A Practical Approach to an Intraoperative Three-Dimensional Transesophageal Echocardiography Examination

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INTRAOPERATIVE THREE-DIMENSIONAL (3D) echocardiography has been studied since the mid-1990s,[1–3] but its clinical use has grown exponentially over the last few years.[4–7] Time-consuming and cumbersome acquisition and reconstructive 3D techniques now have been replaced by "live" 3D imaging.[8–10] Post-acquisition manipulation and quantitative analyses also can be performed on 3D images acquired using the "live" technique.[11] With simultaneous improvements in image processing techniques and computational speed, quantitative aspects of 3D echocardiography are now readily available for clinical use.[12,13] Specifically, the technique of multi-planar reformatting (MPR) can be used for extracting an infinite number of two-dimensional (2D) slices for accurate linear measures and chamber quantification.[14] Therefore, 3D echocardiography has introduced another dimension, literally and figuratively, to intraoperative transesophageal echocardiography examination (TEE).

Recognizing the need for a uniform methodology for 3D imaging, the American Society of Echocardiography recently published guidelines for 3D imaging for transthoracic echocardiographic (TTE) and TEE imaging.[7] However, the requirements for the perioperative arena are different in that it is point-of-care in nature and time limited due to the dynamic nature of the environment. Specifically, the quantitative aspects of 3D imaging that can affect intraoperative surgical decision making have not been elaborated on in detail. It is important to approach intraoperative 3D examination in an objective, methodical, and time-efficient fashion to maximize the diagnostic and therapeutic yield from the acquired data. Based on patient peculiarities and clinical circumstances, 3D imaging modes and techniques often need to be individualized for data acquisition. Therefore, drawing on the authors' experience and available literature, the authors present such an approach for this *Journal*. The authors have attempted to incorporate the qualitative and quantitative aspects of 3D echocardiography data in a routine intraoperative 2D and 3D TEE examination. In addition, the authors also have suggested the specific modalities (Live vs. R-wave gated acquisition) most suitable for each structure/view and the technical aspects of 3D data acquisition, analyses, archiving, and retrieval in the light of current guidelines and regulations. Details of the logistics, personnel, and limitations of 3D imaging in the perioperative arena also are presented.

CURRENT STATUS OF THREE-DIMENSIONAL ECHOCARDIOGRAPHY

There has been a gradual increase in the use of 3D imaging in the perioperative arena. Specifically, 3D echocardiography has shown value in assisting intraoperative valve repair/replacement decision making.[15,16] Using 3D TEE imaging, views of intracardiac structures have been described that resemble surgical views obtained after valve exposure.[17–20] This has introduced a level of uniformity in nomenclature and enhancement in communication across disciplines. With significantly more "raw" Cartesian coordinate data, complex cardiac structures now can be analyzed quantitatively without geometric assumptions. Intraoperative 3D imaging also has shown its value during percutaneous interventions for structural heart disease and has established itself as a vital procedural adjunct.[7,21] 3D TEE is used to assess suitability and for guidance, to exclude complications, and establish the success of percutaneous intervention.[22,23] Information obtained from intraoperative 3D imaging is an adjunct to a comprehensive 2D TEE examination and provides supplemental information. Specifically, it improves spatial orientation and accuracy of linear measures, allows visualization of simultaneous orthogonal views, and cardiac chambers can be analyzed volumetrically without geometric assumptions. 2D imaging provides a broad approach to the cardiac anatomy, physiology, and identification of structures of interest, whereas 3D TEE currently is used to acquire specific complementary qualitative and quantitative information from examination of structure(s) of interest.

PRACTICAL ASPECTS OF THREE-DIMENSIONAL IMAGING

A comprehensive intraoperative 3D TEE examination is used for acquiring and archiving supplementary 3D

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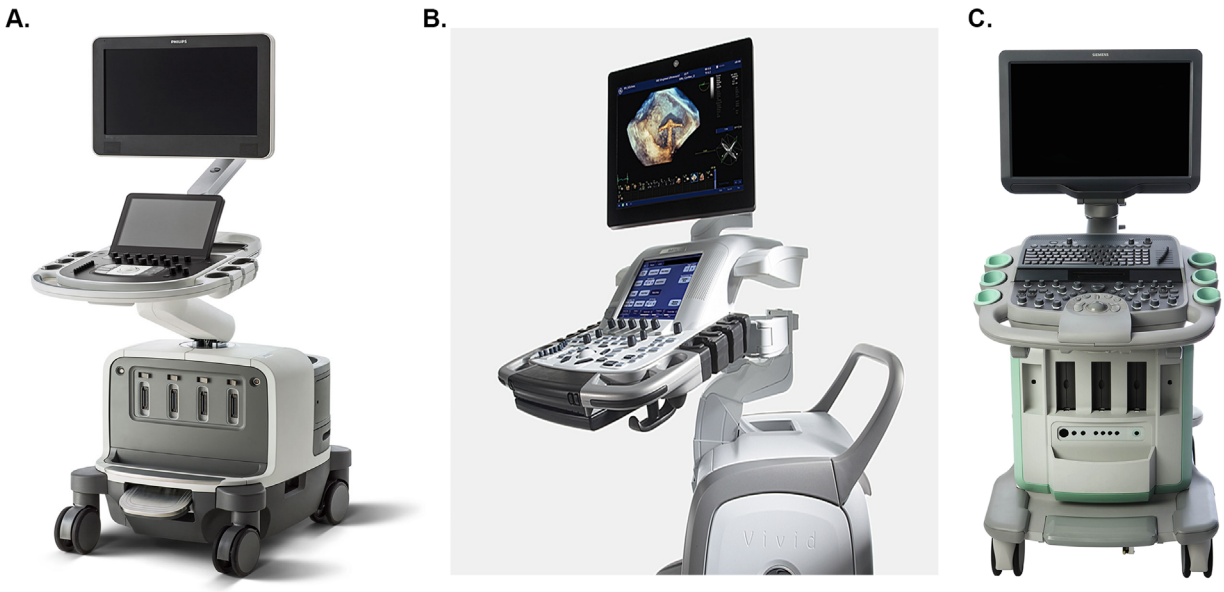

Fig 1. Commercially available three-dimensional ultrasound machines currently in the market. (A) Philips Epiq 7. (B) General Electric E9. (C) Siemens SC2000.

echocardiographic data for real-time and post-acquisition qualitative and quantitative analyses. There are logistic and technical aspects of setting up an intraoperative 3D imaging service. Logistically, it requires availability of equipment and personnel who are trained in its use and competent in acquisition and analyses of acquired 3D images. A 3D imaging laboratory should have the capability to store the acquired 3D image for later retrieval and post-acquisition analysis. Technical aspects of 3D imaging require that there be judicious patient-specific use to supplement information acquired with 2D imaging to improve diagnostic accuracy and patient care.

LOGISTICS

Equipment

There are numerous commercially available ultrasound systems that are capable of 3D imaging. Currently, there is only 1 portable system (CX-50; Philips Healthcare, Andover, MA) that is equipped to perform 3D imaging. However, 3D imaging in this system is limited to only "live" modes. Although ultrasound systems differ in their workflow of raw ultrasound data, they generally follow the same basic methodology of imaging of intracardiac structures. Nonetheless, using an ultrasound system to its full potential requires equipment familiarity, significant experience, and expertise. An intraoperative 3D echocardiography service should possess the following characteristics: (1) A TEE probe capable of 3D imaging, (2) an ultrasound system capable of the entire spectrum of 3D imaging modalities (Fig 1), (3) software for online basic 3D quantification, (4) capacity to archive 3D data, (5) ability to retrieve 3D data, and (6) ability for offline quantification and analyses.

Equipment availability constraints may preclude provision of 3D echocardiography services to all cardiac surgery patients. At the authors' institution, 3D TEE is performed for all surgical (cardiac and noncardiac) and percutaneous cardiac interventions. Minimally, patients undergoing valvular surgery (repair and replacement), congenital cardiac surgery, and percutaneous interventions should undergo 3D TEE examination.

Single Versus Multi-Vendor Ultrasound Service

There are various commercially available ultrasound systems capable of 3D TEE imaging, with accompanying vendor-specific offline viewing and archiving capabilities (see Fig 1). The advantage of a single-vendor laboratory is that it is less expensive to maintain, with uniformity of workflow of data acquisition, personnel training, archiving, and retrieval of data. A multi-vendor laboratory is more expensive to maintain and requires separate service contracts for equipment and training for each system. Multi-vendor system laboratories are suited for teaching facilities because they offer the training advantages for fellows and flexibility to upgrade systems individually. At the authors' institution, to comprehensively train residents and fellows, the authors' division possesses ultrasound systems from multiple vendors.

Personnel

Even though credentialing is determined by the local healthcare facility and institutional policies, most institutions require evidence of some form of TEE training/education for anesthesiologists offering services by cardiac anesthesia teams. In the authors' department, intraoperative TEE privileges are approved by the chairman of the department based on the recommendations of the director of cardiac anesthesia. Even though all members are certified, a testamur status in the advanced perioperative transesophageal echocardiography examination of the National Board of Echocardiography is a minimum requirement for requesting these privileges. The authors' division also requires yearly continuing medical education related to echocardiography to maintain privileges as a cardiac anesthesiologist.