the echocardiographer to have direct access to the epicardial surface within the operative field. Experience in epicardial echocardiography is an important component of advanced, rather than basic perioperative echocardiographic training as defined by the ASE and SCA Task Force Guidelines for Training in Perioperative Echocardiography.[5] Epicardial echocardiographic training should include the study of 25 epicardial examinations of which 5 are personally directed under the supervision of an advanced echocardiographer, before a trainee should pursue independent interpretation and application of the information to perioperative clinical decision-making.

EPICARDIAL PROBE PREPARATION

Epicardial echocardiography is performed by placing the ultrasound transducer on the epicardial surface of the heart to acquire 2-dimensional and color flow, and spectral Doppler images in multiple planes. Because of the proximity of the probe to the heart, epicardial echocardiography typically uses higher frequency probes (5-12 MHz). The probe is placed in a sterile sheath along with sterile acoustic gel or saline to optimize acoustic transmission. Two sheaths may also be used in an attempt to increase sterility. Warm sterile saline can be poured into the mediastinal cavity to further enhance acoustic transmission from the probe to the epicardial surface. The depth setting and the depth of transmit focus is then adjusted to visualize the near field. If a multifrequency probe is used, the frequency is increased to obtain the highest resolution image possible.

Epicardial images may only be obtained by an operator who is wearing a sterile gown and gloves, and uses sterile technique within the operative field as described in these guidelines. This task may be performed either by a diagnosing physician with advanced perioperative echocardiography training or, alternatively and perhaps more practically, by a cardiac surgeon under the direct guidance of an advanced echocardiographer. Interpretation of epicardial echocardiographic images for the purpose of directing intraoperative surgical and anesthesia decision-making should only be performed by a physician with advanced perioperative echocardiography training.

IMAGING PLANES

The following guidelines describe 7 epicardial echocardiographic imaging planes consistent with the ASE recommendations for transthoracic echocardiography (TTE) nomenclature.[17] We recognize that placement of the transducer directly on the heart provides views that can be slightly different than those obtained by TTE. These views will be identified as "modified" views. Individual patient characteristics, anatomic variations, or time constraints may limit the ability to obtain every component of the recommended comprehensive epicardial echocardiographic examination. Furthermore, there may be certain clinical situations where additional views may be necessary to address specific anatomic or pathologic questions. However, the 7 recommended views should permit the completion of a comprehensive 2-dimensional and Doppler echocardiographic evaluation in the vast majority of cardiac surgical cases, and should be obtainable in 5 to 10 minutes.[13]

Epicardial AV Short-axis View (TTE Parasternal AV Short-axis Equivalent)

The ultrasound transducer is placed on the aortic root above the AV annulus, with the ultrasound beam directed toward the AV in a short-axis (SAX) orientation to obtain the epicardial AV SAX view (Figure 1, *A*). Appropriate transducer alignment and orientation is critical and requires the orientation marker (indentation) on the transducer to face toward the patient's left. The transducer typically has to be rotated approximately 30 degrees clockwise to develop this view. The right coronary cusp will be at the top of the monitor screen, the left coronary cusp will be on the right, and the noncoronary cusp will be on the left side of the screen adjacent to the interatrial septum (Figure 1, *B*). By slowly moving the transducer, the coronary ostia can be visualized. The area of the AV can also be measured in this view using planimetry.

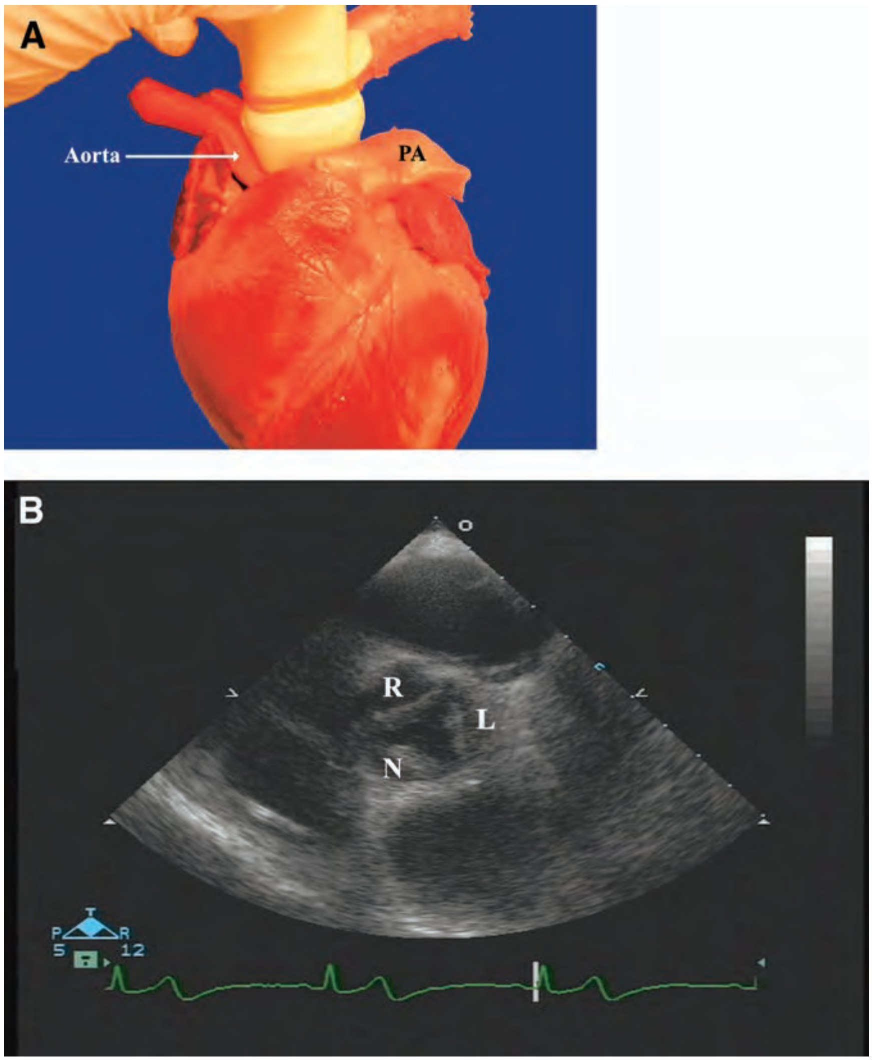

Figure 1 Epicardial aortic valve (AV) short-axis (SAX) view (transthoracic echocardiographic parasternal AV SAX equivalent). **A**, Porcine anatomic specimen demonstrating ultrasound transducer oriented above AV annulus so that ultrasound beam can be aligned in SAX plane to AV. **B**, When orientation marker (indentation) on transducer is pointed toward patient's left, right coronary cusp (*R*) will be at top of monitor screen, left coronary cusp (*L*) will be on right, and noncoronary cusp (*N*) will be on left side of screen adjacent to interatrial septum. *PA*, Pulmonary artery.

Epicardial AV Long-axis View (TTE Suprasternal AV Long-axis Equivalent)

The epicardial AV long-axis (LAX) view is obtained from the epicardial AV SAX view by positioning the probe parallel to the right-sided surface of the aortic root with the orientation marker slightly rotated clockwise and directed to the patient's left. The ultrasound beam is directed posteriorly to visualize the left ventricular (LV) outflow tract (LVOT) and AV (Figure 2). This view can be used to determine LVOT, aortic annulus, and sinotubular junction diameters. Furthermore, the LAX orientation provided by this view permits optimal alignment of a continuous wave and pulse wave Doppler ultrasound beam, to measure pressure gradients across the AV and LVOT. Similarly, color flow Doppler interrogation of the AV can be used to grade the degree of aortic insufficiency.

Epicardial LV Basal SAX View (TTE Modified Parasternal Mitral Valve Basal SAX Equivalent)

The epicardial LV basal SAX view is obtained from the epicardial AV SAX position by moving the probe toward the apex along the right ventricle (RV) with the transducer orientation marker again directed toward the patient's left (Figure 3, *A*). This view will approximate what will be achieved with a right parasternal TTE imaging plane, and shows more of

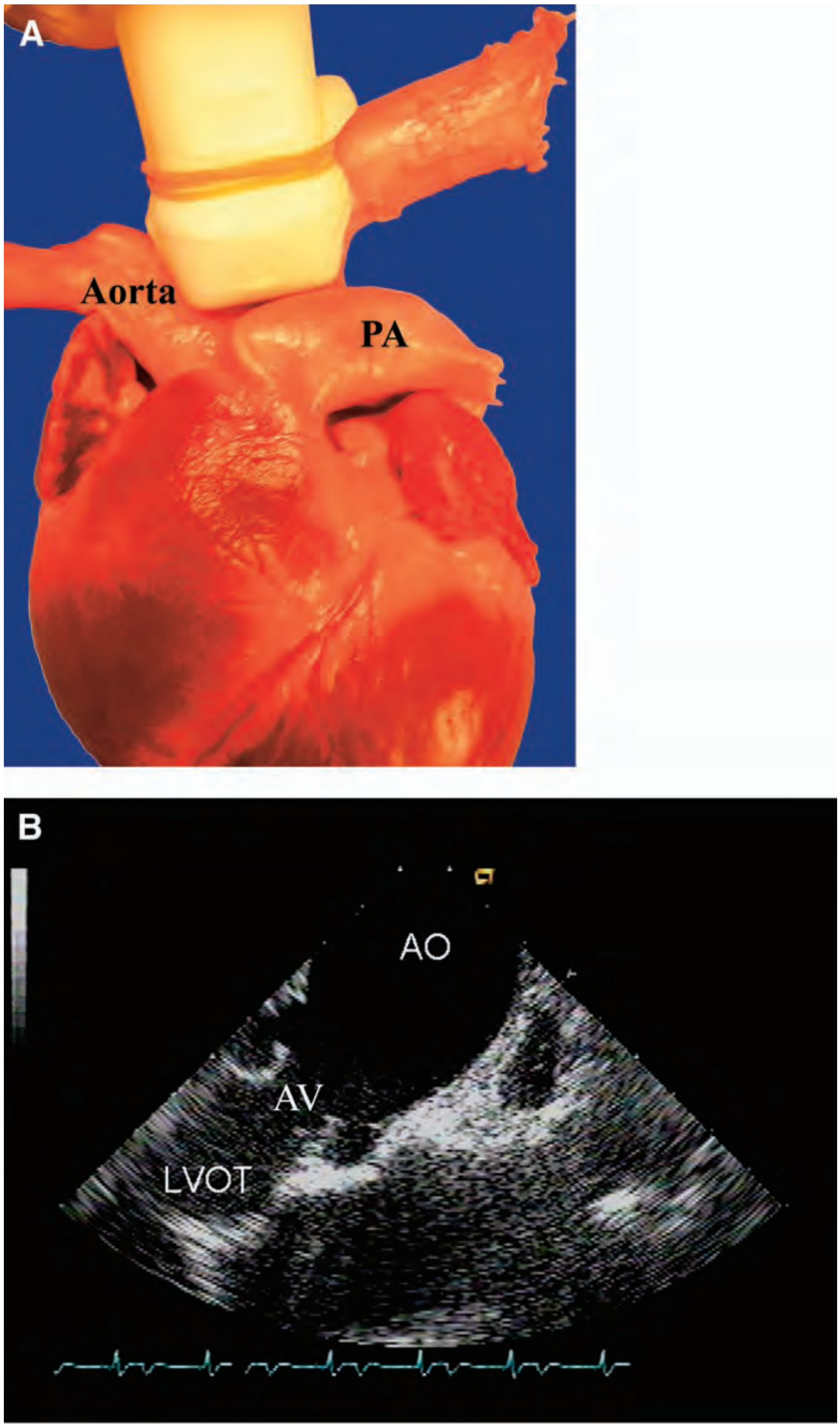

Figure 2 Epicardial aortic (*AO*) valve (*AV*) long-axis (LAX) view (transthoracic echocardiographic suprasternal AV LAX equivalent). **A**, Porcine anatomic specimen demonstrating ultrasound transducer oriented along AO root, and directing ultrasound beam posteriorly to visualize left ventricular outflow tract (*LVOT*) and AV. **B**, AV and LVOT are well visualized. *PA*, Pulmonary artery.

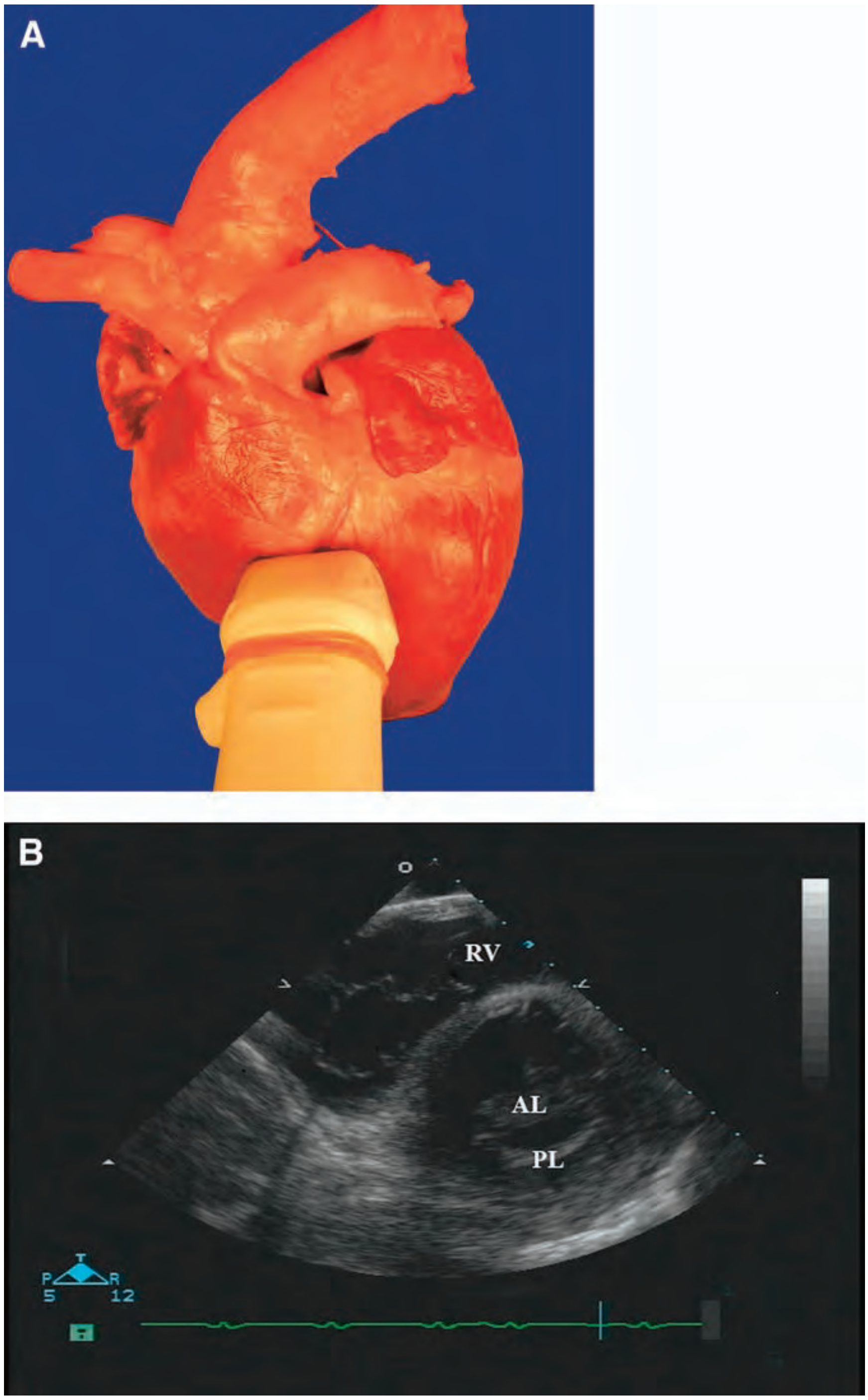

Figure 3 Epicardial left ventricle (LV) basal short-axis (SAX) view (transthoracic echocardiographic modified parasternal mitral valve [MV] basal SAX equivalent). **A**, Porcine anatomic specimen demonstrating proper probe positioning for developing epicardial LV basal SAX view. **B**, MV annulus is well visualized with its typical "fish mouth" appearance. MV anterior leaflet (*AL*) appears on top of screen and posterior leaflet (*PL*) is underneath. When transducer orientation marker is directed toward patient's left, MV anterolateral commissure will be on right and posteromedial commissure will be on left of screen. *RV*, Right ventricle.

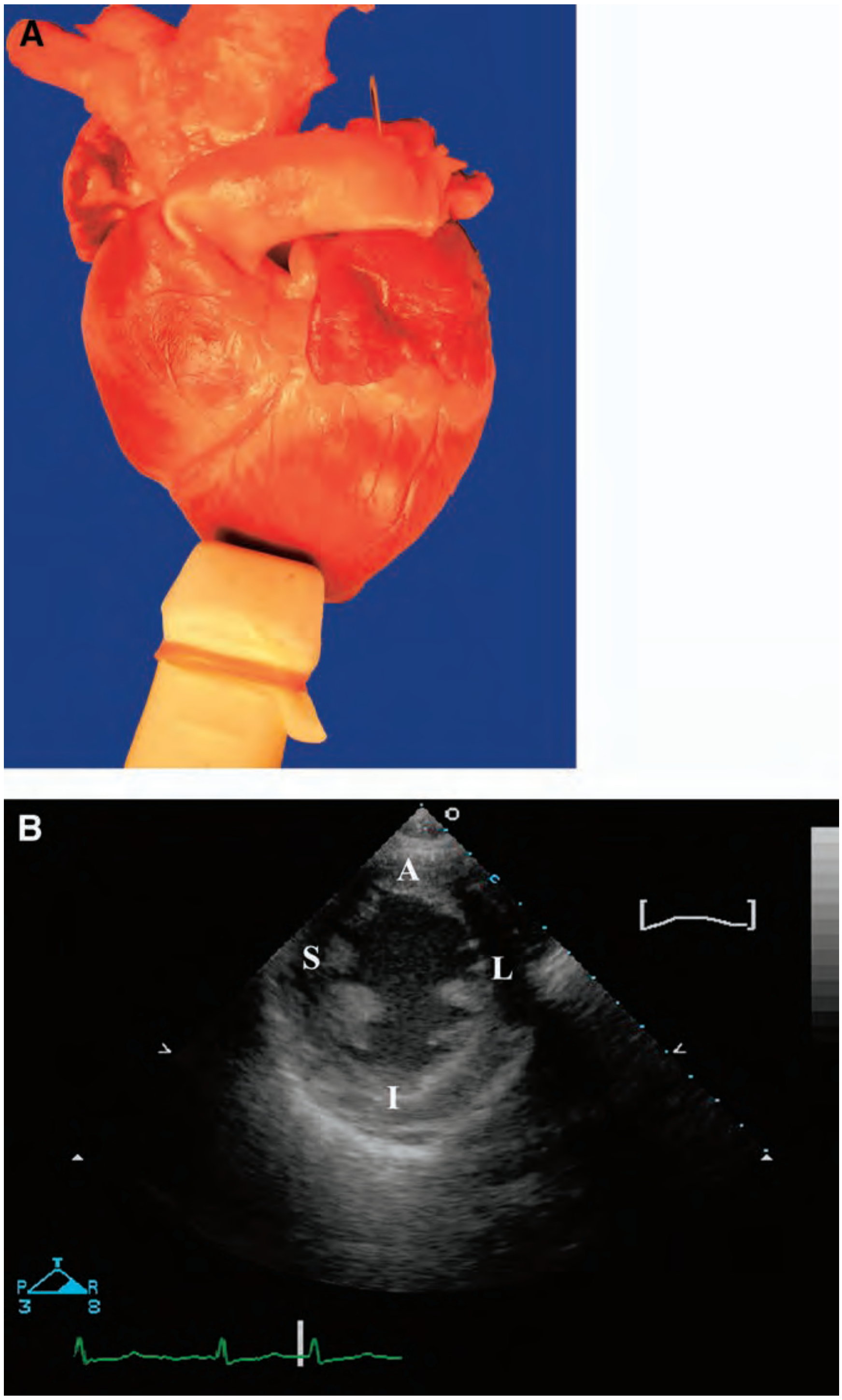

Figure 4 Epicardial left ventricle (LV) mid short-axis (SAX) view (transthoracic echocardiographic parasternal LV mid-SAX equivalent). **A**, Porcine anatomic specimen demonstrating proper epicardial probe positioning toward right ventricle apex for developing epicardial LV mid-SAX view. **B**, With transducer orientation marker directed toward patient's left, LV anterolateral papillary muscle will be on right and posteriomedial papillary muscle will be on left of ultrasound sector displayed on monitor. Septal (*S*) wall of LV is displayed on left followed by anterior (*A*), lateral (*L*), and inferior (*I*) walls, respectively, in clockwise rotation. The right ventricle is not visualized in this image.

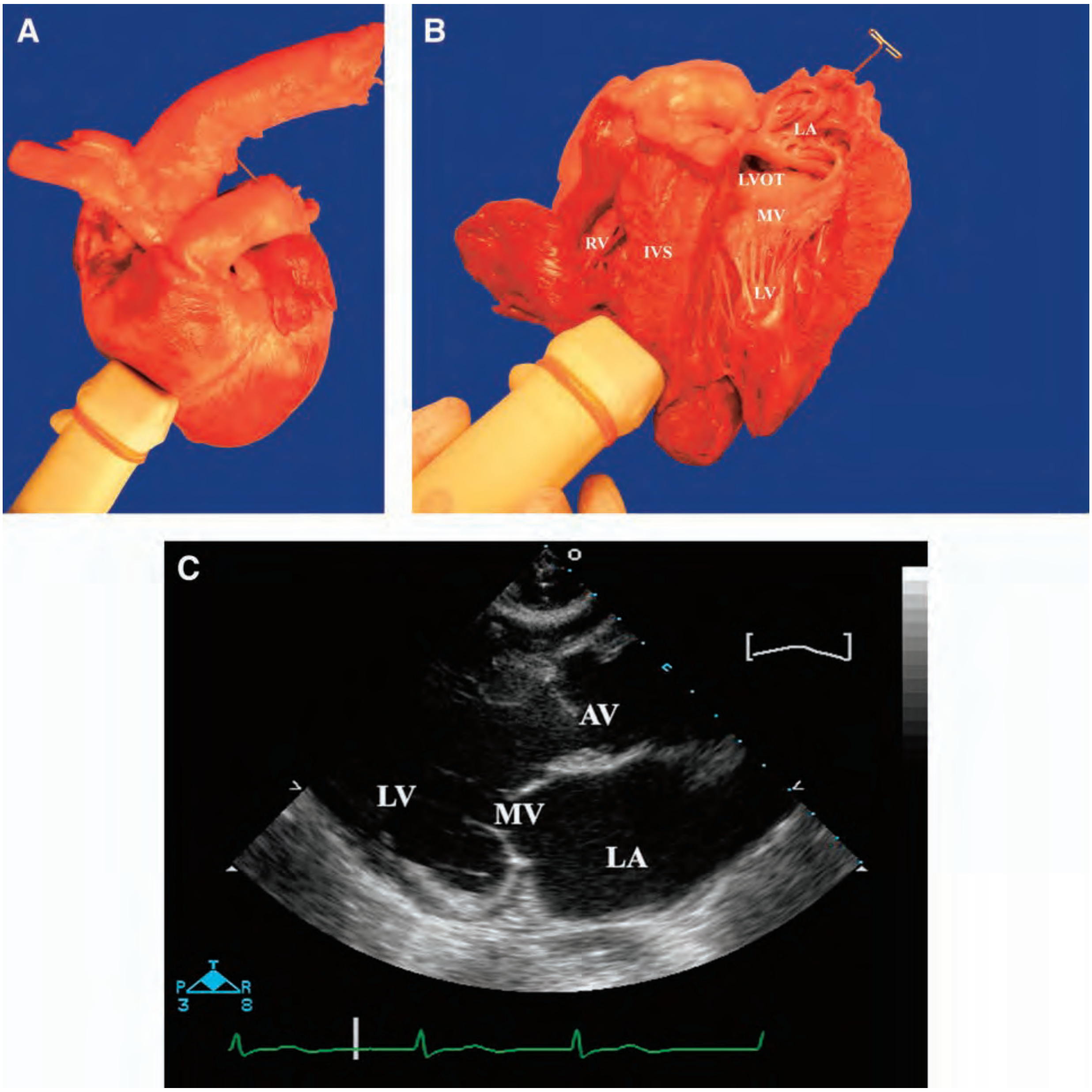

Figure 5 Epicardial left ventricle (*LV*) long-axis (LAX) view (transthoracic echocardiographic parasternal LAX equivalent). **A**, Porcine anatomic specimen demonstrating proper probe positioning with ultrasound beam angled superiorly and toward patients left shoulder to obtain epicardial LV LAX view. **B**, Porcine anatomic specimen with resected anterior ventricular wall demonstrating visualization of LV and right ventricle (*RV*), left atrium (*LA*), LV outflow tract (*LVOT*), interventricular septum (*IVS*), aortic valve (*AV*), and mitral valve (*MV*). **C**, Corresponding epicardial LV LAX echocardiographic view.

the RV and tricuspid valve than the standard left parasternal TTE orientation (Figure 3, *B*). The RV will be on top in the near field and the LV below it in the far field of the ultrasound beam sector. The mitral valve (MV) annulus is well visualized in this view with its typical "fish mouth" appearance. The MV anterolateral commissure will be on the right and the posteromedial commissure will be on the left of the screen. The anterior leaflet will appear on the top of the screen and the posterior leaflet will be underneath. The epicardial LV basal SAX view can be used to evaluate the anterior and posterior leaflets of the MV in 2-dimensional imaging. Color flow Doppler can also be used to determine the origin of mitral regurgitation jets and obtain an estimate of the regurgitant orifice area. Finally, basal LV regional

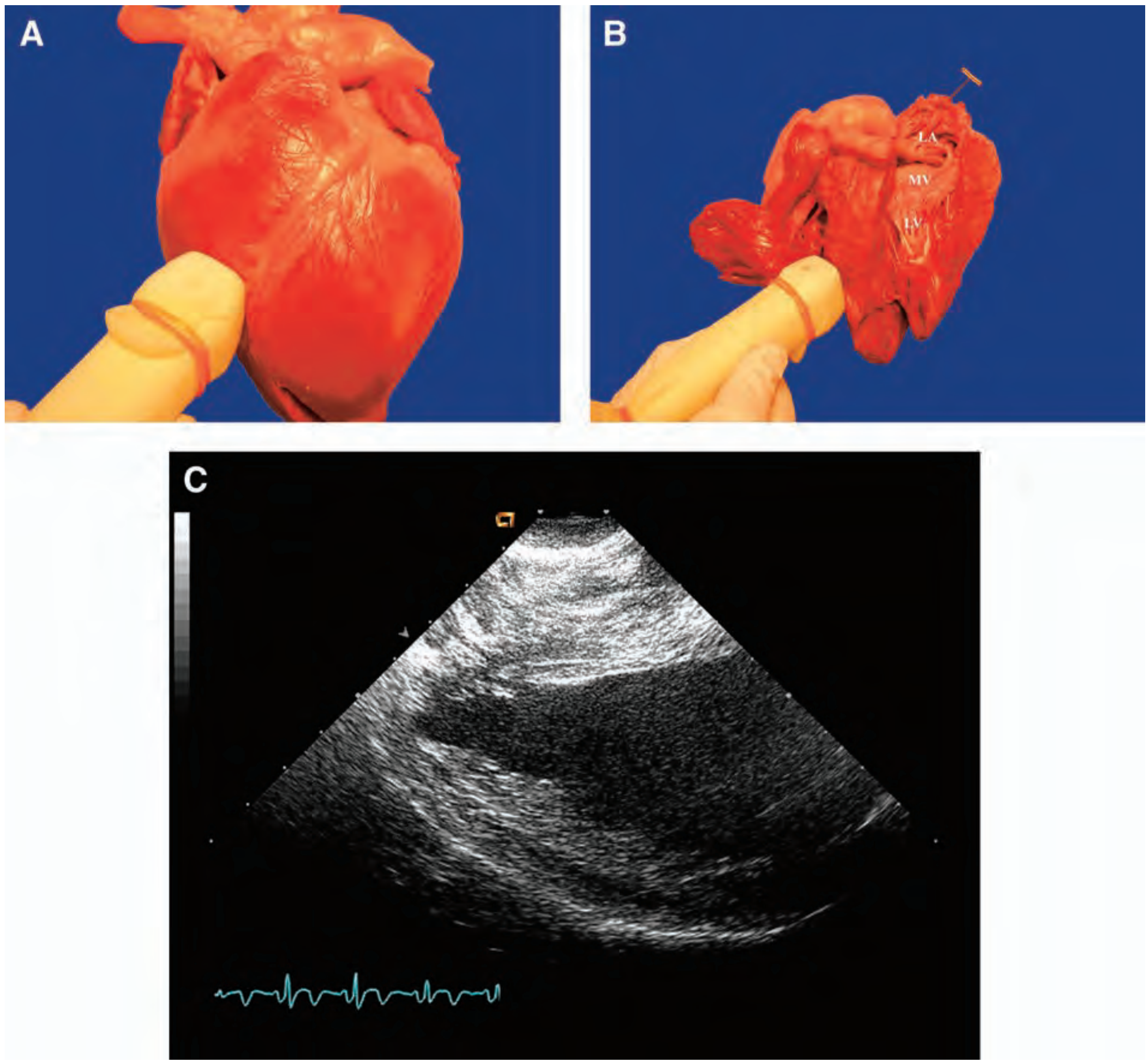

Figure 6 Epicardial 2-chamber view (transthoracic echocardiographic modified parasternal long-axis [LAX] equivalent). **A**, Porcine anatomic specimen demonstrating proper probe positioning with ultrasound transducer rotated 90 degrees from epicardial left ventricle (*LV*) LAX view to obtain epicardial 2-chamber view. **B**, Porcine anatomic specimen with resected anterior ventricular wall demonstrating left atrium (*LA*), mitral valve (*MV*), and LV. To completely eliminate right ventricle, transducer must be placebo directly on LV, which is possible only in patients with severe LV dilation (not shown). **C**, Corresponding epicardial 2-chamber echocardiographic image in a patient with LV dilation.

wall motion can be assessed using the same LV wall orientation as seen in the epicardial LV mid-SAX view discussed below.

Epicardial LV Mid-SAX View (TTE Parasternal LV Mid-SAX Equivalent)

Repositioning or angulating the probe inferiorly and to the left from the epicardial LV basal SAX view (in an apical direction along the RV myocardial surface) allows visualization of the RV and LV in SAX at the level of the papillary muscles and the LV apex (Figure 4, *A*). When the transducer orientation marker faces the patient's left, the anterolateral papillary muscle will be on the right side of the display and the posteromedial papillary muscle will be on the left side. The septal wall of the LV will be displayed on the left followed by the anterior, lateral, and inferior walls, respectively, in a clockwise rotation (Figure 4, *B*). The RV can be evaluated similarly by moving the transducer further toward the patient's right. LV and RV areas, global LV function, and LV regional wall motion can all be evaluated with this view.

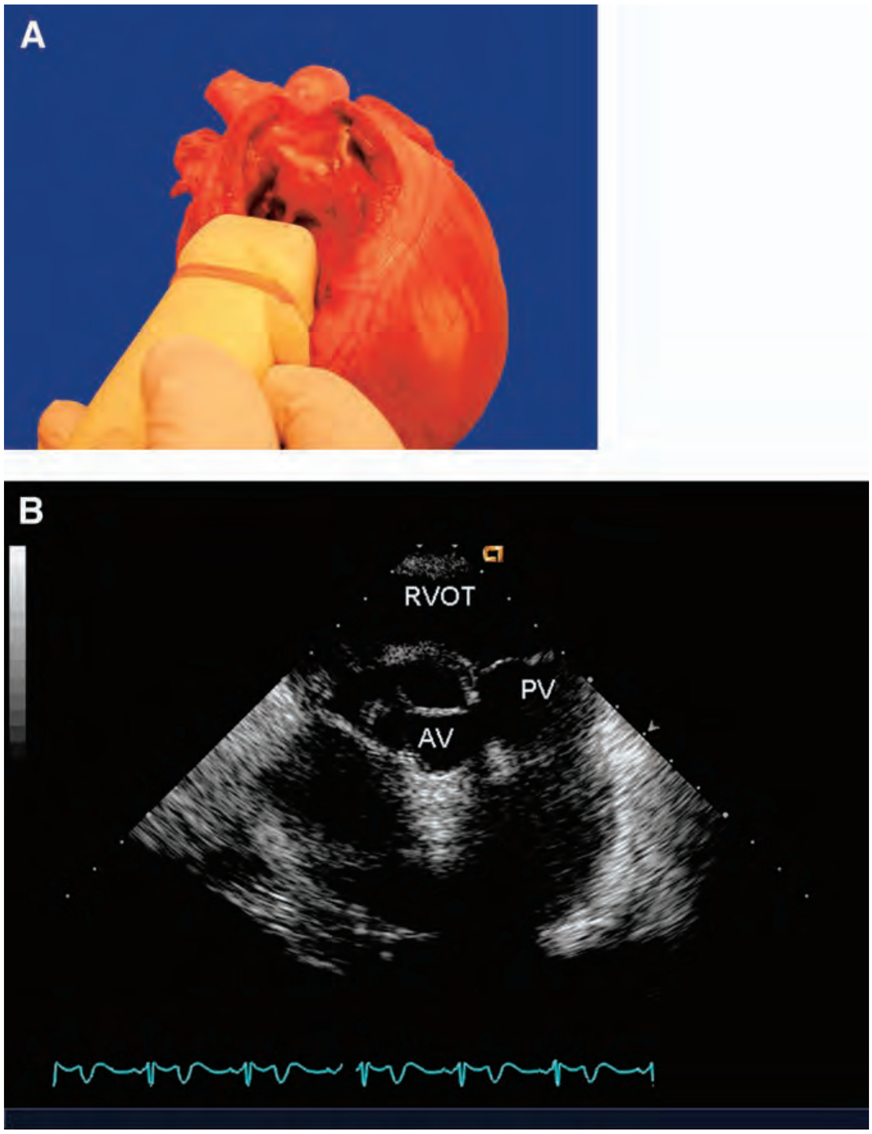

Figure 7 Epicardial right ventricular (RV) outflow tract (*RVOT*) view (transthoracic echocardiographic parasternal short-axis equivalent). **A**, Porcine anatomic specimen with resected anterior ventricular wall demonstrating proper probe positioning for developing epicardial RV inflow tract/RVOT view. **B**, RVOT, pulmonic valve (*PV*), proximal main pulmonary artery, and aortic valve (*AV*) can be visualized.

Epicardial LV LAX View (TTE Parasternal LAX Equivalent)

From the epicardial LV mid-SAX view, the ultrasound beam can be angled superiorly and rotated toward the patient's right shoulder to generate the epicardial LV LAX view as depicted in Figure 5, *A*. This view allows visualization of the inferolateral and anteroseptal walls of the LV and the RV, left atrium (LA), LVOT, AV, and MV (Figure 5, *B* and *C*). Color Doppler interrogation of the AV and MV is possible in this view. A rightward orientation of the beam allows evaluation of the right atrium and tricuspid valve (not shown). Further probe manipulation also permits spectral Doppler of the tricuspid valve. Hence, this view is useful for diagnosing and quantifying aortic, mitral, and tricuspid regurgitation. The interventricular septum can also be evaluated for ventricular septal defects, LVOT obstruction, or systolic anterior motion of the MV.

Epicardial 2-Chamber View (TTE Modified Parasternal LAX Equivalent)

From the epicardial LV LAX view, movement of the probe toward the anterior surface of the LV and further rotation of the transducer clockwise from the parasternal LAX view as described above will develop the epicardial 2-chamber view, permitting evaluation of the LA, LA appendage, MV, and LV (Figure 6). Pathology that can be assessed in this view includes LA masses, and abnormalities in LA size, MV anatomy, and MV leaflet motion. Finally, regional wall motion of the basal and mid segments of the anterior and inferior LV walls can also be obtained. This view is the most difficult to consistently obtain unless the LV is dilated.

Epicardial RV Outflow Tract View (TTE Parasternal SAX equivalent)

The epicardial RV outflow tract view is developed by moving the transducer over the RV outflow tract and directing the ultrasound beam toward the patients left shoulder (Figure 7). The RV outflow tract, pulmonic valve, and proximal main pulmonary artery can be visualized. Orienting a spectral Doppler beam parallel to blood flow permits the evaluation of chamber pressures and quantification of pulmonic stenosis. Color flow Doppler can also be used to evaluate pulmonic regurgitation or stenosis. Finally, this view is also useful for diagnosing a proximal pulmonary embolism or positioning a pulmonary artery catheter.

Conclusion

As the population of patients with complex cardiac surgical conditions and increasing comorbidity becomes more prevalent, there will be a greater and perhaps more important role for experienced perioperative echocardiographers, who should assume the responsibility of acquiring advanced echocardiographic cognitive and technical skills. The most recent recommendations by the ASE and SCA Task Force Guidelines for Training in Perioperative Echocardiography state that advanced training includes the "ability to acquire or direct the acquisition of all necessary echocardiographic data including epicardial and epiaortic imaging."[5] Although intraoperative epicardial echocardiography was introduced into clinical practice in the early 1970s for the evaluation of open MV commissurotomy, its use has declined during the last decade because of the increasing availability and improved technologic design of TEE probes. The epicardial approach to a comprehensive echocardiographic examination has potential limitations and disadvantages compared with TEE. Nonetheless, a fundamental understanding of the skills required to obtain and interpret images, as suggested in these guidelines, may be an advantageous adjunct or even a substitute when TEE probe insertion is contraindicated or cannot be performed. Epicardial echocardiography may also provide the best balance between safety and the efficient acquisition of vital information necessary to optimize the perioperative management of critically ill patients.

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APPENDIX

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