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Nontraditional Transesophageal Echocardiographic Views to Evaluate Hepatic Vasculature in Orthotopic Liver Transplantation and Liver Resection Surgery

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Background. Utilization of intraoperative transesophageal echocardiography (TEE) during orthotopic liver transplantation (OLT) is expanding annually in high-volume transplant centers. During OLT intraoperative TEE is used to gather real-time information on cardiovascular function and intravascular volume status. Although standardized TEE views exist, there are nontraditional views described in the literature which have the potential to diagnose evolving pathology and define normal variants of hepatic vasculature. **Methods.** A literature review was completed utilizing the PubMed database for English-only, peer-reviewed publications discussing nontraditional use of intraoperative TEE during OLT and hepatic vascular-related surgeries from 2009 to 2019. Both case reports and review articles were considered. **Results.** The PubMed literature search offered 8 publications for analysis, including 7 case reports and 1 article review, revealing several nontraditional TEE views not included in a comprehensive transesophageal echocardiographic examination. These nontraditional views were generally obtained using modifications to the transgastric and bicaval views to visualize liver vasculature. We present the various techniques for obtaining these views from the 8 articles identified. **Conclusions.** At high-volume transplant centers, TEE use during OLT is increasing. Intraoperative TEE is a valuable tool to assess hepatic vascular structures critical to allograft/organ function without interruption of the surgical procedure. Nontraditional use of TEE to diagnose intraoperative noncardiac pathology in OLT appears underutilized and underreported. The modified hepatic and modified transgastric views we describe can be used to evaluate hepatic vasculature, influence surgical decision-making and ultimately improve patient care.

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Imaging technology in medical practice has increased diagnostic accuracy and the effectiveness of interventions. Historically, in the field of anesthesiology, basic intraoperative hemodynamic management has been guided by objective changes in vital signs along with limited physical exam data. As ultrasound technology has advanced, echocardiography has become a more prevalent and safe modality to guide diagnoses and treatments intraoperatively.^{1,2}

Transesophageal echocardiography (TEE) is a modality that when compared with transthoracic echocardiography allows for superior visualization of posterior cardiac

structures. TEE is also more practical for intraoperative monitoring, as it avoids the surgical field. The American Society of Echocardiography and Society of Cardiovascular Anesthesiologists have consensus guidelines for a comprehensive transesophageal echocardiographic examination.²⁻⁶

Intraoperative TEE has continued to expand over the last 20 years. Although TEE is most often used during cardiac surgery, its use in liver transplantation and liver resection surgery has grown significantly.⁷ The routine use of TEE in orthotopic liver transplantation (OLT) has been advocated in the literature and is reported to be 40%–72% in high-volume liver

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transplant centers.^{3,8,9} The decision to utilize intraoperative TEE should be guided by the extent of the surgical procedure, the patient's medical status and the anticipated perioperative hemodynamic/physiologic changes. TEE can also be employed in patients with unanticipated hemodynamic instability in any surgical procedure, a phenomenon sometimes referred to as "rescue TEE."^{2,6}

A recent case series by Vetrugno et al¹⁰ suggested that TEE is not just limited to cardiac evaluation in patients undergoing OLT, but can be used to evaluate other organs including the liver, lungs, spleen, and kidneys.⁶ The prevalence and utility of TEE during surgery has expanded rapidly, and several non-traditional views have been described in literature to evaluate hepatic vasculature. These nontraditional TEE views during OLT have the potential to play an important role in the field of transplant anesthesiology.

MATERIALS AND METHODS

Review of Literature

A literature review was accomplished using the PubMed database for English-only, peer-reviewed publications, including review articles and case reports, discussing the use of TEE during OLT with a focus on nontraditional TEE images during OLT and liver resection surgeries. Search dates were specified during a 10-year period from 2009 to 2019. Keywords used in the search included "Orthotopic Liver Transplantation," "Liver resection," "Transesophageal Echocardiography," "Nontraditional TEE," and "Hepatic Vasculature."

RESULTS

The PubMed search results were analyzed and 8 articles were selected based on their relevance to the topic of this review. A total of 7 case reports and 1 review article were chosen to highlight how nontraditional use of TEE illustrated pathology during OLT and hepatobiliary surgery (Table 1). Most of the nontraditional TEE views described in the literature involve visualization of the hepatic veins and the inferior vena cava (IVC). During OLT, visualization of these structures is most useful to diagnose causes of refractory hypotension following reperfusion including anastomotic stenosis and hepatic vein/IVC thromboses. The various methods used to obtain the nontraditional views found in our literature review will be summarized and grouped in 2 main sections below.

Visualization of Hepatic Veins and IVC: The Bicaval View

Cywinski et al¹¹ described the visualization of the IVC and hepatic veins during a vena cava tumor resection with hepatic extension. A midesophageal (ME) bicaval view with an omniplane angle of 40–70° was obtained to visualize the IVC and the probe was then advanced 2–3 cm. Varying the angle at this position (50–130°) allowed for visualization of the right, middle, and left hepatic veins. Alcaraz et al¹³ utilized a similar approach during an extended right hepatectomy to visualize the intrahepatic IVC utilizing a modified bicaval view. A ME 4 chamber view and transgastric midpapillary view were then obtained to evaluate refractory hypotension and ultimately diagnose Budd-Chiari syndrome in this same case.

Robertson and Eagle¹⁶ in their review article highlight a method to visualize the IVC and hepatic veins with the

addition of color flow Doppler. Utilizing a ME bicaval view with a slight rightward turn and advancement of the probe, they were able to visualize and evaluate the "piggyback technique" of anastomoses following OLT. Stoll et al¹⁵ in a case report described a unique view revealing the cause of recurrent supraventricular tachycardia due to extrinsic compression of the right atrium by the liver and diaphragm in a post-liver transplant case. In that case, a ME 4 chamber view, and a ME 5 chamber view with an omniplane angle of 70° were used to guide surgical plication of the diaphragm in real time, ultimately alleviating the recurrent supraventricular tachycardia.

Visualization of Hepatic Veins and IVC: The Transgastric View

The transgastric view is the starting point for the additional nontraditional TEE views described in the remaining 4 articles reviewed. There are similarities in obtaining these views with the general description that begins with a short axis transgastric view, followed by a rightward (clockwise) rotation of the probe and an omniplane angle of anywhere from 0° to 60°. Vannucci et al¹² used this technique to visualize cephalad migration of a transjugular intrahepatic portosystemic shunt into the IVC. By retracting the probe cephalad while maintaining this probe orientation, an attached thrombus extending into the cavoatrial junction was visualized. Vetrugno et al¹⁰ in 2 separate case reports utilized this strategy with an omniplane angle of 40–60° to visualize the donor and recipient IVC during OLT. In another case report, this approach was used as a supplemental surgical guide during a liver hemangioma resection.¹⁴

Last, Khurmi et al⁶ described utilizing a modified transgastric view along with a modified bicaval view to diagnose allograft outflow obstruction secondary to a thrombosed hepatic vein and suprahepatic caval anastomotic stenosis. In this instance, refractory hypotension following hepatic reperfusion could not be explained by standard TEE views or by intraoperative surface ultrasound of the hepatic graft. These findings led to a diagnosis for refractory hypotension following reperfusion that could not be adequately visualized using on the field intraoperative ultrasound. The findings using non-standard TEE views guided real time surgical decision-making in the postimplantation phase of the operation, leading to hepatic vein and IVC thrombectomy along with surgical revision of the suprahepatic anastomoses (Figure 1).

DISCUSSION

Intraoperative use of TEE during OLT is increasing in prevalence.¹⁷ Although probe insertion and manipulation carries risks, the literature demonstrates that intraoperative TEE use is safe, with a low incidence of major hemorrhagic complications even in patients with preexisting varices and Model for End-stage Liver Disease scores over 25.^{18,19} Despite the increasing prevalence of TEE use in liver transplantation, basic TEE certification is not a requirement for credentialing in providing anesthetic care for OLT. In 1 study, only 64% of responding centers had at least 1 anesthesiologist with basic TEE certification on the liver anesthesia team.⁷

Liver transplantation and liver resection surgery are exceptionally high-risk procedures due to multiple factors including patient comorbidities, surgical complexity, and organ quality. There is a paucity of literature describing nontraditional use

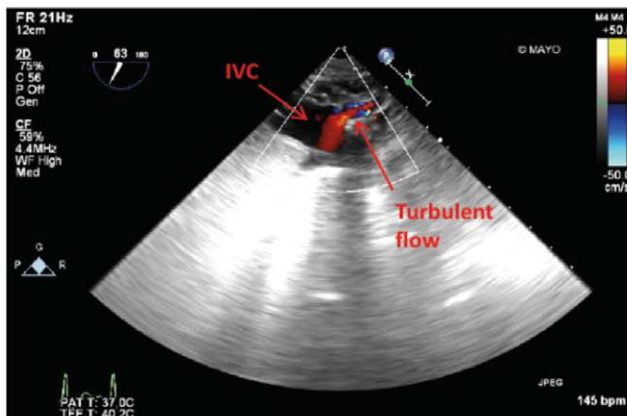
TABLE 1.

PubMed literature review 2009–2019

Publication type	Surgery type	Intraoperative findings	Surgical/anesthesia modification performed
Case report ¹¹	Hepatobiliary	Imaging of IVC Right, middle, and left hepatic vein	Monitor for complete resection of a vena cava tumor resection with hepatic extension
Case report ¹²	Orthotopic liver transplantation	Cephalad migration of TIPS into IVC with thrombus extending to cavoatrial junction	Findings led to modification of the standard piggyback technique to prevent thromboembolization
Case report ¹³	Hepatobiliary	Underfilled and hyperdynamic LV Extrinsic compression of RA Turbulent flow in intrahepatic IVC with mosaic pattern on color Doppler	Diagnosis of refractory hypotension (Budd-Chiari syndrome) leading to surgical revision during same procedure
Case report ¹⁴	Hepatobiliary	Visualization of right hepatic vein	Guide for intraoperative hemangioma resection
Case report ¹⁰	Orthotopic liver transplantation	Visualization of donor and recipient IVC and Doppler flow through cavoatrial anastomoses Graft swelling	Surgical performance of a rescue terminolateral cavo-cavostomy by anastomosis of the donor infrahepatic vena cava to the recipient's suprarenal vena cava to correct the inadequate outflow
Case report ¹⁵	Orthotopic liver transplantation	Visualization of RA compression by liver/diaphragm	Used to guide surgical plication of diaphragm and monitor for RA compression
Case report ⁶	Orthotopic liver transplantation	Long axis view of the middle hepatic vein to visualize thrombus IVC from hepatic veins to atriocaval junction to visualize suprahepatic anastomotic stenosis	Diagnosis of refractory hypotension leading to surgical thrombectomy and revision of suprahepatic anastomoses
Review article ¹⁶	Orthotopic liver transplantation	Visualization of IVC and hepatic veins with color flow Doppler	Identification and verification of "Piggyback Technique" anastomoses integrity

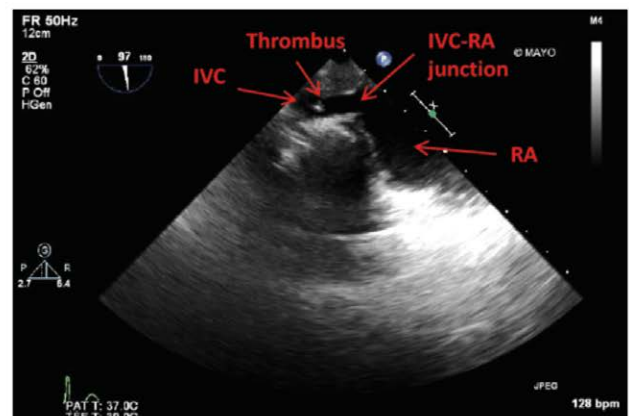
This table illustrating the literature search including the publication type, reference, surgery type, intraoperative findings, and surgical/anesthesia modification performed. IVC, inferior vena cava; LV, left ventricle; RA, right atrium; TIPS, transjugular intrahepatic portosystemic shunt.

Modified Transgastric Views

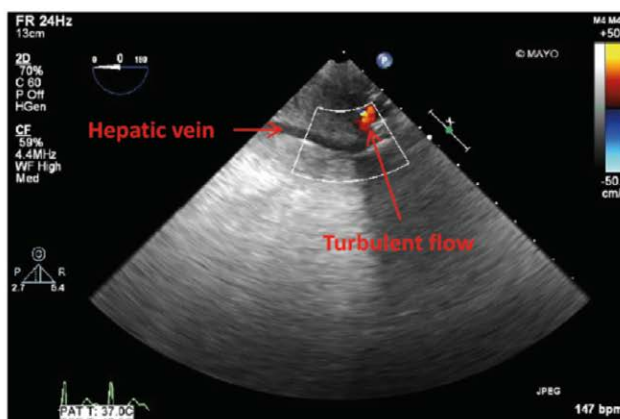


Suprahepatic IVC Stenosis with turbulent flow

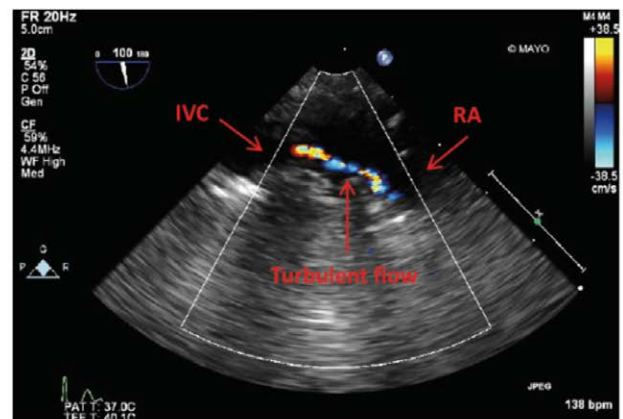
Modified Bicaval Views



Thrombus at the RA/IVC Junction



Hepatic vein stenosis in the neohepatic phase



IVC Stenosis with a turbulent jet near the right atrium

FIGURE 1. Examples of both the modified transgastric transesophageal echocardiography (TEE) views (on the left) and the modified bicaval TEE views (on the right) showing suprahepatic inferior vena cava (IVC) stenosis and right atrium (RA)/IVC thrombus along with hepatic vasculature. Adapted from Khurmi et al.⁶ CF, parameter regarding color flow; FR, frequency; PAT, patient; WF, wall filter.

of TEE to diagnose intraoperative noncardiac pathology in OLT. Using the nontraditional TEE views described, including the ME bicaval view with a slight right turn and advancement (modified bicaval view), and the transgastric view with the probe rotated to the right and an omniplane angle of 0–60° (modified transgastric view), transplant anesthesiologists can have another valuable tool to evaluate intraoperative anatomic and physiologic anomalies that can lead to hemodynamic disturbances.^{6,10,16,20}

Intraoperative TEE is a valuable tool to assess hepatic vascular structures critical to allograft function and survival without interruption of the surgical procedure. Anatomic proximity of the distal esophagus and gastric antrum allow for adequate visualization of hepatic veins and detection of hepatic vein flow by TEE.⁶ The nontraditional TEE views obtained during OLT have the potential to positively effect outcomes in selected situations. Given the case reports, utilization trends in available literature, and relative safety it seems reasonable to recommend the use of TEE routinely in liver transplantation. The ability to define and evaluate hepatic vasculature using these nonstandard TEE views during hepatobiliary surgery, allow for real time diagnosis of intraoperative problems such as anastomotic stenosis and hepatic venous outflow thromboses.

With the ability to establish an early definitive diagnosis intraoperatively, the use of TEE during hepatic resection and OLT can facilitate uninterrupted surgical and medical management of life threatening problems. Although more data is needed to support the regular use of these nontraditional TEE views, earlier diagnosis and intervention intraoperatively has the potential to improve patient outcomes following OLT. The nontraditional modified hepatic views described in this review are not part of the basic 11-view TEE certification endorsed by the American Society of Echocardiography and Society of Cardiovascular Anesthesiologists. With this in mind, further research is needed to standardize these described modified views with the goal of improving their diagnostic accuracy and utility in both OLT and liver resection surgery.⁶

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