Rescue Transesophageal Echocardiography

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Transesophageal echocardiography (TEE) has been used in the operating room for over 20 yr. Thousands of published reports document its role in helping perioperative physicians reduce morbidity and mortality. The majority of the time TEE is used in cardiac surgery, where it has been instrumental in advancing valvular reconstruction, congenital heart repairs, and minimally invasive techniques. However, the most immediate and dramatic results from the use of TEE occur when it is used in a "rescue" role, that is, when it is used to diagnose the cause of life-threatening hypotension. In 1996, the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists (SCA) published guidelines recognizing this application as a category I indication, i.e., published studies and expert opinion confirm that TEE is frequently useful in improving clinical outcomes (1). Moreover, these guidelines defined this application as a responsibility of the basic TEE practitioner. Therefore, in this review, I will delineate the background information and studies that demonstrate how effective TEE can be in this rescue role. In addition, I will outline a basic TEE examination that is optimal for this clinical challenge, one that requires the least amount of time and yet reveals the majority of life-threatening cardiac pathologies.

Background Information and Studies

Ultimately, inadequate cardiac output or inappropriately low systemic vascular resistance, or both, cause hypotension. TEE is remarkably well suited for addressing this differential diagnosis. During severe hypotension, qualitative TEE estimates of ventricular filling and function serve as the practical guides for administration of fluids, inotropes, and vasopressors. An experienced observer can differentiate severe ventricular dysfunction from other life-threatening causes of hypotension (Figs. 1A and 1B). For example, in severe left-ventricular failure, ventricular filling (as assessed by end-diastolic area) is increased and ejection is decreased, whereas in inappropriately low systemic vascular resistance, ventricular filling is usually normal or slightly decreased and ejection is markedly increased. Hypovolemia is easily recognized as a marked decrease in ventricular filling and a marked increase in ejection. Although inappropriately low systemic vascular resistance, severe aortic regurgitation, severe mitral regurgitation, and ventricular septal defect can manifest the same LV filling and ejection pattern at the transgastric short-axis cross section, distinguishing these causes of hypotension is not difficult using other cross-sections and color Doppler.

A dramatic example of the use of TEE in hypotensive patients is provided by a study of 60 consecutive patients with severe, persistent hypotension after cardiac surgery despite intensive therapy guided by invasive monitors (2). TEE confirmed the presumed etiology of the hypotension in only 30 of these patients. In two patients, TEE revealed unsuspected cardiac tamponade, and, in six others, unsuspected hypovolemia. In five patients, TEE prevented unnecessary reoperation by proving that tamponade was not present despite hemodynamic data suggesting it. In another study, unstable cardiac surgical patients in the operating room (n = 57) or intensive care unit (n = 83) underwent emergent TEE (3). Based on the TEE findings alone, 22 of these patients had urgent surgical interventions. The average time to diagnosis was 11 min. In another study involving critically ill surgical patients, TEE was shown to be more cost-effective than transthoracic echocardiography because the latter so often fails to reveal diagnostic images (4). Moreover, TEE has prognostic value in the hypotensive, critically ill patient: when it reveals nonventricular causes of hypotension (e.g., valvular or pericardial), patients are twice as likely to survive than patients with other causes of hypotension (5). Even in the setting of prolonged CPR, TEE may reveal crucial diagnostic information (6).

Basic Examination

In the setting of life-threatening hypotension, the goal in performing TEE is to reveal the etiology of the hypotension correctly as fast as possible so that the

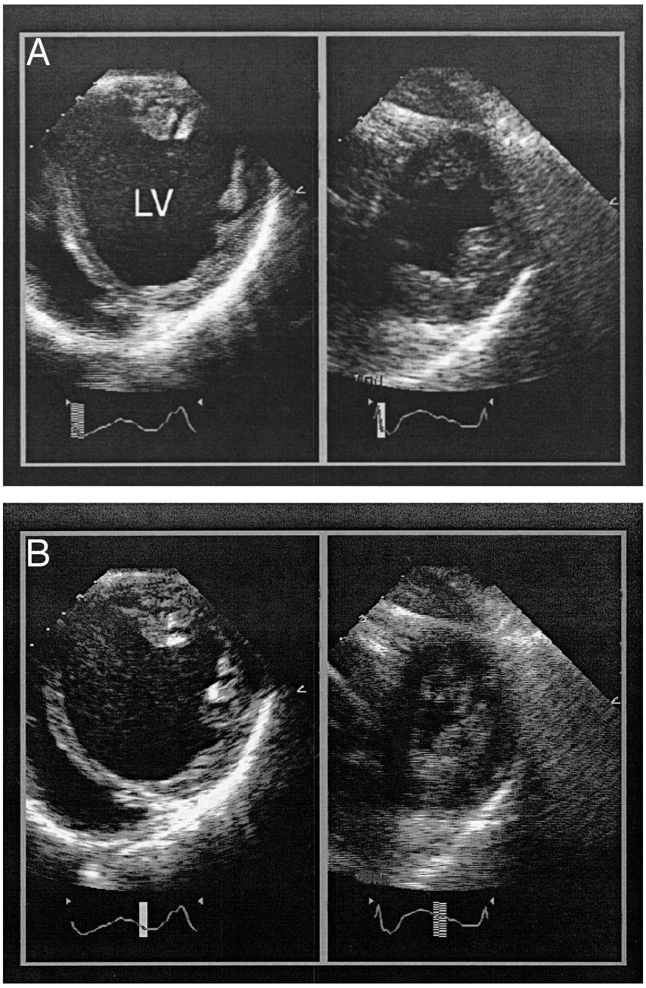

Figure 1. A, two echocardiograms are shown in stop action at end-diastole. Both are transgastric short-axis views of the left ventricle, and both were recorded during hypotension (mean arterial pressure, 50 mm Hg). Left, before heart transplantation; right, a few minutes after. Notice that the pretransplantation left ventricle (LV) has a much greater end-diastolic volume than the new ventricle. B, the corresponding end-systolic stop action images are shown. Notice that the new ventricle has ejected a much greater fraction of its end-diastolic volume. Low cardiac output was the principal cause of the hypotension before transplantation whereas inappropriately low systemic vascular resistance was the principal cause after transplantation.

appropriate resuscitation measures can be immediately instituted. In 1999, the American Society of Echocardiography and the SCA published recommendations for a comprehensive TEE examination, but this examination can take ≥15 min to complete and much of it is designed to detect problems that are not immediately life threatening (i.e., source of emboli) (7). Therefore, when time is critical, I recommend a simpler examination (I will call it the "basic" examination) that consists of the minimum number of cross-sections required to detect markedly abnormal ventricular filling or function, extensive myocardial ischemia or infarction, large air embolism, severe valvular dysfunction, large cardiac masses or thrombi, large pericardial

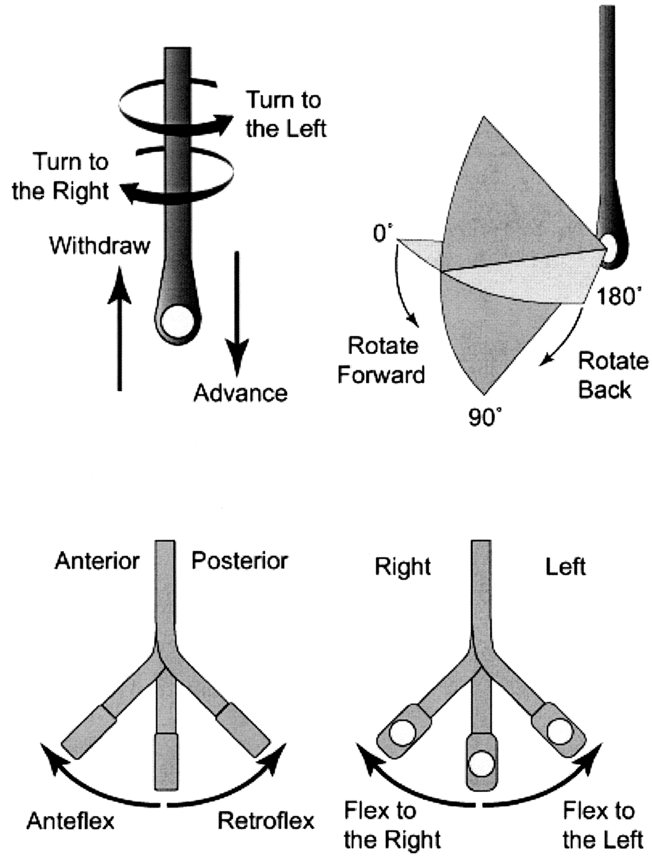

Figure 2. These drawings depict the terminology used to describe the manipulations of the probe and transducer used in transesophageal echocardiography. Reproduced with permission from (7).

effusions, and major lesions of the great vessels. Detection of these pathologies are the diagnostic goals of this examination because they are the most common perioperative causes of severe hypotension and because basic TEE practitioners are required by the 1996 practice guidelines to be able to diagnose these pathologies (1).

Eight different cross-sections drawn from the 20 cross-sections delineated in the comprehensive examination are required to meet these goals. Three of the cross-sections are imaged in both 2-dimensional and color Doppler to assess valvular function. In the next paragraph, I will describe the probe manipulations required to perform this examination. In fact, reading this description requires more time than performing the technique once it is mastered! Please see Figure 2 for definitions of terms used to describe probe and transducer movements.

After the TEE probe is safely introduced into the esophagus, advance it to the midesophageal (ME) level (28–32 cm measured at the upper incisors), and image the aortic valve (AV) in the short axis (SAX) by turning the probe, adjusting its depth in the esophagus, and rotating the multiplane transducer forward to 25°–45° until the three cusps of the valve are seen as

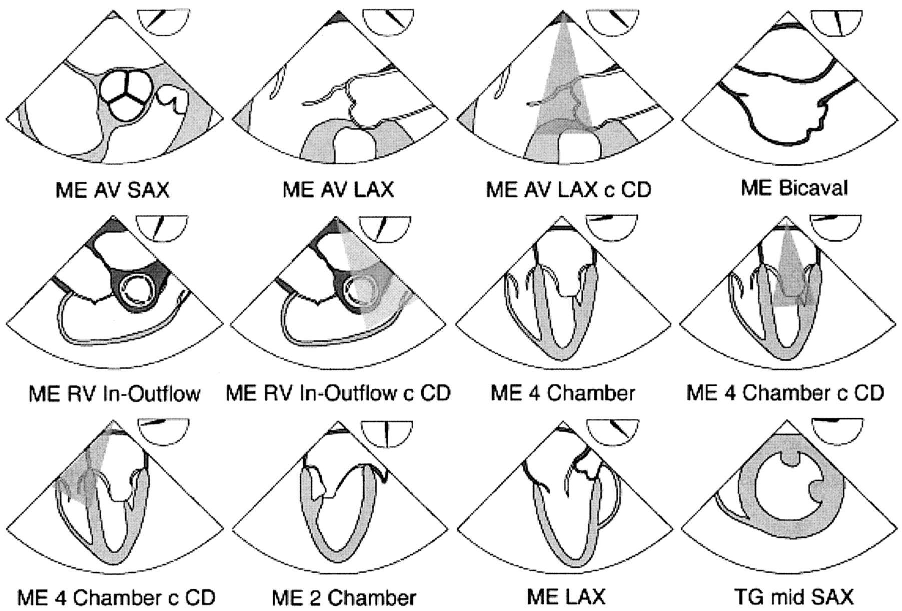

Figure 3. The eight basic cross-sections are depicted. Four cross sections are show with color Doppler (CD) sectors superimposed over the four different cardiac valves. ME = midesophageal; TG = transgastric; AV = aortic valve; SAX = short axis; LAX = long axis; RV = right ventricle; In-Outflow = inflow and outflow; mid SAX = midventricular short axis. Adapted from and reproduced in part with permission from (7).

approximately equal in size and shape (Fig. 3, ME AV SAX). This cross-section is ideal for detection of aortic valve abnormalities, including aortic stenosis. Activate the videotape at this point and keep it running throughout the rest of the examination. A colleague of mine once noted that videotape is cheap relative to the cost of a missed diagnosis (if you record your examination digitally, then record single cardiac cycle loops liberally). Next, turn the probe to position the AV in the center of the video screen and then rotate the transducer forward to 110°–130° to bring the long axis (LAX) of the AV in view (Fig. 3, ME AV LAX). This cross-section is best for detection of ascending aortic abnormalities including type I aortic dissection. Activate color Doppler over the left ventricular outflow track and assess the AV for regurgitation (Fig. 3, ME AV LAX c CD). Next, discontinue the Doppler and turn the probe rightward until the bicaval cross-section comes into view (Fig. 3, ME Bicaval). This cross-section is usually best seen at a transducer angle of 110° and is ideal for assessing caval abnormalities as well as compression of the right atrium from anteriorly located masses and the left atrium from posteriorly located masses. In addition, the bicaval cross section may reveal collections of air located anteriorly in the left or right atrium. Next, rotate the transducer to 60°–80° and turn the probe leftward just past the aortic valve to bring the ME right ventricular (RV) inflow and outflow cross-section into view (Fig. 3, ME RV In-Outflow). This cross-section will reveal the function of the RVOT, any compression of the RVOT, and pulmonary valve function with the application of color Doppler (ME RV In-Outflow c CD). Next, rotate the transducer backward to 0°, advance the probe 4–6 mm into the esophagus, and gently retroflex it until all four cardiac chambers are visualized (Fig. 3, ME 4 Chamber). Often, rotating the transducer forward to 10°–20° will enhance the view of the tricuspid annulus. This cross-section is best for evaluation of relative LV and RV filling and function as well as compression from laterally positioned masses or pericardial collections. In 2-dimensional imaging, be sure to assess lateral and septal RV and LV segmental wall function. With color Doppler, examine both the mitral and tricuspid valves (Fig. 3, ME 4 Chamber c CD). Next, discontinue color Doppler, turn the probe to position the left ventricle in the center of the screen, and rotate the transducer to 90° to bring into view the ME 2-chamber cross-section (Fig. 3, ME 2 Chamber). It is best for revealing the function of the basal and apical segments of the anterior and inferior LV walls as well as anterior and inferior pericardial collections. When air emboli collect in the left ventricle, they can be seen best in this view as a very echogenic area located along the anterior apical endocardial surface. Further rotate the transducer to 135° to reveal the ME LAX cross section that is best for assessment of basal anteroseptal and basal posterior segmental LV function (Fig. 3, ME LAX). Together, the ME 4-chamber, 2-chamber, and LAX reveal all 16 segments of the left ventricle (6 basal, 6 midventricular, and 4 apical segments) However, the next and last of the basic cross-sections provides a second look at the midventricular segments as well as other benefits (see below). To achieve this cross-section, rotate the transducer to 0°, turn the probe to center the left ventricle in the screen and advance the probe 4–6 cm into the stomach. Then, gently flex it anteriorly to reveal the transgastric (TG) midventricular SAX cross section (Fig. 3, TG mid SAX). This cross-section is ideal for monitoring LV filling and ejection, because all major coronary arteries supply myocardium viewed in this cross-section, changes in preload cause greater changes in the LV short-axis than in the long-axis dimension, and movement of the probe from this cross-section is readily apparent because the papillary muscles provide prominent landmarks. Because this cross-section is used to judge filling and ejection, image depth is consistently set to 12 cm so that the size and function of the heart is judged easily relative to previously examined hearts.

Precautions and Limitations

Even in the emergent situation of severe hypotension, the operator must determine that the benefits of TEE outweigh the risks. Except in the presence of esophageal disease or injury, the risk is quite low. Absolute contraindications include prior esophagectomy, severe esophageal obstruction, esophageal perforation, and ongoing esophageal hemorrhage. Relative contraindications include esophageal diverticulum, varices, fistula, previous esophageal surgery, as well as a history of gastric surgery, mediastinal irradiation, unexplained swallowing difficulties, and other conditions that might be worsened by placement and manipulation of the TEE probe. During transducer insertion or withdrawal, the controls of the gastroscope must be in the neutral or relaxed position to allow the transducer to follow the natural course of the esophagus, thereby potentially minimizing the risk of injury. In addition, the basic rescue examination is an abbreviated TEE examination and may not reveal all the diagnostic information available from the comprehensive examination (7). Whenever time permits and the clinical situation requires additional information, the comprehensive examination should be performed.

Summary

TEE is ideally suited for the rapid and accurate assessment of patients with severe hypotension. Numerous studies confirm that it can provide diagnostic information essential for the successful treatment of the patient. A basic TEE examination consisting of eight standard cross-sections can be performed in 2–3 min and will reveal most of the life-threatening causes of severe hypotension, including those that are difficult or impossible to diagnose with other readily available perioperative techniques.

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