Review

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Use of Transesophageal Echocardiography During Orthotopic Liver Transplantation: Simplifying the Procedure

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Abstract. The intraoperative management of patients undergoing orthotopic liver transplantation (OLT) is influenced by the cardiovascular manifestations typically found in the context of end-stage liver disease, by the presence of concomitant cardiovascular disease, and by the significant hemodynamic changes that occur during surgery.

Hypotension and intraoperative blood pressure fluctuations during OLT are associated with liver graft dysfunction, acute kidney failure, and increased risk of 30-d mortality. Patients also frequently present hemodynamic instability due to various causes, including cardiac arrest.

Recent evidence has shown transesophageal echocardiography (TEE) to be a useful minimally invasive monitoring tool in patients undergoing OLT that gives valuable real-time information on biventricular function and volume status and can help to detect OLT-specific complications or situations. TEE also facilitates rapid diagnosis of life-threatening conditions in each stage of OLT, which is difficult to identify with other types of monitoring commonly used.

Although there is no consensus on the best approach to intraoperative monitoring in these patients, intraoperative TEE is safe and useful and should be recommended during OLT, according to experts, for assessing hemodynamic changes, identifying possible complications, and guiding treatment with fluids and inotropes to achieve optimal patient care.

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Patients with end-stage liver disease present a series of cardiovascular disorders that have a significant impact on perioperative anesthesia management during orthotopic liver transplant (OLT) surgery.[1] In these patients, the hemodynamic pattern is typically one of high cardiac output (CO), decreased peripheral vascular resistance, and cirrhotic cardiomyopathy.[2]

During OLT, patients frequently present hemodynamic instability due to various causes, including cardiac arrest in up to 5.5% of cases.[3] Importantly, hypotension and intraoperative blood pressure fluctuations are associated with liver graft dysfunction, acute kidney failure, and increased risk of 30-d mortality.[4-8]

Transesophageal echocardiography (TEE) has been used in cardiac surgery for >25 y. Recent evidence has shown it to be a useful minimally invasive monitoring tool in patients undergoing high-risk non–cardiac surgery, where TEE gives valuable real-time information on biventricular function and volume status and can help detect OLT-specific complications or situations, such as myocardial ischemia, pulmonary thromboembolism, pulmonary hypertension, and the presence of a patent foramen ovale (PFO) or air within the cardiac cavities.[9-13]

Despite the difficulties involved in the intraoperative hemodynamic management of patients undergoing OLT, no guidelines or protocols have yet established the best monitoring technique to optimize perioperative anesthesia management in these patients, but it is known that intraoperative monitoring with TEE + pulmonary artery catheter (PAC) during OLT was associated with the shortest length of hospitalization and lowest 30-d mortality rate.[14] Although 84% of anesthesiologists acknowledge that TEE provides crucial clinical information during OLT, only approximately half of them use it routinely.[15,16] The use of TEE during OLT surgery has increased steadily and is expected to continue to do so in coming years as more anesthesiologists gain the necessary experience and training in TEE management. Another advantage is the concept of monitoring patients' CO in a relatively noninvasive way compared with PAC.[17] In contrast, it requires time for both basic and advanced training in TEE.[18]

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Recently, the Society for the Advancement of Transplant Anesthesia appointed experts in liver transplantation and who were certified in TEE to evaluate the use of TEE during liver OLT surgery. There were observations that TEE facilitated rapid diagnosis of life-threatening conditions in each stage of OLT difficult to identify with other types of monitoring commonly used. They concluded that TEE is an effective form of monitoring with a safety profile similar to that in cardiac surgery patients.[19]

In this article, we describe how TEE can be used during OLT surgery to obtain valuable information on the patient's hemodynamic status, allowing the surgical team to detect and treat potential complications at each phase of the intervention.

CONTRAINDICATIONS FOR TRANSESOPHAGEAL ECHOCARDIOGRAPHY

The use of TEE during OLT surgery is considered safe and reasonable. A recent study reported a 0.86% rate of major complications, slightly higher than the 0.2% reported in the cardiac literature.[20] There are very few absolute contraindications for the use of TEE,[2] but the presence of esophageal disease probably poses the greatest risk and would be an absolute contraindication. However, esophageal varices (present in up to 73% of patients scheduled for OLT) are a relative contraindication for TEE that depends on operator skills.[21,22] Other relative contraindications are dysphagia, odynophagia, gastroesophageal reflux, cervical spine instability, history of mediastinal radiation, and upper airway disease (eg, pharyngeal tumors or severe facial trauma).

Therefore, it is important to always perform a patient-specific cost/benefit analysis of TEE before deciding whether to use the technique in OLT surgery.[23] All contraindications for TE are summarized in Table 1.

RECOMMENDED TRANSESOPHAGEAL ECHOCARDIOGRAPHIC VIEWS

A comprehensive echocardiographic examination must include the 20 standard views recommended in the 1999 ASE/SCA guidelines (Figure 1) or even the 28 views recommended by the same societies in 2013.[24,25]

However, these guidelines have also been the basis for simplified protocols such as rescue TEE in patients presenting intraoperative hypotension and cardiac arrest, which only include 5 and 9 views, respectively.[26,27] These examinations, even when performed by clinicians who are not experts in the use of TEE, provide a sufficiently accurate clinical diagnosis to warrant an immediate change in the patient's therapeutic management.[28-30]

A specific 5-view protocol for OLT has also been developed to help clinicians diagnose critical pathology and guide clinical management (Table 2).[3] We added the transgastric (TG) mid short-axis view to this protocol, although this view is sometimes impossible to obtain because of posterior retraction of the stomach by the surgeon.[31]

TABLE 1.
Contraindications for transesophageal ultrasound

Absolute	Relative
Esophageal tumor or mass	Cervical spine instability
Esophageal stricture, perforation, or trauma	Dysphagia, odynophagia
Esophageal diverticulum	Gastroesophageal reflux, esophagitis
Esophagectomy	History of chest radiation
Esophageal spasm or contraction	UA pathology (pharyngeal tumor, facial trauma)
Scleroderma	Symptomatic hiatal hernia, peptic ulcer
Mallory-Weiss syndrome	Barrett's esophagus
Recent upper GI surgery	Thoracoabdominal aneurysm
Active GI bleeding	Coagulopathy, thrombocytopenia
	Recent upper GI bleeding
	History of GI surgery

GI, gastrointestinal; UA, upper airway.

USE OF TEE IN THE DIFFERENT PHASES OF OLT

OLT surgery consists of 3 distinct phases, each of which involves major hemodynamic events: the dissection phase (preanhepatic), the anhepatic phase, and the reperfusion phase. TEE can provide crucial information that can be used to optimize and treat the different hemodynamic patterns typically encountered in each phase.

Anesthesia Induction and Dissection Phase (Preanhepatic)

The preanhepatic or dissection phase is the period between anesthesia induction and portal clamping. Immediately after induction, the operator performs a comprehensive echocardiographic examination to evaluate the different cardiac structures and the patient's basal cardiac function and to determine the correct placement of the different vascular catheters. Patients with end-stage liver disease frequently present a hyperdynamic pattern characterized by high left ventricle (LV) ejection fraction (EF) and CO, loss of peripheral vascular resistance, and cirrhotic cardiomyopathy.[2]

Pulsed Doppler TEE can be used to calculate CO and stroke volume using the continuity equation. This is done using the ME long-axis and deep TG views. First, the diameter of the LV outflow tract (LVOT) is calculated in the ME long-axis view (Figure 2) to determine its area, assuming that the LVOT is circular. Then, the deep TG view (Figure 2) is used to determine the velocity time integral of the Doppler spectrum that is traced in the LVOT with each heartbeat (for this, pulsed Doppler must be used at that level). These measurements are used to calculate the LVOT stroke volume using the following formula: LVOT stroke volume (cm^3) = LVOT area (cm^2) × LVOT velocity time integral (cm). Once this volume has been calculated, the patient's CO (L/min) can be obtained by factoring in the heart rate displayed on the monitor (cardiac output = stroke volume × heart rate).

Obtaining CO (L/min) with the use of TEE:

$$\text{LVOT stroke volume }\left(\text{cm}^3\right) = \text{LVOT area }\left(\text{cm}^2\right) \times \text{LVOT VTI (cm)}$$

$$\text{LVOT stroke volume }\left(\text{cm}^3\right) = \pi r^2 \times \text{LVOT VTI}$$

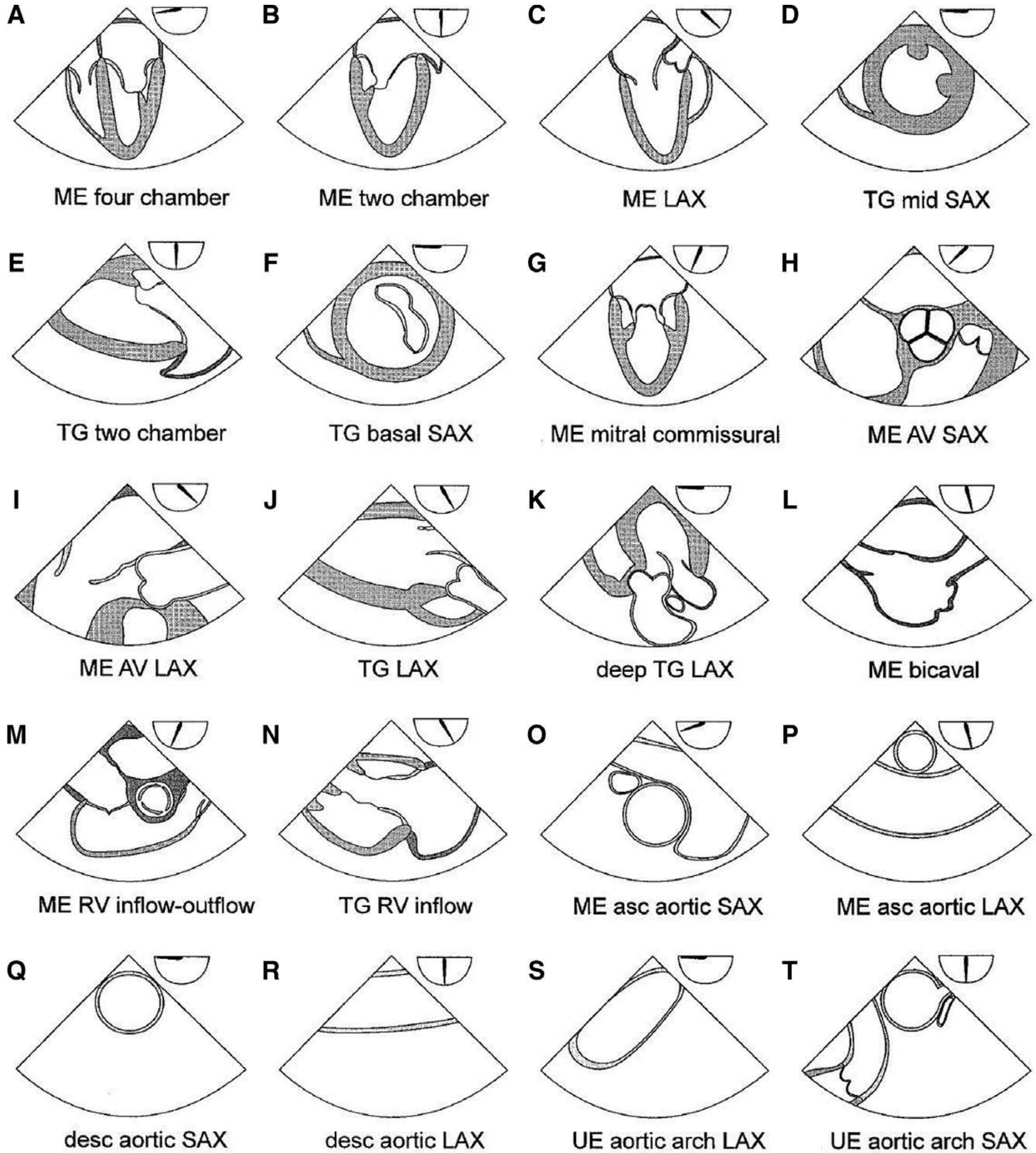

FIGURE 1. Twenty standard views recommended by the ASE/SCA guidelines. ASE, American Society of Echocardiography; LAX, long-axis view; ME, midesophageal; RV, right ventricle; SCA, Society of Cardiovascular Anesthesiologists; SAX, short-axis view; TG, transgastric; UE, upper esophageal.

$$\text{LVOT stroke volume } \left(\text{cm}^3\right) = \pi(D/2)^2 \times \text{LVOT VTI}$$

$$\text{Cardiac output } (\text{L/min}) = \text{stroke volume} \times \text{heart rate}$$

To study LV function, the views usually used are the ME 4-chamber view, the ME aortic valve long-axis view, and the TG mid short-axis view (Figures 3–5). Most expert TEE operators estimate ventricular function during OLT on the basis of a visual assessment of the EF in the TG mid-papillary short-axis view and classify it as hyperdynamic, normal, or depressed.[32] There is another, more specific and objective way of measuring LV EF called the modified Simpson method.[33,34] The software in cardiac ultrasound machines divides the LV into 19 stacked cylindrical disks with 1 elliptical disk at the ventricular apex and automatically calculates the sum of the volumes of all disks to determine both end-diastolic and end-systolic volumes

TABLE 2.

Recommended TEE views during OLT surgery

Diagnosis	View
LV or RV dysfunction Hypovolemia. Tamponade	ME 4-chamber (Figure 2)
Systolic anterior motion/LV outflow tract obstruction	ME long axis (Figure 3)
Patent foramen ovale Pulmonary embolism	ME bicaval (Figure 4)
Hypovolemia Myocardial ischemia	TG mid short axis (Figure 5)
RV dysfunction Intracardiac thrombus Pulmonary embolism	ME RV inflow/outflow (Figure 6)
Hepatic vein or IVC flow obstruction	IVC or hepatic veins (Figure 7)

IVC, inferior vena cava; LV, left ventricle; ME, midesophageal; OLT, orthotopic liver transplant; RV, right ventricle; TEE, transesophageal echocardiography; TG, transgastric.

(Figure 6). The ME 4-chamber view is used in this case, although the ME 2-chamber view can also be used. Once the volumes have been calculated, the following formula is used to calculate EF:

$$EF = \frac{EDV - ESV}{EDV} \times 100 = EF\,(\%)$$

Other objective methods to assess LV function are fractional area change and fractional shortening. Despite their drawbacks, these methods are useful for estimating ventricular function as a trend over time and not as an isolated parameter.

It is also important to diagnose possible alterations in LV segmental contractility (which is assessed using the TG mid short-axis view), because it is important to bear in mind that up to 32% of patients aged older than 50 y of age who are candidates for OLT present alterations in the coronary arteries.[35,36]

After the surgical incision, the preanhepatic phase may include alterations in preload secondary to drainage of ascites, bleeding, or compression of the IVC. In this phase, TEE allows the surgical team to instantly assess blood volume to guide fluid management and to distinguish between systolic dysfunction (requiring pharmacological support with inotropes) and LV underfilling (requiring additional fluids). Estimating blood volume with TEE during OLT allows the surgical team to optimize the patient's intravascular volume. The test is performed in the TG mid short-axis view (Figures 7 and 8), and the area of the LV (or end-diastolic diameter) is determined. A diameter of <8 cm^2 indicates hypovolemia (further confirmed whether the LV end-systolic area is also small), whereas a small end-systolic area with a normal end-diastolic area suggests a reduction in peripheral vascular resistance.[2] Another echocardiographic sign in the TG short-axis view that indicates hypovolemia is the kissing papillary muscle sign, in which opposing papillary muscles come into contact with each other due to a loss of preload.

Tricuspid annular plane systolic excursion (TAPSE) and fractional area change are used to assess right ventricular (RV) function, although it is important to bear in mind that reference values are based on studies performed with transthoracic echocardiography. TEE can rapidly and accurately identify and evaluate RV failure during OLT; however, unlike LV assessment, a qualitative visual assessment of the RV is insufficient.[37] Due to its simplicity, we recommend evaluating RV function on the basis of TAPSE, which is measured in M-mode ultrasound imaging by placing the cursor on the lateral tricuspid annulus and measuring the distance between the lowest and highest point of the curve. A value of <16 mm is considered abnormal.[37] For this purpose, an ME 4-chamber view must be obtained (Figure 9). There are other more complex methods of assessing RV function (RV–to–LV diameter ratio, systolic velocity using tissue Doppler, speckle-tracking, and 3-dimensional TEE), but a description of these techniques is beyond the scope of this article.

TEE is also used after anesthesia induction to verify the correct placement of the central venous catheter and the pulmonary artery catheter (PAC) and to guide insertion of the venovenous bypass (VVB) cannula. PAC is now rarely used in patients undergoing OLT and are instead reserved for very high-risk patients with associated comorbidity (severe ventricular dysfunction and severe portopulmonary hypertension [PPHTN]). The PAC is placed using the pressure waveform transduction technique, although this can be difficult and may lead to complications (arrhythmias, injury to the tricuspid valve, or pulmonary valve).[38] In these cases, TEE can aid placement by following the course of the PAC from the superior vena cava through the right atrium and ventricle until it reaches the pulmonary artery (Figure 10). It can also identify

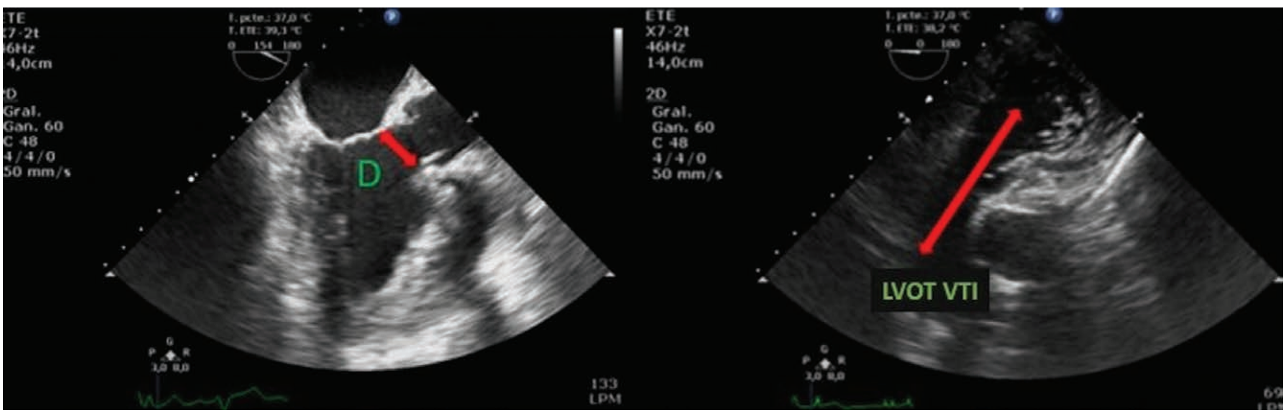

FIGURE 2. ME long-axis and deep TG long-axis views used to calculate diameter (D) and VTI of the LVOT, necessary to obtain patient's cardiac output. LVOT, left ventricle outflow tract; ME, midesophageal; TG, transgastric; VTI, velocity time integral; 2D, 2-dimensional.

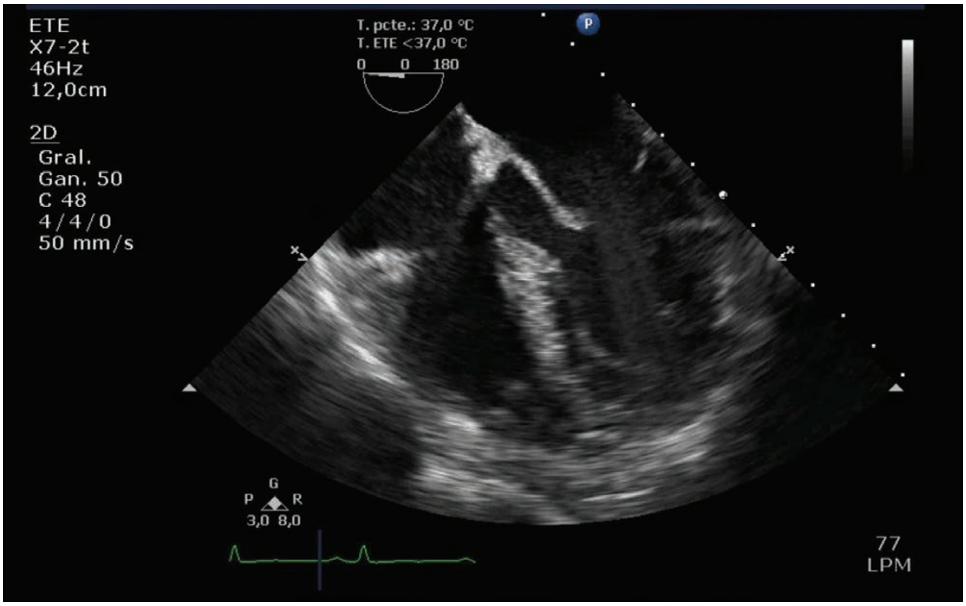

FIGURE 3. ME 4-chamber view. ME, midesophageal; 2D, 2-dimensional.

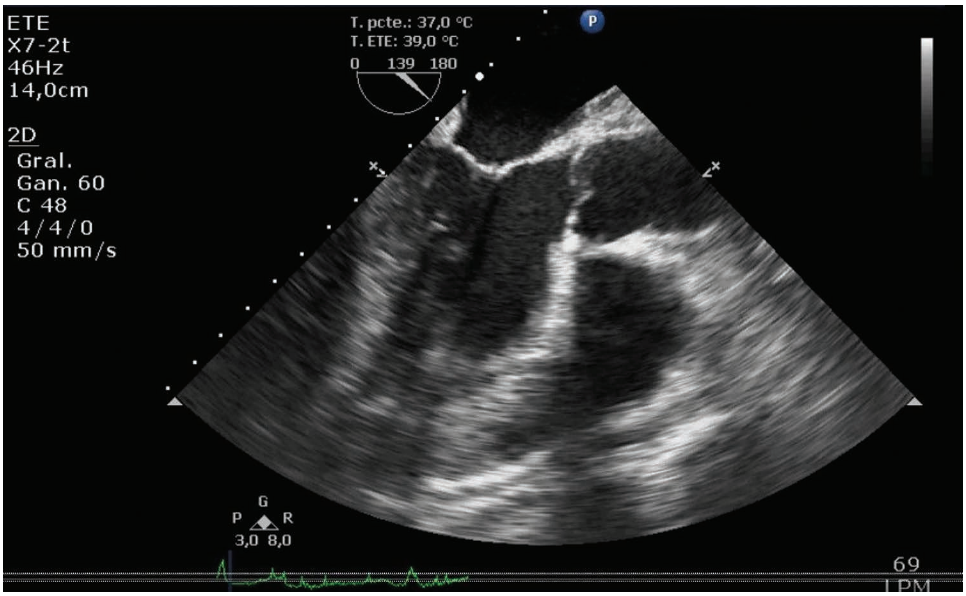

FIGURE 4. ME aortic valve long-axis view. ME, midesophageal; 2D, 2-dimensional.

the presence of PPHTN—a major complication that occurs in between 5% and 8.5% of patients with end-stage liver disease.[39,40] Diagnostic criteria for PPHTN include mean pulmonary artery pressure of >25 mmHg, pulmonary vascular resistance of >240 dynes.s/cm^5, and pulmonary wedge pressure of <15 mmHg. Patients with pulmonary artery systolic pressure of >80 mmHg have an increased risk of perioperative death.[41] Echocardiographic findings of severe pulmonary hypertension include RV dilatation, RV hypokinesia, decreased TAPSE, and a "D"-shaped interventricular septum (Figure 11). These findings should be evaluated using an ME 4-chamber view, which will also allow the operator to assess the efficacy of intraoperative measures to improve RV function.[42]

TEE is also used to guide the insertion of VVB cannulas. VVB is sometimes needed during OLT surgery to minimize the potentially deleterious hemodynamic effects of temporary IVC and portal vein clamping during the standard surgical technique by facilitating venous drainage from the IVC and the portal system to the right heart chambers.[10] This improves cardiac filling pressures and CO and stabilizes hemodynamics.[43] However, the piggyback technique facilitates venous return to the heart, so VVB is not usually necessary. VVB should be considered in the following clinical circumstances: severe portal hypertension, acute liver failure with high intracranial pressure, kidney failure, and severe hypotension after IVC clamping during the standard surgical technique. Some authors describe using TEE to aid the correct placement of VVB cannulas.[44] The bicaval view is used for this purpose, allowing the operator to visualize the insertion of the guide wire in the internal jugular vein, through the superior vena cava, until it reaches the right atrium (Figure 12). The VVB can also be inserted through

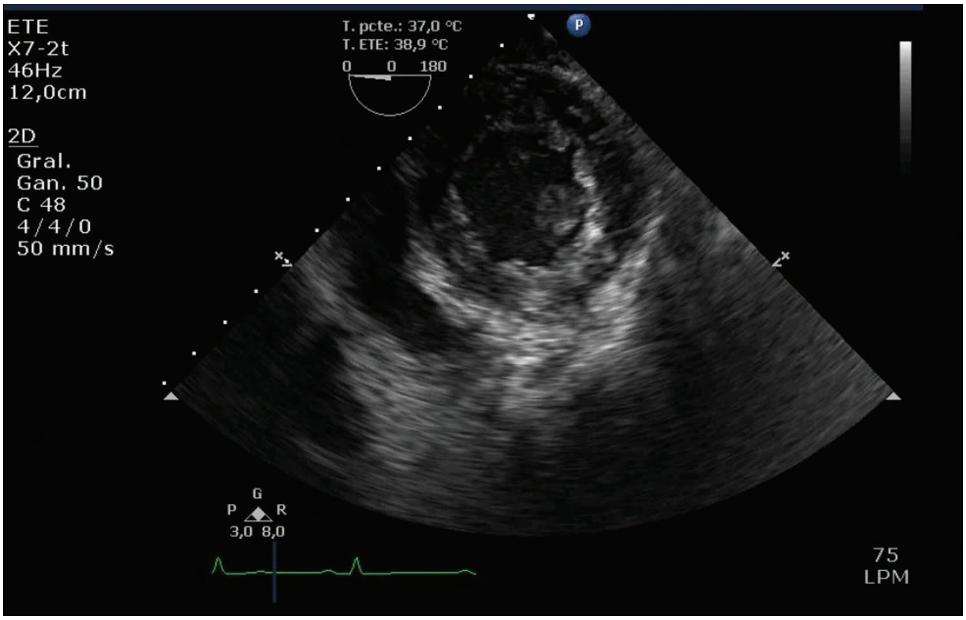

FIGURE 5. TG mid short-axis view. TG, transgastric; 2D, 2-dimensional.

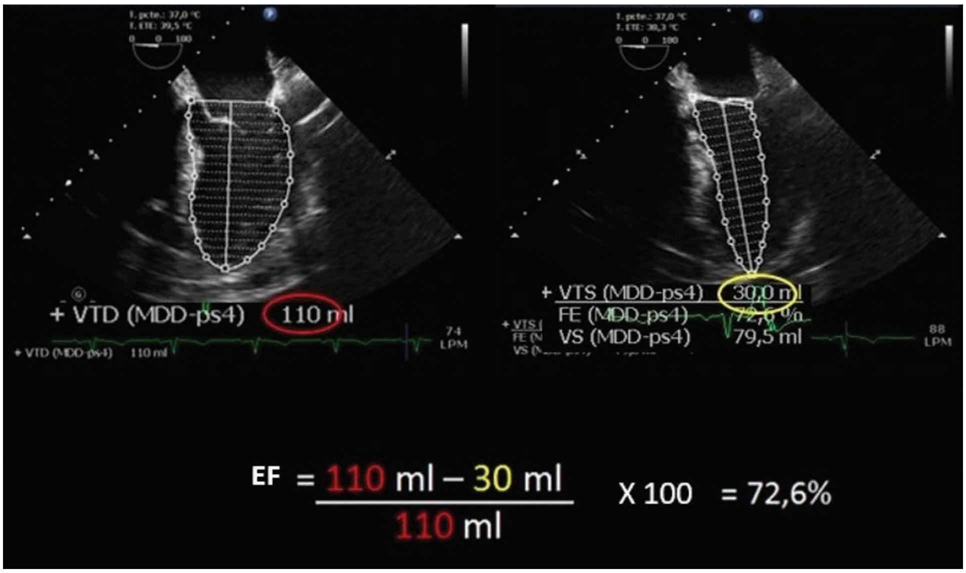

FIGURE 6. Ejection fraction calculation using the Simpson method. Note the measurement in the ME 4-chamber view of the volume at the end of systole and diastole. EF, ejection fraction; ME, midesophageal.

the femoral vein, in which case TEE can be used to observe the guidewire passing through the IVC until it reaches the right atrium.

In this phase, TEE can identify patients at risk of dynamic left ventricular outflow tract obstruction (LVOTO) because of small LV diameter, basal interventricular septal hypertrophy, and systolic anterior motion of the mitral valve. In these patients, hypovolemia, tachycardia, and increased ventricular contraction can lead to displacement of the anterior mitral leaflet toward the interventricular septum during systole, thereby worsening LVOTO.[45] Although few cases of patients with LVOTO undergoing OLT have been described, they are particularly susceptible to the appearance of adverse hemodynamic effects during surgery.[46-48] LVOTO can be treated with pharmacological measures to increase afterload and ventricular filling and reduce both ventricular contraction and heart rate.[49] In these patients, TEE is an essential tool for evaluating the cardiac structures involved in LVOTO and guiding the aforementioned therapeutic interventions.[50,51] The ME long-axis view is used for this purpose because it shows the systolic anterior movement of the anterior leaflet of the mitral valve approaching the interventricular septum (Figure 13). A mosaic pattern can also be observed at the level of the LVOT. This indicates turbulent flow at that level with associated mitral regurgitation due to poor coaptation of the mitral valve leaflets caused by displacement of the anterior leaflet (Figure 14). Due to its dynamic nature, this entity can be overlooked until it is triggered by certain events during OLT (eg, hypovolemia, tachycardia), resulting in a significant decrease in CO. There are even isolated reports of patients undergoing OLT who presented LVOTO despite normal preoperative

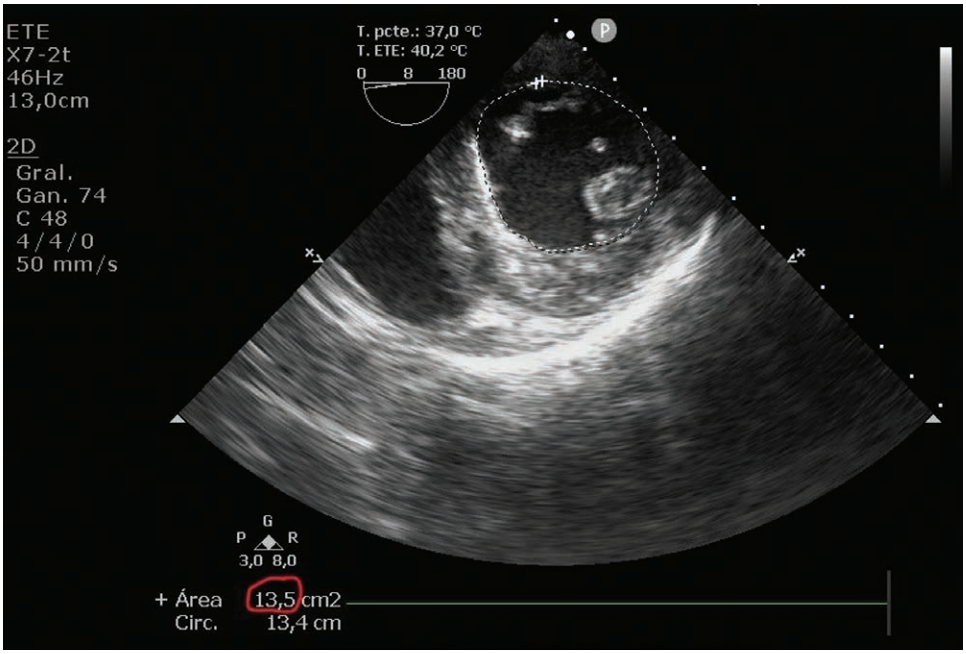

FIGURE 7. TG mid short-axis view showing a normal end-diastolic area (13.5 cm^2), ruling out hypovolemia. TG, transgastric; 2D, 2-dimensional.

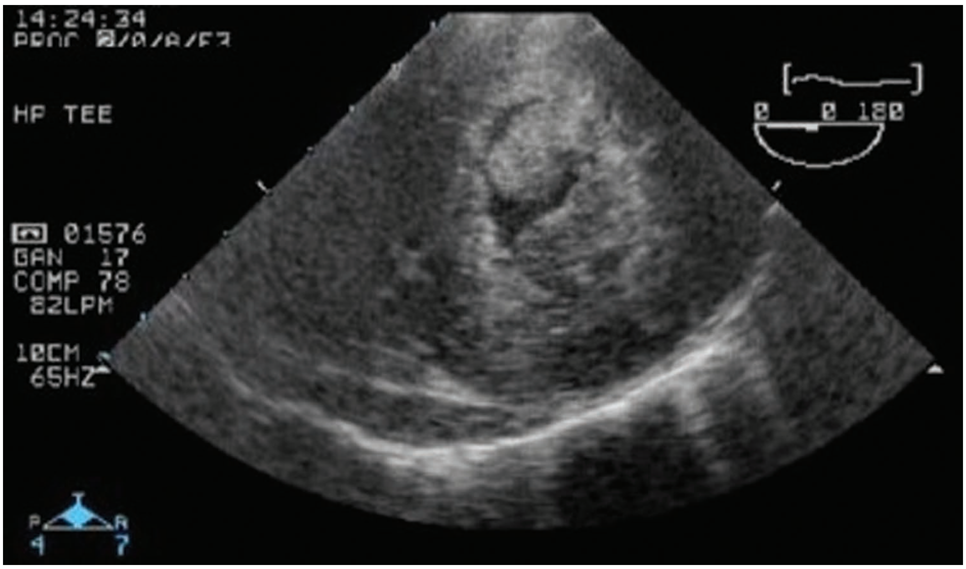

FIGURE 8. TG mid short-axis view showing the approach of the papillary muscles, an indirect sign of hypovolemia. TG, transgastric.

cardiac tests. In these cases, all the therapeutic measures applied to optimize hemodynamics failed, and it was only after intraoperative TEE correctly identified the presence of LVOTO that the surgical team was able to correctly address the situation.[52]

Finally, TEE is used in the preanhepatic phase to diagnose the possible presence of associated pleural or pericardial effusion and to guide surgical drainage (Figure 15).

Anhepatic Phase

This phase starts with occlusion of vascular blood flow to the liver and ends with graft reperfusion. The hemodynamic changes that occur in this phase are mainly caused by the interruption of venous return from the IVC and the portal vein. In this phase, CO is expected to be reduced by 40% to 50%.[10] TEE in this phase is mainly used to detect 2 different hemodynamic patterns: hypovolemia and decreased systemic vascular resistance and hemodynamic instability caused by changes in myocardial contractility. The ME 4-chamber and TG mid short-axis views are ideal for distinguishing between these patterns, because both allow continuous monitoring of biventricular function and filling. On TEE, loss of LV preload associated with a decrease in systemic vascular resistance will result in an approximation of the papillary muscles and reduction in LV end-diastolic diameter (Figure 8).

Reperfusion and Neohepatic Phase

This phase starts with the completion of portal anastomosis and unclamping of the portal vein and is associated with considerable hemodynamic instability.[53] Reperfusion

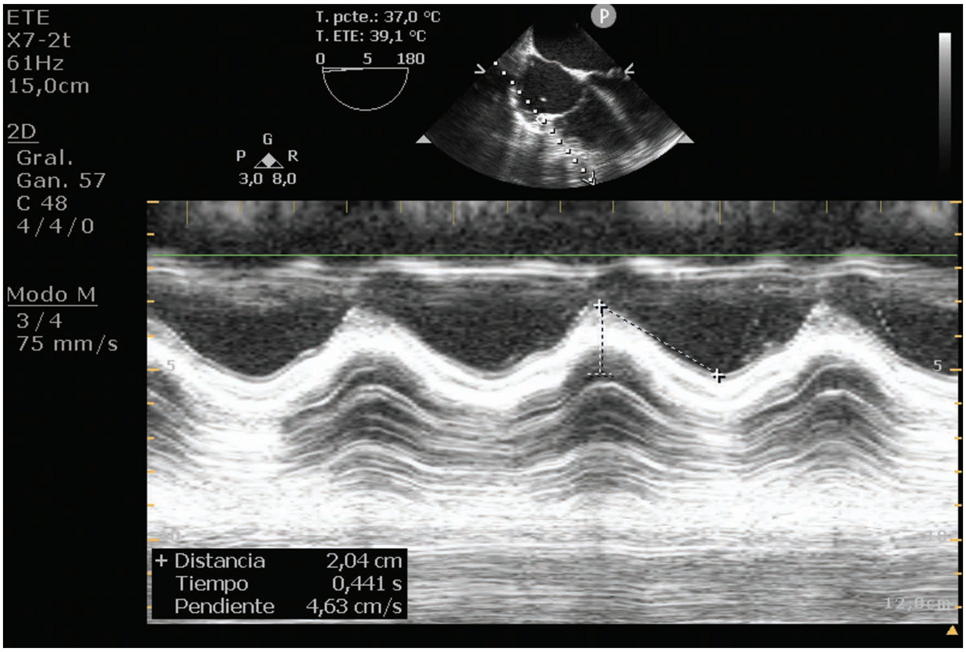

FIGURE 9. ME 4-chamber view used to measure TAPSE (in this case, it presents a value of 20.4 mm, considered normal). ME, midesophageal; TAPSE, tricuspid annular plane systolic excursion; 2D, 2-dimensional.

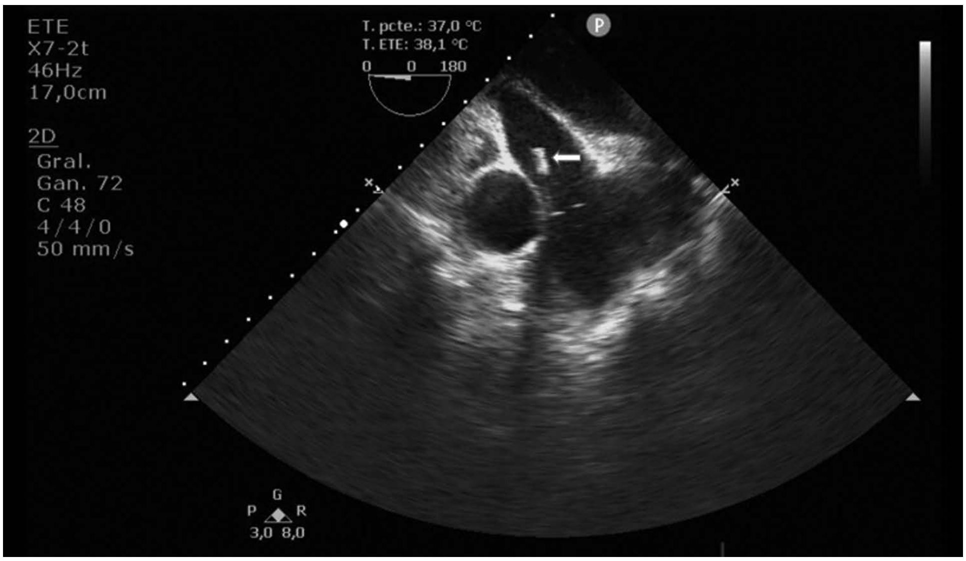

FIGURE 10. ME ascending aorta short-axis view, showing the PAC tip located in the right pulmonary artery (white arrow). ME, midesophageal; PAC, pulmonary artery catheter; 2D, 2-dimensional.

syndrome occurs when liver graft reperfusion causes significant cardiovascular changes and is defined as a decrease in mean arterial pressure >30% below the baseline value, lasting for at least 1 min, occurring during the first 5 min after reperfusion of the liver graft.[54] This syndrome occurs in between 25% and 50% of patients undergoing OLT and is due to cardiovascular changes brought on by a complex phenomenon that is probably related to the sudden release of cold, acidotic, hypokalemic preservation solution, and vasoactive mediators into the bloodstream.[55,56] In this phase, the ME 4-chamber or TG mid short-axis views are usually used because they show the typical echocardiographic findings: left, right, or biventricular ventricular dysfunction, segmental contractility abnormalities, intracardiac thrombosis, and mitral and tricuspid valve regurgitation.

This phase is also characterized by the entry of significant amounts of venous air into the systemic circulation through an existing PFO or an intrapulmonary shunt. This air can embolize the coronary arteries (particularly the right coronary artery) and produce hypokinesia and severe RV dilation with severe tricuspid regurgitation (Figure 16), acute myocardial ischemia with mitral regurgitation, and changes in segmental contractility and may even cause ventricular fibrillation. The TG mid short-axis view is used to assess the regional motion of the LV walls corresponding to the 3 main coronary arteries.

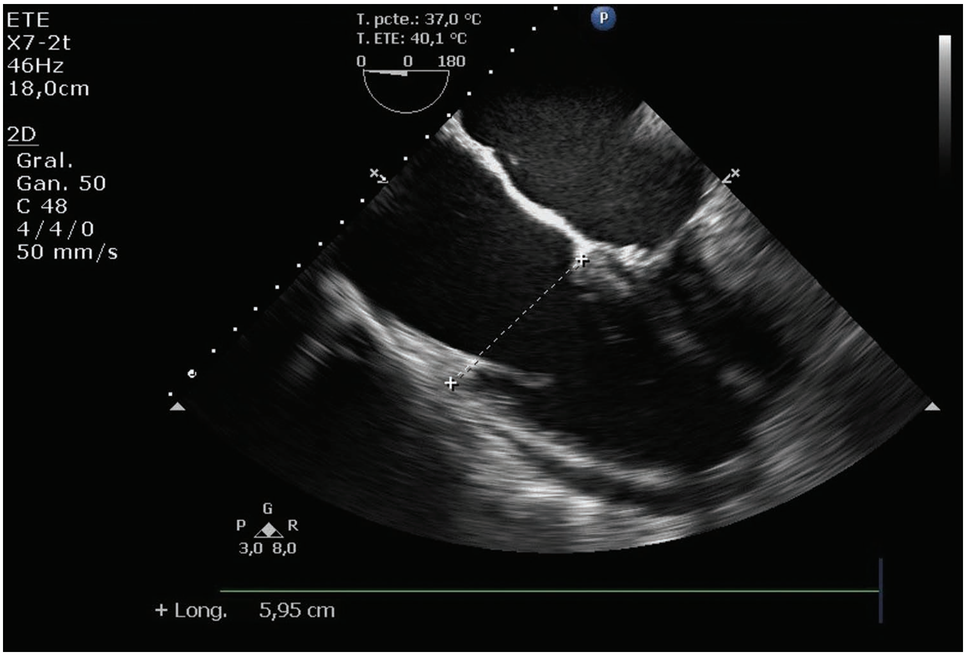

FIGURE 11. ME 4-chamber view showing dilation of the right cavities and the tricuspid annulus. ME, midesophageal; 2D, 2-dimensional.

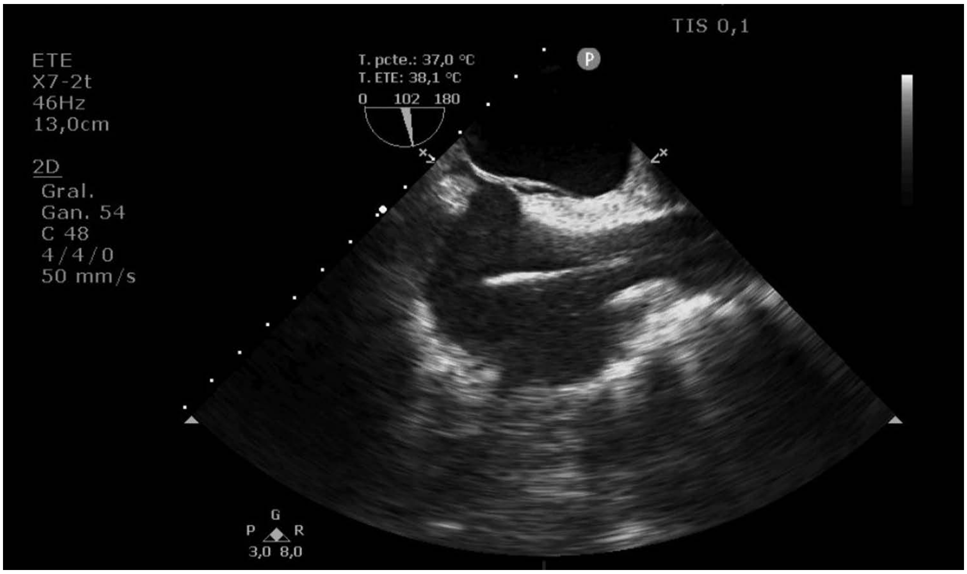

FIGURE 12. ME bicaval view showing the cannula entering the right atrium through the superior vena cava. ME, midesophageal; 2D, 2-dimensional.

None of the currently available guidelines discuss the importance of the presence of PFO in patients undergoing OLT, and this condition does not appear to affect perioperative outcomes in OLT surgery.[57] However, some authors have shown that the combined presence of PFO and interatrial septal aneurysm increases the risk of stroke 3-fold to 5-fold and therefore recommend PFO screening during the preoperative evaluation of patients scheduled for OLT.[58,59] This screening should be performed using the ME bicaval view, in which the entire interatrial septum is visualized. The septum must be evaluated in both 2-dimensional mode and color Doppler because some septal aneurysms are associated with intra-atrial shunt (Figures 17 and 18).[32]

In this phase, around 40% to 50% of patients scheduled for OLT may also present diastolic dysfunction (DD) caused by increased stiffness of the myocardial wall due to myocardial edema secondary to cirrhotic cardiomyopathy.[60,61] DD is assessed in the ME 4-chamber view by calculating the early filling of left ventricle to filling of left ventricle by atrial contraction wave ratio using pulsed Doppler TEE, aligning the cursor on the tip of the mitral valve leaflets to obtain the transmitral flow pattern (Figure 19). DD can also be assessed using tissue Doppler, although this option is not available in all TEE systems used in the operating room. It is important to note the statistically significant correlation between DD and mortality in patients undergoing OLT, although more studies are needed to clarify its true role.[62]

Evaluation of the New Liver Graft

TEE can also be used to assess venous drainage and the integrity of the vena cava and portal venous anastomosis.

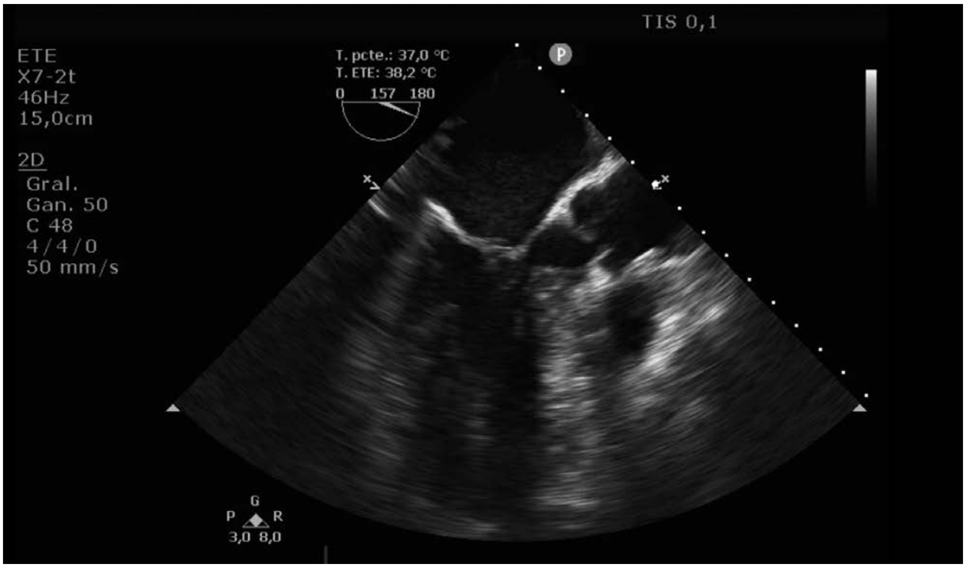

FIGURE 13. ME aortic valve long-axis view showing LVOTO caused by the systolic movement of the anterior leaflet of the mitral valve. LVOTO, left ventricular outflow tract obstruction; ME, midesophageal; 2D, 2-dimensional.

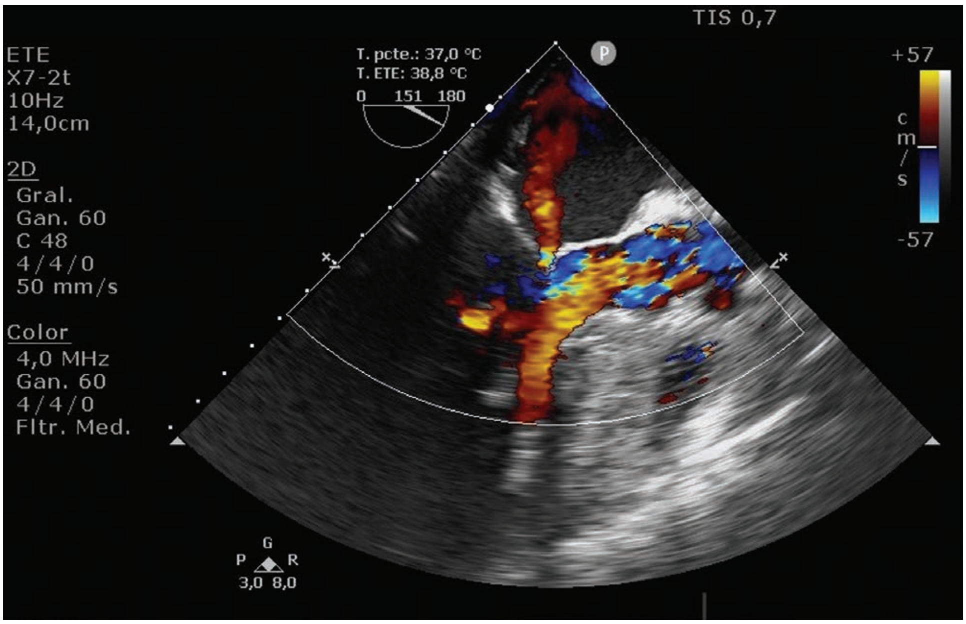

FIGURE 14. ME aortic valve long-axis view showing LVOTO caused by anterior systolic movement of the mitral valve, which causes turbulent flow through the LVOT and associated mitral regurgitation. LVOT, left ventricle outflow tract; LVOTO, left ventricular outflow tract obstruction; ME, midesophageal; 2D, 2-dimensional.

Turbulent or high-velocity blood flow, suggestive of graft dysfunction, can be detected at this level; however, no specific pathological cutoff values for TEE Doppler have been established in these vessels.[63] Further studies are needed to establish the role of TEE in diagnosing and reducing the incidence of early graft dysfunction.

If hemodynamic instability persists in the final phase of reperfusion, the reconstructed IVC must be visualized, and its flow and patency evaluated because undiagnosed stenosis, thrombosis, or torsion of this vessel have devastating consequences that call for reintervention or even retransplantation.[22,64] TEE can be used to visualize the IVC of both the donor and the recipient in the context of OLT using the piggyback technique. The IVC is visualized in the ME bicaval view by advancing and rotating the probe gently to the right. Color Doppler TEE can be used to determine the presence or absence of flow through the IVC, and to detect the presence of a thrombus (Figure 20).

CONCLUSIONS

The intraoperative management of patients undergoing OLT is influenced by the cardiovascular manifestations typically found in the context of end-stage liver disease, by the presence of concomitant cardiovascular disease, and by the significant hemodynamic changes that occur during surgery. Although there is no consensus on the best approach to intraoperative monitoring in these patients, intraoperative

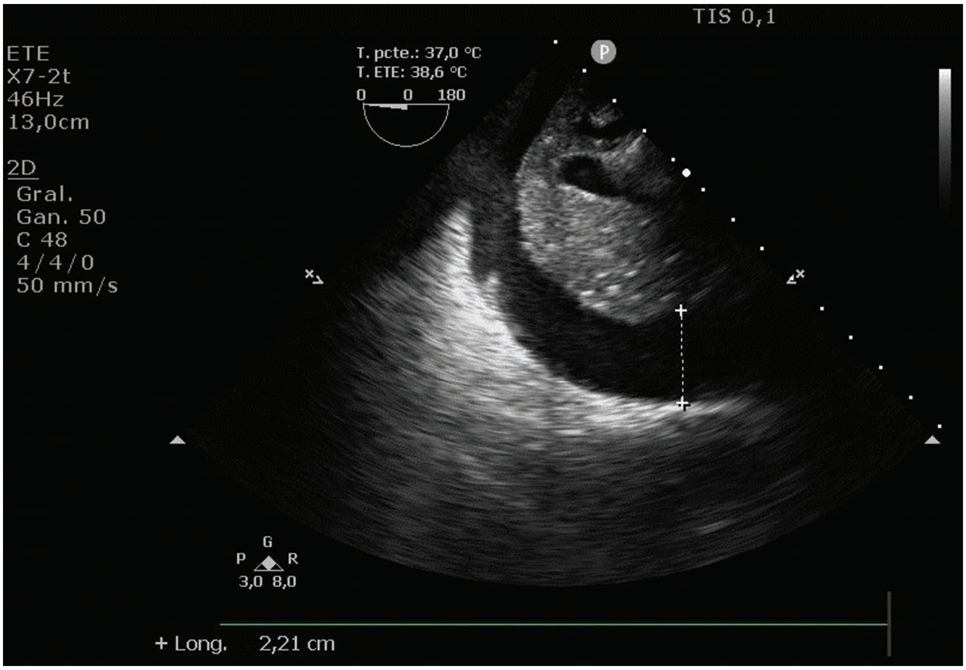

FIGURE 15. TG mid short-axis view showing an important pericardial effusion in the anterior and septal wall of the LV. LV, left ventricle; TG, transgastric; 2D, 2-dimensional.

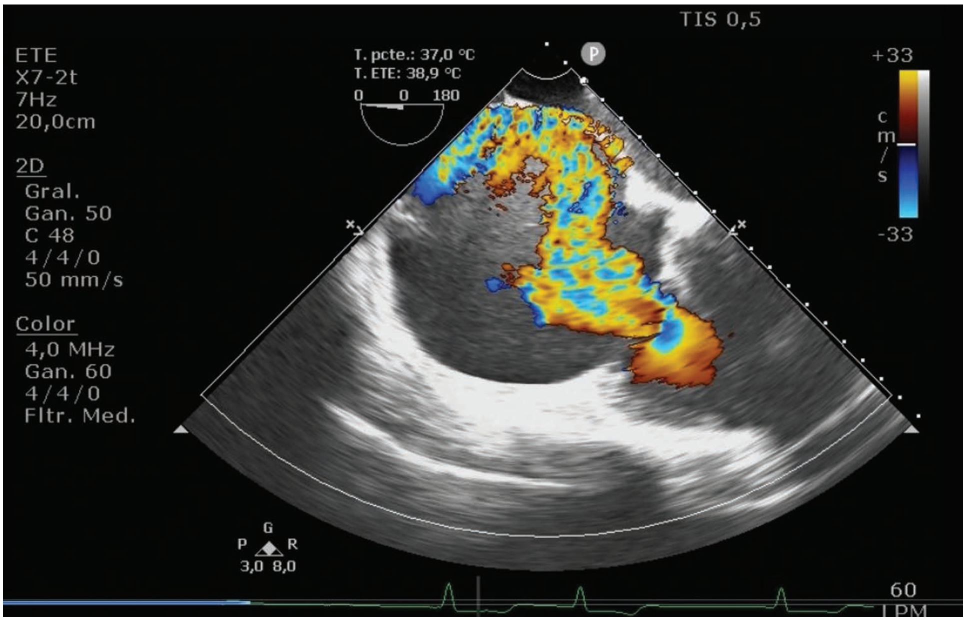

FIGURE 16. ME 4-chamber view with slight movement of the probe to the right that allows visualization of the right cavities, observing severe tricuspid regurgitation with color Doppler modality (note that the regurgitant jet reaches the roof of the atrium). ME, midesophageal; 2D, 2-dimensional.

TEE is safe and useful and should be recommended during OLT, according to experts, for assessing hemodynamic changes, identifying possible complications, and guiding treatment with fluids and inotropes to achieve optimal patient care.

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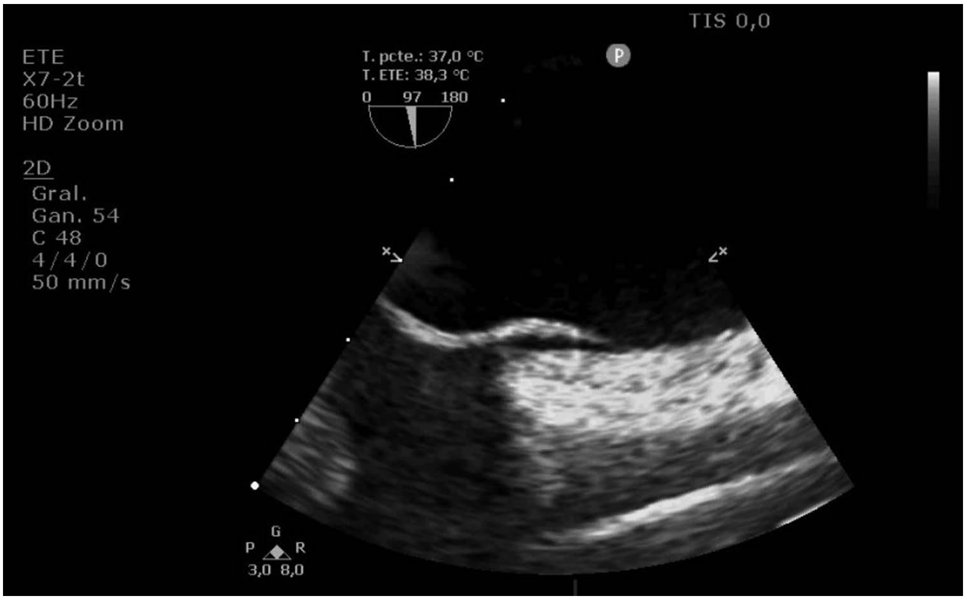

FIGURE 17. Zoom applied in the ME bicaval view where lack of integrity of the interatrial septum is observed. ME, midesophageal; 2D, 2-dimensional.

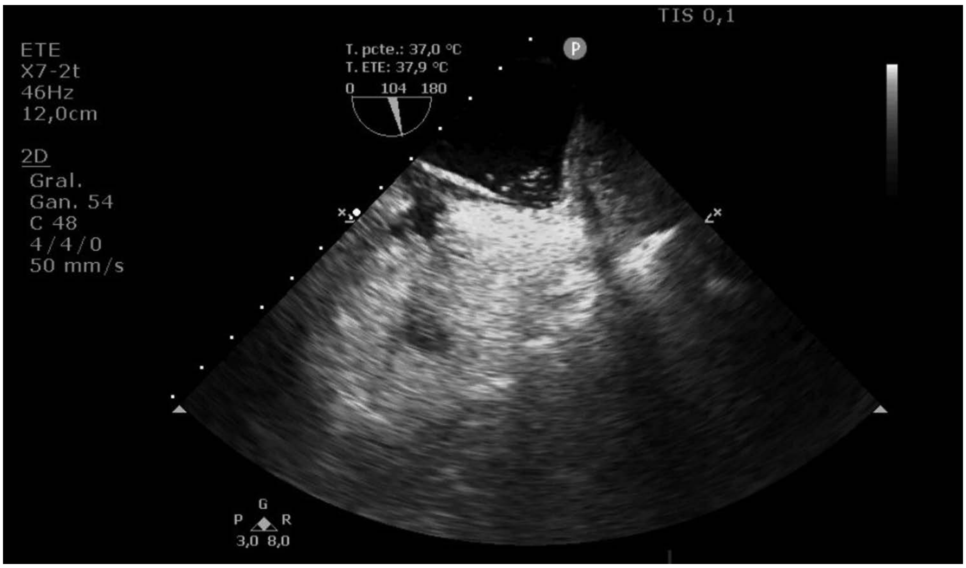

FIGURE 18. Bubble test performed in the ME bicaval view, where the passage of bubbles from the right to the left atrium is observed, confirming the presence of a PFO. ME, midesophageal; PFO, patent foramen ovale; 2D, 2-dimensional.

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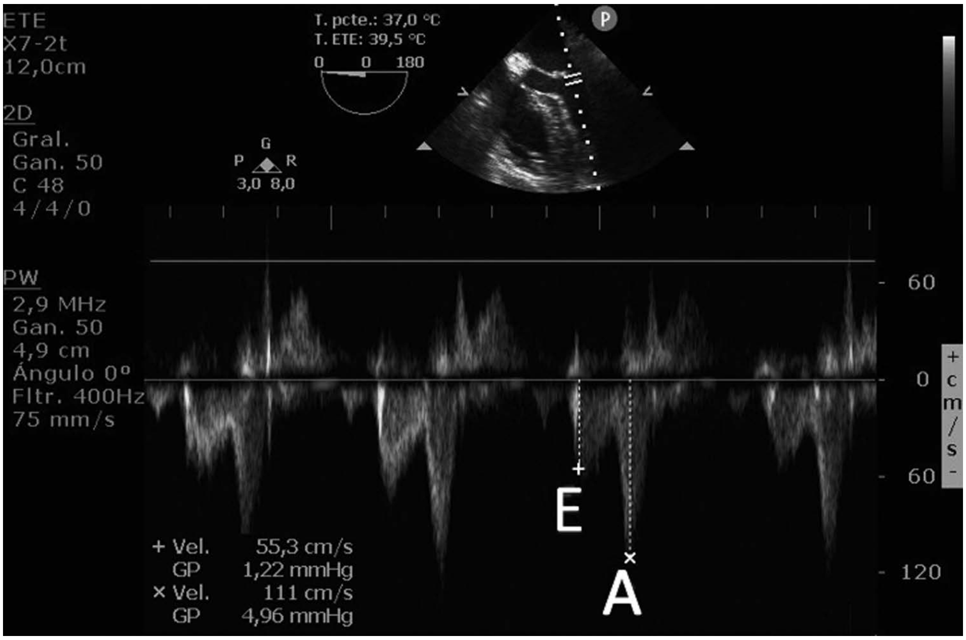

FIGURE 19. ME 4-chamber view used to assess diastolic function (in this case, an alteration in the LV relaxation is observed, because E/A <0.8). E/A, early filling of left ventricle to filling of left ventricle by atrial contraction; LV, left ventricle; ME, midesophageal; 2D, 2-dimensional.

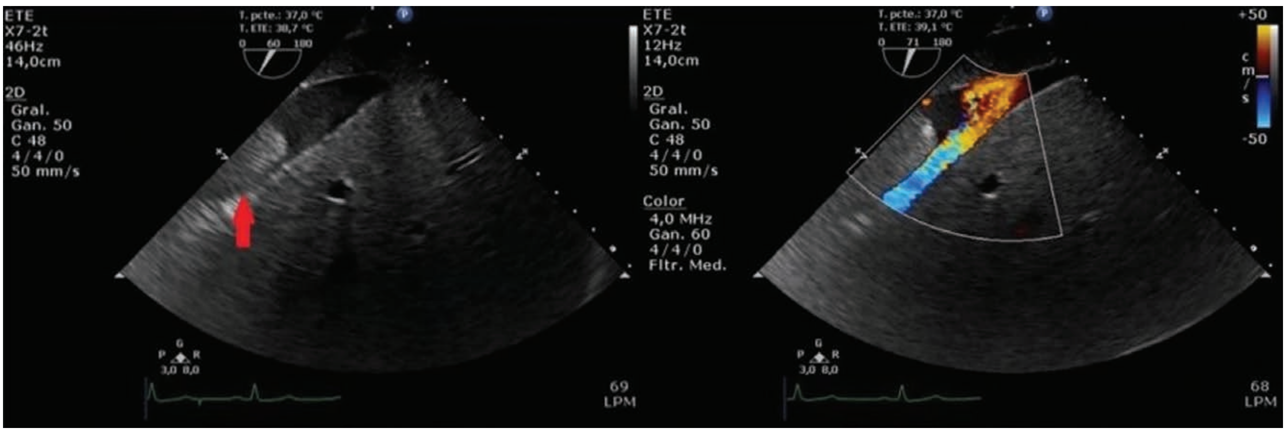

FIGURE 20. TG view showing a thrombus in the IVC (white arrow) that conditions blood flow through it. IVC, inferior vena cava; TG, transgastric; 2D, 2-dimensional.

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