What Information Can TEE Provide the Surgical Team During CPB?

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Although most intraoperative echocardiographers would consider the cardiopulmonary bypass (CPB) period to be quiescent, there is information that is obtainable and beneficial to the conduct of the surgical case that can be obtained while on CPB. Some echocardiographers have opted to reduce the gain, disconnect the probe from the TEE device, or to turn off the TEE machine to reduce the risk of thermal injury to the patient from energy absorption of esophageal tissue adjacent to the TEE probe. Yet, with continuous or intermittent TEE imaging while on CPB, additional information can be garnered. This additional information includes cannula position, chamber size, thromboembolism, retained intracardiac air, as well as assistance with novel bypass scenarios used for aortic dissection, beating heart surgery, and minimally invasive procedures. The utility of TEE for separation from CPB has been well demonstrated. Perhaps the most important aspect of TEE utilization while on CPB arises from the ability to detect or monitor complications and allowing for rapid, flexible management guided by real-time information.

Cannula positioning is critical to the smooth conduct of cardiopulmonary bypass and circulatory assist devices, whereby it establishes vital blood flow for end organ perfusion. Standard superior vena cava cannulation (SVC) via the mediastinum is generally uncomplicated, so long as the surgeon inspects that the cannula tip is in the body of the SVC and it is not malpositioned. TEE can be utilized for SVC cannulation via the jugular vein by the anesthesiologist, by identifying the guide wire passage into the right atrium, using the bicaval imaging plane. Retrograde coronary sinus cannulation is likewise indentified by TEE whether placed via the mediastinum by the surgeon or via the jugular vein by the anesthesiologist. Adequate maintenance of cannula position can be demonstrated by continuous assessment of intracardiac chamber size. Chamber dilation would suggest inadequate venous drainage or venting of the heart, thereby prompting alert and investigation by the surgeon. Inappropriate inferior vena cava (IVC) cannulation may be demonstrated by abdominal distention and observations of poor venous return by the perfusionist. Ten percent of IVC cannulas are noted to be placed in the right hepatic vein, however it is cannula placement or migration too deeply into the IVC that is associated with the greatest reduction in venous return. The Eustachian valve can be a source of obstruction to flow in an IVC cannula placed via a femoral vein. Maintenance of proper cannula position is likewise necessary for mechanical support device function. For any type of extracorporeal circulatory assist device the inflow and outflow cannula tips must be identified to assess for ideal location and lack of obstruction from either thrombus or cavity/vessel wall. Improper cannula position should be addressed by the surgical team for correction and optimal patient outcome.
Thromboembolic events are not uncommon in relation to cardiopulmonary bypass and circulatory support devices. Some emboli are inherent with the routine conduct of standard CPB practice. In those patients undergoing CABG surgery on CPB utilizing TEE, 42% of embolic events were detected within four minutes of aortic cross clamp release. These were demonstrated as large, echogenic particles. Comparing TEE with transcranial Doppler (TCD) for detection of embolic events, TEE and TCD both proved effective for embolic detection on CPB, but TEE was able to distinguish between the smaller, barely echogenic particles seen at the beginning of CPB versus the larger echogenic particles seen following release of the aortic clamp. Specific clinical entities also carry the risk of thromboembolism not inherent to CPB. In the setting of right atrial thrombus or paradoxical embolus, TEE is used to confirm the location of the thrombus. TEE is also utilized to strategically place cannula and to monitor that surgical manipulation has not caused distal or systemic embolization. In the setting of pulmonary embolism, surgical manipulation while on CPB may precipitate distal embolization, thereby increasing the difficulty of thromboembolectomy or causing CPB circuit thrombosis. Although massive tumor embolization of renal cell carcinoma is relatively rare, it can have catastrophic consequences. Therefore many surgical teams consider TEE to be crucial in the management of migratory tumor embolus during excision of renal cell carcinomas invading the IVC whether performed with or without the assistance of CPB. TEE permits immediate detection, localization, resuscitation, and retrieval of tumor fragments.

Retained intracardiac air is likewise an additional source of embolic events that occur while on CPB and in the immediate perioperative period. Although there is no known minimum safe quantification of air volume, air embolism is associated with perioperative neurocognitive dysfunction, myocardial ischemia/dysfunction, and cardiac arrest. Air may be detected as small echogenic microbubbles that bounce, or as large undulating echolucent masses that are outline in a thin echogenic border that represents the interface between the blood filled fluid cavity and the large air pocket. Larger volumes of microbubbles associated with open-chamber valve surgery are not associated with a higher rate of neuropsychologic deterioration compared to the fewer microbubbles seen with CABG surgery. It is the large undulating masses of air that are perhaps the most dangerous and concerning, in that they represent a larger volume of air and the ability to disrupt blood supply to a multitude end organs. Aggressive measures to evacuate retained air while on CPB include direct agitation of the heart with venting of the left atrium, left ventricle, or aortic root. If unsuccessful, direct aspiration of the identified air can be attempted.

Non-standard cannulation or variant circuit strategies call for specialized TEE evaluation and monitoring. One such setting is aortic dissection. As part of the initial pre-CPB TEE examination, either a TEE probe or a hand held probe can be utilized to establish arterial flow and identification of an intimal flap in the carotid arteries bilaterally. Once CPB has been established, either antegrade flow via the distal ascending aorta/innominate/axillary artery or retrograde flow via a femoral artery, carotid arterial flow can again be assessed to establish flow in the carotid arteries and hence within the true lumen. In order to discern this from venous flow, the perfusion may assist
by pulsing the arterial flow. Additionally, some investigators have documented “switching” or a change in rotational flow in the aorta that either correlated with brain infarction or suggested implications for atheroembolism.\textsuperscript{8,9} Should acute desaturation of cerebral oxygenation occur with the absence of arterial flow detected in the carotid arteries then an alternative means of reestablishing arterial flow can be attempted. In aortic arch reconstruction cerebral oxygenation, orbital ultrasound, and TEE have been used to demonstrate the adequacy of selective cerebral perfusion.\textsuperscript{10} With any of the alternative arterial cannulation strategies, the paramount objective is to have flexible management guided by real-time information in an effort to avoid malperfusion morbidity and mortality.\textsuperscript{11} Port-Access surgery (PAS) and various minimally invasive procedures rely heavily on TEE imaging. TEE is utilized for IVC, SVC, coronary sinus cannulation, aortic cannulation, and endoaortic occluder (endoclamp) placement in the pre-CPB period. Once on CPB, migration of the endoclamp can be assessed utilizing TEE to evaluate the position of the occlusion balloon in the ascending aorta and to evaluate the presence of arterial flow in the innominate or right carotid artery.\textsuperscript{12-14} With the endoclamp inflated, TEE is also used to assess the sufficiency of cardioplegia delivery to the coronary ostia, the presence of aortic insufficiency in the pressurized aortic root, and the adequacy of ventricular venting. Following the aortic endoclamp period and prior to separation from CPB, TEE is employed to assess the adequacy of deairing and the detection of regional wall motion abnormalities. Additionally, the integrity of the aorta is assessed by TEE since use of an endoclamp has been associated with retrograde aortic dissection. During total endoscopic robotic-assisted techniques (TECAB) on CPB TEE is used to detect the presence and resolution of regional wall motion abnormalities. Investigational studies of endovascular and transapical aortic valve replacement rely on TEE assessment on CPB. In this setting TEE is utilized to assess sizing of the aortic annulus, the adequacy of the balloon valvuloplasty, the placement of the device at the level of the annulus, and the parameters of the device following deployment, including the transvalvular gradient and detection of paravalvular leak.

TEE is likewise used in the process of separation from CPB. This allows for a final evaluation of the adequacy of deairing and determines if additional or aggressive measures should be undertaken. In the setting of valvular repair or replacement, a preliminary assessment of valvular function can be initiated to detect gross defects. Otherwise, final evaluation of the adequacy of the valve should be undertaken during optimal loading conditions. An evaluation of cardiac structures for complications resulting from surgical manipulation and an assessment of global and regional function is performed, while final evaluation is completed after separation from CPB.

TEE has provided an avenue for evaluation, diagnosis, and monitoring of cardiac structures and CPB circuitry. This has facilitated developments in surgical technique and provides the collective surgical team with enhanced ability to avoid serious detrimental patient intraoperative events.
References