

The Advantages and Disadvantages of Perioperative Transesophageal Echocardiography during Liver Transplantation

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Abstract

In the last 50 years of liver transplantation there has been significant improvement in all aspects of the operation, and it has become the standard of care in the treatment of end stage liver disease. Perioperative hemodynamic monitoring during the transplant operation is critical and currently the pulmonary artery catheter (PAC) remains the gold standard for cardiovascular monitoring. Transesophageal echocardiography (TEE), with the ability to visualize cardiac function and provide real-time feedback on the adequacy of intervention has had an increasing use in liver transplantation. The primary advantage of TEE is the ability to visualize cardiac function. Disadvantages of TEE include instrumentation cost, operator use, and familiarity with the information provided by the TEE. TEE provides a useful adjunct to PAC in intraoperative hemodynamic monitoring during liver transplantation, especially in those patients at risk for cardiac complications due to pre-existing cardiovascular disease.

Introduction

Liver transplantation has become the standard of care in the treatment of end stage liver disease. Over the course of the last 50 years, liver transplantation has become a common procedure at many major medical centers. Current standard of care for perioperative hemodynamic monitoring during liver transplantation remains the pulmonary artery catheter (PAC). However, perioperative transesophageal echocardiogram (TEE) has the potential to provide for instantaneous hemodynamic monitoring that may improve outcomes, and its use is increasing.

Hemodynamics of Liver Transplantation

Patients with cirrhosis and portal hypertension have a hyperdynamic circulation with increased cardiac output, decreased peripheral vascular resistance and mean arterial pressures while at rest [1-3]. Despite this hyperdynamic state, cirrhotic patients are also at risk for "cirrhotic cardiomyopathy," a state where the ventricular response to stress (e.g. hemorrhage or vasoactive drugs) is impaired. Intraoperative fluid management is made difficult not only by the inability of the cirrhotic patient to respond to cardiac stress in an appropriate fashion, but also the overall hypovolemic state of the patient and the massive fluid shifts that occur with clamping of the inferior vena cava and on reperfusion of the liver allograft [2,3]. Unique hemodynamic changes occur from the anhepatic to reperfused states and rapid assessment of and adjustment to fluid shifts is needed to optimize outcomes.

Additionally, cirrhotic patients often have cardiovascular disease that is not initially apparent because it is masked by the cirrhotic hyperdynamic state and lower systemic vascular resistance. With the increasing number of patients undergoing liver transplantation for non-alcoholic steatohepatitis the number of cirrhotic patients with undiagnosed cardiovascular disease will likely increase as well. Clinical risk factors (advanced age, severe pulmonary hypertension, and elevated right ventricular systolic pressure) have been identified to predict cardiac dysfunction following liver transplantation [4]. Cardiac disease may also exist in conjunction with liver disease in patients with hemochromatosis, Wilson's disease, and sarcoidosis, where the etiology of disease is a process that affects multiple organ systems simultaneously.

Imaging and Utility during Liver Transplantation

Perioperative TEE is a semi-invasive imaging technique for comprehensive rapid, real-time evaluation of cardiac morphology and

function used for monitoring and diagnosis. By changing the probe positioning, dynamic assessment of anatomic structures and both systolic and diastolic function can be obtained throughout the stages of liver transplantation to help guide management or interventions.

Placement of the probe in the mid-esophagus at 0 degrees provides the classic four chamber view with visualization of both atria and ventricles and the intervening valves. During liver transplantation, this view is best for continuous monitoring of right and left ventricular function, valvular function, and atrial abnormalities. With rotation of the probe to 90 degrees, the mid-esophageal two chamber view permits assessment of the inferior and anterior left ventricular walls. Slight rotation of the probe towards the right allows for viewing of the right ventricle and its inflow and outflow tracts. This view can be used to identify right ventricular dysfunction or thrombus during revascularization of the liver allograft. With further rightward rotation of the probe, the mid-esophageal bicaval view (or right atrial long view) is visualized, and is best for identifying a patent foramen ovale or other atrial septal defects. Slight withdrawal from the classic mid-esophageal four chamber view at 0 degrees gives the "five chamber" view for visualization of the aortic outflow tract, and rotation to 110-120 degrees demonstrates the long axis view of the aorta. These views can document problems with left ventricular outflow. Further withdrawal to the upper esophagus displays the basal view, which shows the main pulmonary artery bifurcation for PAC positioning and assessment for a saddle embolus.

Transgastric views can be used in the early phases of the liver transplantation procedure, but functional limitations impact its utility as the procedure progresses. Additionally, concerns about safety in patients with liver disease have limited its use [5]. By placing the probe in the

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stomach at 0 degrees, the transgastric classic short axis view is seen and permits assessment of left and right ventricular function. This is the only view that demonstrates all the walls of the left ventricle simultaneously and in other surgeries is most commonly used for continuous monitoring of LV function. By rotating the probe 90 degrees the transgastric long axis view visualizes the anterior and inferior walls as well the mitral valve apparatus. By rotating the probe 120 degrees, the transgastric long axis view gives visualization of the aortic outflow tract and can be used to determine flow using Doppler interrogation.

Advantages of Perioperative Transesophageal Echocardiography

The primary advantage to TEE is the real-time assessment of cardiac function. Obtaining a numerical value for left ventricular volume and cardiac output with TEE requires mathematical calculations, e.g., Simpson's rule, and does not necessarily correlate with PAC readings [6], but qualitative determination of right and left ventricular filling and ejection fraction can be made quickly with the TEE. PAC measurements are based upon changes in the temperature of the surrounding blood, and unlike critical care patients in the intensive care unit, there are frequently large core body temperature shifts during OLT before and after revascularization of the new graft, which could affect PAC values. There is also an inherent delay, from 5 to 15 minutes with even continuous thermodilution PAC which could contribute to a delay in appropriate intervention [6,7].

Suriani [8] evaluated the results of the first 100 liver transplants at their institution performed with TEE and found that intraoperative TEE had an impact on the management in 64% patients. In the study, in 11% of patients TEE had a major impact and in 48% TEE had minor impact in patient management. A major impact was defined as TEE providing information that allowed for the treatment of a life threatening event or if it altered surgical technique. A minor impact was defined as any finding that changed pharmacological management or if the TEE was used as the primary form of cardiac monitoring during the case. For large volume transplant centers, this is not an insignificant number of patients whose treatment is altered by the use of the TEE [8].

Right and left ventricular dysfunction can be exacerbated during the transplant operation by the clamping and unclamping of major vascular structures such as the IVC and portal vein and the sudden fluid shifts associated such maneuvers. TEE provides a rapid qualitative assessment of ventricular filling and ejection and the adequacy of any interventions. Unlike the PAC, the TEE provides volumetric rather than pressure data which can be misleading in the setting of pulmonary hypertension, valvular dysfunction or ventricular failure. Patients are at particular risk for right ventricular failure during the reperfusion phase of the operation. The unique shape and function of the right ventricle may not lead to changes in PAC readings until significant dilation of the right ventricle has already occurred, as central venous pressure readings do not necessarily correlate with right ventricular preload or ejection [9]. Right ventricular end diastolic volume index is generally superior to central venous pressure readings in regards to correlation with right ventricular preload measurements, however, as this is a calculated value, concerns over mathematical coupling exist [1]. There is also an inconsistent relationship between pulmonary artery wedge pressure and left ventricular function and the left ventricular end diastolic volume index provides a much better estimation of left ventricular function. Unfortunately, the transgastric view required to obtain the left ventricular end diastolic volume index is not available during liver transplantation due to the orientation of the retractors [1,7]. Additionally, some authors recommend avoiding this view so as not to disrupt gastroesophageal varices in the distal esophagus [5].

Unlike the PAC, TEE can provide information other than just the pressure readings used to infer cardiac function. As an imaging modality, TEE can detect new wall motion abnormalities, shunting, as well as emboli that may be showered following reperfusion. There are numerous case reports of emboli identified by TEE following graft reperfusion in the literature, but the clinical significance of small emboli is probably minimal in most patients. More clinically significant are new wall motion abnormalities and previously undiagnosed outflow obstruction that can occur during reperfusion. These functional cardiac changes can be diagnosed and quickly addressed with real-time feedback on the efficacy of the intervention. Those patients with hypertrophic obstructive cardiomyopathy (HOCM) in particular are sensitive to volume status. These patients may develop an outflow obstruction with hypovolemia which is exacerbated by inotropic administration. TEE is ideal in managing this patient population, as the left ventricular outflow tract can be visualized with the TEE probe [10]. Even patients with prior "normal" preoperative cardiac evaluations may have dynamic outflow obstruction during reperfusion, and there should be a low threshold to use TEE for patients with refractory hemodynamic instability despite appropriate treatment [10,11].

Disadvantages of Perioperative Transesophageal Echocardiography

TEE in patients with gastroesophageal varices is considered a relative contraindication, but concerns with traumatizing gastroesophageal varices have been shown to be largely unfounded [8,11,12]. There is a paucity of data related to the manipulation of the TEE probe in patients with gastroesophageal varices, but a recent retrospective analysis by Spier and others specifically analyzed this cohort and demonstrated no major bleeding complications, even in higher risk patients [13]. Similarly, the safety of blind esophageal instrumentation was also shown with nasogastric intubation and esophageal stethoscopes [14]. As with any procedure involving intubation of the esophagus, there is a small, but not non-existent risk of esophageal perforation or trauma. An editorial by Spencer commenting upon Spier's study provided some recommendations to aid decision-making regarding the use of TEE in patients with gastroesophageal varices [15].

From a technical standpoint, positioning of the retractors during the operation can also affect the quality of the TEE and the images that are able to be obtained. Often times the only views that can be reliably obtained are the upper and mid-esophageal views because of retraction on the stomach and diaphragm, precluding the better transgastric short axis view for the left ventricular function [7]. Additionally, TEE cannot be taken with the patient from the operating room to the intensive care unit for continued postoperative monitoring the way the PAC is utilized. Despite these limitations, TEE does provide a direct measurement of left ventricular function, compared to PAC measurements which are purely indirect measurements of left ventricular function through pressure readings and the rapid assessment of which is more important in the phase switching from the anhepatic to reperfusion portions of the transplant operation [16].

Unfortunately, the measurements of cardiac output from PAC and TEE are not interchangeable and the degree of correlation appears to vary with the model for end stage liver disease (MELD) score [17]. Perilli et al. [17] compared standard bolus thermodilution PAC with TEE during standard time periods during liver transplantation. The recipients were stratified by their biochemical MELD scores. Overall, the cardiac output was underestimated by the TEE as compared to the PAC and there was a lower reduction of error in patients with lower MELD scores. It is unclear, as the authors of this study admit, how newer continuous thermodilution PAC would compare to TEE. Boucaud et al. [6] performed similar

comparisons of cardiac output measurements during and after hepatic vascular exclusion. Cardiac output measurements in this study were using TEE versus continuous thermodilution PAC. This study too showed no correlation between cardiac output values during hepatic vascular exclusion and indicated a worsening of the cardiac output correlation after hepatic vascular exclusion [6]. At this time, TEE appears to be an important adjunct, but not replacement, to PAC for hemodynamic monitoring during liver transplantation [18].

A barrier to the greater utilization of TEE is the need for advanced training and the lack of credentialing standards for anesthesiologists. Outside of cardiac anesthesia fellowship training, most anesthesiologists learn the use of TEE in an informal manner after completing training and this is an area for possible improvement [19]. A significantly smaller proportion of liver transplant anesthesiologists use perioperative TEE due to unfamiliarity with TEE and the data it provides [20]. Like any technology that requires human interpretation, there is also a degree of user variability with the results of TEE [21]. The American Society of Echocardiography recommends a training program involving 300 transthoracic echocardiographic exams, 25 esophageal intubations and 50 TEE exams within a six month time period to obtain proficiency, and the performance of 50-75 TEE examinations a year to maintain proficiency [22,23]. However, in cooperation with the American Society of Anesthesiology, the National Board of Echocardiography offers certification in advanced perioperative TEE that requires extensive training and 300 intraoperative exams as well as a written exam. It has also recently begun offering basic perioperative TEE board certification, which can be obtained by performing 150 basic perioperative TEE examinations under appropriate supervision and completion of a written examination [24]. The skill required for this basic certification should be adequate for use in liver transplantation. Aside from the human factors, the TEE machine is expensive, also limiting widespread use.

Summary

Transesophageal echocardiography will not soon replace the use of pulmonary artery catheters in the monitoring of perioperative hemodynamics during liver transplantation; however, in select situations, TEE may provide real-time information essential to improve patient outcomes. The use of TEE may be indicated in specific liver transplant patient populations such as those with known HOCM, pulmonary hypertension and those with liver disease secondary to hemochromatosis, Wilson's disease, or sarcoidosis where cardiac involvement is also present. The concern for complications, the cost of machinery and the lack of training in the use of TEE may contribute to the limited use of TEE in liver transplantation at most centers.

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