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North American Practice-Based Recommendations for Transjugular Intrahepatic Portosystemic Shunts in Portal Hypertension

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AUTHOR CONTRIBUTIONS

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DESCRIPTION OF SUPPORTING MATERIAL

Supplemental Methods. Expanded methods mapped to AGREE II criteria and terms used for literature search strategy.

Supplemental Discussion. Specific comments on strengths and limitations of available literature in across specific aspects of care for patients undergoing TIPS as indicated in the main text.

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Abstract

Complications of portal hypertension, including ascites, gastrointestinal bleeding, hepatic hydrothorax, and hepatic encephalopathy are associated with significant morbidity and mortality. Despite few high quality randomized controlled trials to guide therapeutic decisions, transjugular intrahepatic portosystemic shunt (TIPS) creation has emerged as a crucial therapeutic option to treat complications of portal hypertension. In North America, the decision to perform TIPS involves gastroenterologists, hepatologists, and interventional radiologists, but TIPS creation is performed by interventional radiologists. This is in contrast to other parts of the world in which TIPS creation is primarily performed by hepatologists. Thus, the successful use of TIPS in North America is dependent on a multidisciplinary approach and technical expertise, so as to optimize outcomes. Recently, new procedural techniques, TIPS stent technology, and indications for TIPS have emerged. As a result, practices and outcomes vary greatly across institutions and significant knowledge gaps exist. In this Consensus statement, the Advancing Liver Therapeutic Approaches (ALTA) group critically reviews the application of TIPS in the management of portal hypertension. ALTA convened, for the first time, a multidisciplinary group of North American experts from hepatology, interventional radiology, transplant surgery, nephrology, cardiology, pulmonology, and hematology to critically review existing literature and develop practice-based recommendations for the use of TIPS in persons with any cause of portal hypertension in terms of candidate

selection, procedural best practices and post-TIPS management; and to develop areas of consensus for TIPS indications and prevention of complications. Finally, future research directions are identified related to TIPS for the management of portal hypertension.

Keywords

TIPS procedure; cirrhosis; end-stage liver disease; complications; consensus statement; guidance document; ascites; variceal bleeding

INTRODUCTION

Portal hypertension, defined as elevated pressure in the portal venous system, can lead to major clinical complications including ascites, gastrointestinal hemorrhage, hepatic hydrothorax (HH), and hepatic encephalopathy (HE), all associated with significant morbidity and mortality.[1] While medical therapies and liver transplantation (LT) are effective treatments in many scenarios, transjugular intrahepatic portosystemic shunt (TIPS) creation is a crucial therapeutic option.(Figure S1)

In North America, the decision to perform TIPS is determined by specialists in gastroenterology and hepatology who treat patients with portal hypertension, but TIPS creation is performed by interventional radiology (IR). This is in contrast to other parts of the world (e.g., Europe) in which hepatologists primarily perform TIPS. While TIPS creation is effective for management of complications of portal hypertension,[2–7] it is associated with several risks, including deterioration in liver function, new onset or worsening HE,[8] and changes in cardiopulmonary and renal hemodynamics (Figure S1).[9] Over the past decade there have been important advancements in TIPS devices, procedural techniques, and immense growth in the literature supporting the role of TIPS in the management of portal hypertension.[10, 11] However, there are few high quality randomized controlled trials (RCTs) of TIPS use. New indications for TIPS placement have also emerged, including treatment of portal vein thrombosis (PVT), which require rigorous assessment. As a result, practices and outcomes vary greatly across institutions and significant knowledge gaps exist.

The goals and objectives of the Advancing Liver Therapeutic Approaches (ALTA) Consensus Conference were to convene, for the first time, a multidisciplinary group of North American experts from hepatology, IR, transplant surgery, nephrology, cardiology, pulmonology, and hematology to critically review existing literature and develop practice-based recommendations for the use of TIPS in persons with any cause of portal hypertension in terms of candidate selection, procedural best practices and post-TIPS management across seven key topic areas: general considerations for TIPS, TIPS in the management of ascites/HH, TIPS in the management of variceal bleeding, novel indications for TIPS, cardiopulmonary considerations of TIPS including management of hepatopulmonary syndrome (HPS), renal considerations of TIPS including management of hepatorenal syndrome (HRS), and HE and TIPS.

METHODS

A consensus-building process was conducted consistent with standards described in the Appraisal of Guidelines for Research and Evaluation II[12] and used a modified Delphi approach to achieve consensus (Supplemental Methods).[13] Practice-based recommendations were developed by 30 ALTA group members with extensive experience in the management of portal hypertension and the use of TIPS, who participated in the consensus conference held on October 23, 2020. The target users are gastroenterologists, hepatologists and sub-specialty physicians who refer for TIPS and/or provide care for patients undergoing TIPS.

PubMed, EMBASE, and Cochrane were queried for English language papers published between January 1, 1990 and July 1, 2020. The target population was persons with any cause of portal hypertension undergoing TIPS. Terms were chosen through input from participants and by consultation with a medical librarian (Supplemental Methods). We considered peer-reviewed articles in the following order of relevance: RCTs, systematic reviews and meta-analyses, and observational studies. For select topics where studies were limited, case reports were included. Between August 2020 and October 2020, literature for each topic was iteratively discussed by workgroups of physicians with expertise in the identified topics. Level of evidence for all consensus statements was graded using the Oxford Centre for Evidence-based Medicine Levels of Evidence.[14]

RESULTS AND DISCUSSION

The literature search yielded 2,116 articles, with 703 remaining after titles and abstracts were screened for relevance (Supplemental Methods). An additional 81 articles not captured by the literature search were included on the basis of panel agreement of relevance.

A total of 105 clinical statements were developed for assessment throughout the two iterations of the Delphi survey. All panelists completed all survey items. After two iterations of the Delphi survey, 87 statements met the standardized definition for consensus (Supplemental Methods and Table S1). The recommendations are outlined in Tables 1–3. The following text provides brief rationale supporting these recommendations. Expanded rationale, where indicated, is available in the supplemental material.

General Considerations for TIPS

Table 1 summarizes recommendations concerning TIPS planning, procedural best practices, and care of the TIPS recipient independent of indication for TIPS.

Pre-TIPS Considerations

Q1. Who should be involved in the decision to place a TIPS?: A team-based approach to TIPS is critical in all stages of TIPS planning and management (Figure 1).[15, 16] Initial consideration for decision on TIPS candidacy should involve the patient and caregiver as well as a gastroenterologist or hepatologist and a proceduralist with competency in TIPS. Complex cases should include consultation with additional specialties (e.g., transplant surgery, nephrology, etc.) as appropriate.

Q2. What services should be readily available at centers where TIPS is performed and what referral pathways should be established for a higher level of care?: Centers that offer TIPS creation should ensure availability of multidisciplinary services to provide high quality care for this high-risk population (Figure 1).[16] Centers should have access to expertise in IR, gastroenterology/hepatology, cardiology, surgery, nephrology, and critical care medicine. In complex cases, including patients meeting criteria for referral for transplant or requiring specific technique expertise (e.g., PVT), referral to centers with additional expertise is recommended.

Q3. Is there a Model for End-Stage Liver Disease (MELD) threshold above which elective TIPS should not be considered?: A multidisciplinary approach, rather than an absolute MELD cutoff, is recommended to assess TIPS candidacy. MELD score is the strongest predictor of 90-day mortality after TIPS when compared to MELD-Na and other scoring systems (e.g., Child-Turcotte-Pugh (CTP) score, etc.; Supplemental Discussion).[17–22] MELD score performs better in patients with TIPS for variceal bleeding compared to patients with refractory ascites (RA).[23–25] Studies have examined additional risk factors for poor outcomes with mixed results, including older age and specific numerical MELD score cutoffs.[24–30] Variability in patient population and study design limit the ability to determine firm cutoffs.[4, 31–34] Determination of TIPS candidacy using the MELD score should take into consideration the relative risk and benefit of TIPS creation, considering the TIPS indication, patient comorbidities and alternative treatment options.

Q4. What evaluation is required prior to TIPS creation?: Cross-sectional imaging and echocardiography provide important information for TIPS planning. Cross-sectional imaging should include portal venous phase imaging to adequately define portal veins, hepatic veins, and the liver parenchyma to permit planning of TIPS creation. Comprehensive echocardiography before TIPS is recommended to assess risk for cardiac decompensation after TIPS (details in cardiopulmonary section).[15] Emergent TIPS indications may not allow a complete anatomic and cardiac evaluation; however, a liver ultrasound with doppler and a limited two-dimensional echocardiogram should still be considered.

Q5. What are absolute contraindications to elective TIPS creation?: The absolute contraindications to TIPS creation include American College of Cardiology (ACC)/ American Heart Association (AHA) Stage C or D heart failure (HF, i.e., echocardiographic evidence of systolic +/− diastolic dysfunction combined with clinical features of HF),[35] AHA/ACC stage C or D untreated valvular heart disease (VHD, i.e., asymptomatic severe VHD with or without decompensation of the left or right ventricle or symptomatic VHD),[36] moderate-severe pulmonary hypertension, uncontrolled systemic infection, refractory overt HE and anatomic barriers to shunt creation (e.g., multiple hepatic lesions).[15, 16]

Q6. Should all patients undergo evaluation for LT prior to TIPS creation?: In patients undergoing elective or emergent TIPS, there is insufficient evidence to recommend universal pre-procedure LT evaluation. While patients with cirrhosis and RA or variceal bleeding undergoing TIPS have indications for a LT evaluation, not all will be LT candidates.[37] TIPS should not be delayed in order to consider a LT evaluation.

TIPS Procedural Considerations

Q7. Who should perform TIPS creation?: TIPS should be performed by a credentialed, board certified Interventional Radiologist or a certified provider with equivalent training and procedural competency, acknowledging that training pathways vary worldwide.[16, 38] According to radiology professional society guidelines, TIPS placement must be performed by a physician with board certification or accredited training as well as sufficient experience with TIPS procedures. In the absence of certification or accredited training, TIPS placement can be performed by a competent proceduralist defined as one who has performed competent proceduralist is one who has performed a sufficient number of TIPS procedures under supervision (minimum threshold = 5), in addition to other endovascular techniques (i.e., minimum of 100 angiograms, 50 angioplasties, 10 stent placements, and 5 embolizations), has achieved expected procedure completion thresholds, and has obtained appropriate privileges at their center.[38]

Q8. What type of stent is recommended for TIPS creation?: Numerous studies have demonstrated improved patency, ascites control and rebleeding prevention with the use of expanded polytetrafluoroethylene (ePTFE) covered stent grafts versus bare metal stents at the time of TIPS creation.[39–46] The use of a specialized purpose-designed stent graft appears to yield superior patency compared with shunts created with off-label use of bare metal stent/stent graft constructs.[47] Use of a controlled-expansion stent that allows for incremental and reliable expansion of stent diameter is recommended in order to optimize the amount of portosystemic shunting based on the indication, patient risk factors, and target gradient, while potentially mitigating the risk of HE.[10] Underdilation of a self-expanding stent with a fixed diameter as a method of decreasing HE risk is not recommended because the stent will passively expand over time to its nominal diameter..[48, 49]

Q9. Should coagulopathy be corrected prior to TIPS creation?: It is unclear whether correction of coagulopathy to a specific target internationalized normal ratio (INR) or thrombocytopenia decreases complications or improves survival after TIPS.[50] INR and platelet count are poor measures of bleeding risk in patients with cirrhosis and routine transfusion of blood products prior to invasive procedures does not portend lower procedural bleeding risk.[51–55] However, these studies primarily include patients undergoing paracentesis and liver biopsy, and it is unclear if the results can be extrapolated to patients undergoing TIPS creation, which carries a higher bleeding risk. Plasma fibrinogen levels < 100 mg/dL are associated with increased bleeding risk in critically ill patients with cirrhosis, but causal relationships are not established.[50] The role of correction to levels > 100 mg/dL and reduction of bleeding risk during TIPS creation is unknown.[50]

Q10. Should periprocedural antibiotics be routinely used in TIPS creation?: The use of periprocedural antibiotics will depend on patient (e.g., prior biliary instrumentation) or local risk factors.[56, 57] There is insufficient evidence that the routine use of periprocedural antibiotics decreases infectious complications after TIPS creation.

Q11. Should TIPS creation be performed using general anesthesia or is deep or conscious sedation appropriate?: There is no evidence that the use of any specific type

of anesthetic has an impact on procedural success, complication rate, or post-procedure outcomes. The use of general anesthesia, deep sedation, or conscious sedation will depend on patient risk factors and local practices.

Q12. Is the use of intravascular ultrasound recommended to assist with the portal vein puncture?: The use of intravascular ultrasound to facilitate access into the portal vein is associated with decreased needle passes through the liver, contrast use, procedure time, time to portal access, and radiation exposure.[58, 59] However, no studies have shown that the use of intravascular ultrasound reduces complication rates or improves survival after TIPS creation.

Q13. What is the optimal location from which to measure the systemic venous pressure at the time of TIPS creation?: Either the free hepatic or IVC pressure should be used as the systemic venous pressure when measuring the PSG before and after TIPS creation. In patients with cirrhosis, the use of the free hepatic venous pressure or the inferior vena cava (IVC) pressure as the systemic venous pressure, rather than the right atrial pressure (RAP), when calculating the hepatic venous pressure gradient is well validated.[60, 61] Studies have shown the efficacy of these measurements when assessing clinical response following TIPS creation.[62–64] These studies have also demonstrated a statistically significant difference between the hepatic venous or IVC pressure compared to the RAP due to the effect of intra-abdominal pressure. This difference decreases the prognostic value of the portosystemic gradient (PSG) when the RAP is used and could potentially lead to under- or over-dilation of the TIPS stent to achieve a target gradient.[64]

Q14. Are there specific technical factors that should be considered to ensure that TIPS creation does not adversely influence liver transplant candidacy?: LT candidacy should not be impacted by creation of TIPS. The presence of a patent TIPS in patients undergoing LT is unlikely to negatively impact surgical outcomes although it may increase surgical complexity.[65–68] During LT, the presence of TIPS may cause hyperdynamic circulation and increased portal flow,[67, 69] but does not impact blood transfusion requirements, operative time, or hospital length of stay.[65–68] Operative factors are more favorable with TIPS compared to pre-transplant surgical shunts.[66] TIPS malposition may affect up to 20% of transplants;[66, 68] therefore, care should be taken to ensure that the TIPS device does not extend into the right atrium and leaves a segment of the portal vein for transplant anastomoses.

Care of the Post-TIPS Patient

Q15. What is the recommended duration of intensive post-procedure monitoring?: Most patients may be safely monitored overnight in an acute care unit after TIPS creation. Patients at high risk for TIPS-related decompensation based on patient factors (e.g., cardiac dysfunction, overt HE) or immediate complication based on intraprocedural events (e.g., trans-splenic approach) may require a higher level of care.

Q16. What early testing is recommended following TIPS creation and at what interval?: Laboratory evaluation to assess for bleeding, hepatic dysfunction and to allow

calculation of MELD score prior to discharge after TIPS creation is considered standard of care (Supplemental Discussion). Because early TIPS thrombosis is rare in the era of ePTFE-covered TIPS[41, 46] and early Doppler ultrasound of ePTFE-covered TIPS flow is obscured by the presence of microbubbles,[70, 71] early post-TIPS Doppler ultrasound interrogation is unlikely to impact clinical decisions and is not routinely recommended. However, early imaging in select patients with high risk of early thrombosis (e.g., underlying thrombophilia) may be appropriate.

Q17. Should TIPS venography and intervention be based on ultrasound, clinical findings, or both?: The decision to perform TIPS venography and intervention should depend on the indication for TIPS creation due to low specificity (33–95%) and high false positive rates (50%) of Doppler ultrasound for detecting TIPS dysfunction.[70, 72] In patients who have undergone TIPS for management of varices, TIPS stenosis will increase the PSG and risk for subsequent variceal hemorrhage.[73] Clinical (e.g., ascites) or Doppler ultrasound findings suggesting stenosis in this cohort should prompt TIPS venography and manometry, where stenosis can be confirmed and intervened upon or refuted. In patients who undergo TIPS for ascites/HH and with absence of clinically apparent ascites/HH, intervention based on Doppler ultrasound findings suggesting TIPS stenosis depends on other clinical factors. If ascites/HH is well-controlled, confirmation of TIPS stenosis by venography and manometry may not necessarily prompt intervention.

In patients who undergo TIPS to reestablish portal vein patency, routine scheduled TIPS venography and manometry +/− intervention is suggested within 1–2 months following portal vein recanalization and TIPS creation in order to assess for residual thrombus, perform additional portal vein recanalization, and embolize spontaneous competing portosystemic shunts as needed in order to help maintain portal vein patency (see Supplemental Discussion).[74]

Q18. What are the optimal techniques for altering TIPS flow when intervention is required?: When an indication to change the PSG is identified, stepwise dilation of a controlled expansion stent is the least invasive way to achieve this goal. When a TIPS has been dilated to its maximum potential diameter, the next step relies on individualized decision-making. Interventions to further decrease the PSG include parallel TIPS creation and medical therapy. Multiple techniques have been described to increase the PSG by constraining the flow lumen of pre-existing TIPS. Comparative data between TIPS reduction techniques do not exist.

Q19. Who should see patients with TIPS in follow up?: We recommend a multidisciplinary approach to post-TIPS management involving a gastroenterologist/hepatologist and a proceduralist given the need for ongoing liver care as well as monitoring for any post-procedural complications and potential need for TIPS revision (Figure 2).[15, 16]

Specific Considerations for TIPS by Indication

The approach to TIPS creation should differ depending on clinical indication, as the optimal balance between efficacy and morbidity may vary (Table 2).

TIPS in Ascites or HH

Q1. What is the optimal technical approach to TIPS creation among patients with cirrhosis and RA?: In the setting of elective TIPS for ascites, there is time to carefully titrate the amount of portal decompression obtained while monitoring for shunt morbidity, including HE. After weighing the advantages and disadvantages of various approaches (Table S1), we favor the creation of a small diameter TIPS (8 mm, based on the minimum 8 mm diameter with current generation on-label use of controlled expansion stent graft) followed by progressive dilation, if needed, based on clinical response at 6-week intervals. This approach minimizes the risks of overshunting and offers the greatest opportunity for procedural uniformity.

Q2. Is TIPS associated with better outcomes than serial large volume paracentesis (LVP) for the treatment of RA?: As compared to LVP, TIPS is associated with improved control of ascites, but increased risk of HE (Table S2).[4, 75–80] The impact of TIPS on survival has been more controversial, with some,[4, 76, 79, 80] but not all RCTs demonstrating improved transplant-free survival (TFS).[77, 78] Several subsequent meta-analyses[81–86] have confirmed the superiority of TIPS compared to serial LVP in prevention of recurrent ascites, but remained split in terms of TFS benefit, depending upon methodology and whether one potentially outlier[75] paper was included (Table S2, Supplemental Discussion).

Q3. Is there a threshold of liver dysfunction above which TIPS for RA should be contraindicated and how should it be defined?: Among patients with cirrhosis and RA, elevated bilirubin, MELD score and CTP Class C cirrhosis are associated with increased post-TIPS complications including mortality.[76, 84–86] However, strong evidence for a specific cutoff for any of these parameters is lacking (Table S2, Supplemental Discussion).

Q4. What is the impact of age on candidacy for TIPS for RA?: Among patients with cirrhosis and RA, advanced age is associated with increased post-TIPS complications including HE and mortality. However, there are no studies that provide strong evidence of a specific cutoff above which TIPS should be considered contraindicated (Table S2, Supplemental Discussion).

Q5. What is the role of TIPS in patients with ascites that is not refractory?: TIPS should be considered in selected patients with at least three LVPs for tense ascites in a year despite optimal medical therapy.[1] Among RCTs comparing TIPS vs LVP, those which included patients not fulfilling strict criteria of RA showed improved TFS[4, 79] or a trend for improved TFS.[76] Among trials including patients with RA with a strict definition, only one showed an improvement in survival. The specific definitions of non-RA vary by trial (Table S3).

Q6. What is the role of TIPS in HH?: For patients with HH on maximal medical therapy requiring frequent thoracentesis or those with significant clinical symptomatology (e.g., hypoxia, resting dyspnea), TIPS should be considered.[1] TIPS creation for refractory HH leads to complete response in over 50% of patients, with partial responses observed in approximately 20%, similar to response rates for RA.[87–91] Predictors of inferior outcomes of

TIPS for recurrent HH are similar to those observed in TIPS placed for RA, including older age, severity of liver disease, and renal insufficiency.[5, 17, 89]

Q7. Is prior LT a contraindication to TIPS for RA? Is TIPS superior to surgical shunt, serial LVP or splenic artery embolization in LT recipients with RA?: There is insufficient evidence to support any recommendation regarding therapy (TIPS and other modalities) in LT recipients with RA (Supplemental Discussion). The technical success for TIPS creation post-LT is similar to that observed in patients pre-transplant; however, the clinical efficacy is inferior to that observed in RA pre-LT.[92–94] Careful assessment for the underlying etiology of ascites should be undertaken prior to TIPS creation and the timing post-LT should be considered.

Q8. What is the expected timeline for TIPS to be effective for reduction of ascites/HH?: In detailed pathophysiological studies, a negative sodium balance (under a very strict low-sodium diet) is achieved at around four weeks after TIPS.[95] With a less restrictive diet this level of natriuresis might not be achieved and patients may require the use of diuretics after TIPS. If using a staged approach to TIPS (progressive stent dilation from 8 to 9 to 10 mm of diameter based upon clinical response), the decision to increase TIPS diameter should not be made before 6 weeks.

TIPS in Variceal Bleeding

Q1. When is TIPS indicated in acute variceal hemorrhage?: TIPS is recommended in patients with cirrhosis with uncontrolled acute variceal hemorrhage at endoscopy or who have successfully undergone endoscopic variceal ligation (EVL) but who rebleed at any time during admission (after endoscopy).[73] In addition, select patients with CTP Class C cirrhosis or CTP B with active bleeding at endoscopy are at highest risk for rebleeding and may benefit from early or pre-emptive TIPS within 72 hours of admission to improve survival (Supplemental Discussion)[2, 3, 96–101]

Q2. When should TIPS be used in the management of bleeding gastric fundal varices (GV)?: Variceal obliteration/embolization with or without TIPS should be considered for bleeding GV if unable to be managed endoscopically (Figure 2). TIPS combined with variceal obliteration may be associated with a decrease in rebleeding rates,[102–104] particularly when the pre-treatment PSG is less than 12 mmHg. The most appropriate management for bleeding from GV will depend on the vascular anatomy of the portal venous system and center expertise (Supplemental Discussion).[94]

Q3. What are the procedural considerations in TIPS creation for variceal hemorrhage?: The main procedural factors to consider are the target PSG, the optimal shunt diameter and whether or not to perform concurrent variceal embolization. When placing a TIPS for variceal hemorrhage, the risk of rebleeding is decreased by obtaining an absolute PSG < 12 mmHg or a relative reduction in the PSG of at least 50–60% from the pre-TIPS gradient.[10, 63, 105–107] These thresholds are best studied in bleeding from esophageal varices as GV and other ectopic varices may bleed at a lower PSG.[108] Studies using shunt diameter as a predictor of rebleeding rates have shown mixed results.[10, 31, 45]

Concurrent embolization at the time of TIPS creation decreases the risk of rebleeding in variceal hemorrhage.[109–114] There is currently insufficient data to show superiority of a specific embolic agent (see Supplemental Discussion).

Q4. How should patients be monitored after TIPS creation for variceal hemorrhage?: Imaging surveillance with Doppler ultrasonography post-TIPS for variceal hemorrhage is recommended, because TIPS stenosis/occlusion can lead to recurrent variceal hemorrhage. The optimal frequency of surveillance is not known, yet typically is performed 1–6 months post-TIPS initially, and then every 6–12 months thereafter. If TIPS stenosis/occlusion is suspected based on imaging or recurrent symptomatic portal hypertension (e.g., ascites, variceal bleeding), a TIPS venogram is indicated with consideration for TIPS revision. Non-selective beta blockade can reduce the PSG even after TIPS[115] and may be considered as an adjunctive treatment.

Novel Indications for TIPS

Q1. Does preoperative TIPS creation in patients with portal hypertension improve perioperative outcomes following non-transplant abdominal surgery?: Use of prophylactic TIPS to prevent bleeding complications or improve survival after elective non-liver transplant surgery is not recommended. Specific patient and surgical factors may warrant TIPS creation in individual cases (Table S4).[116, 117] Theoretical benefits of portal decompression prior to abdominal, non-liver transplant surgery (e.g., ascites control) must be weighed against the potential risks of TIPS in the preoperative setting (e.g., overt HE, liver insufficiency).

Q2. Does TIPS creation in patients with cirrhosis and portal vein obstruction facilitate listing for LT and/or improve outcomes after LT?: The specific degree of portal vein obstruction resulting in exclusion from LT candidacy varies by center. While partially occlusive PVT can be easily extracted at surgery, this is not the case when complete obliteration of the lumen has occurred, particularly when surrounded by venous cavernoma. Increased case complexity and inferior outcomes are reported for LT in patients with extensive chronic PVT.[118] Successful recanalization of the main portal vein using a transhepatic and trans-splenic approach followed by TIPS creation in order to re-establish a patent main portal vein has been reported in a single center case series without a control population.[74]

Q3. Does TIPS creation prevent or reduce portal hypertensive complications in patients with non-cirrhotic portal hypertension due to extrahepatic portal vein obstruction?: Acute or chronic extrahepatic PVT are associated with significant morbidity and may require urgent decompression. In general, TIPS creation is technically feasible and effective in reducing portal hypertension in patients with PVT, especially in patients with extensive PVT and bowel ischemia (Table S4).[119, 120] There are a lack of studies comparing revascularization with or without TIPS creation to anticoagulation alone in patients with PVT (Supplemental Discussion).

Q4. Does TIPS creation in patients with idiopathic non-cirrhotic portal hypertension (INCPH) and without extrahepatic portal vein obstruction prevent or reduce portal hypertensive complications?: Limited series evaluating outcomes after TIPS creation in patients with INCPH, including one case control series with a comparator group of patients with cirrhotic portal hypertension, have demonstrated similar technical outcomes and control of portal hypertensive complications compared with patients with cirrhotic portal hypertension. It is unclear whether patients with INCPH have lower rates of overt hepatic encephalopathy and mortality compared with patients with cirrhotic portal hypertension (Table S4).[121–123]

Q5. Does TIPS creation improve outcomes in patients with Budd-Chiari Syndrome (BCS)?: In patients with BCS who remain symptomatic or without improving liver function despite medical therapy and who are not candidates for percutaneous revascularization of the hepatic venous outflow tract, creation of a percutaneous portosystemic shunt, either TIPS or direct intrahepatic portosystemic shunt (DIPS), should be strongly considered.[124] TIPS creation is technically successful in 84–100% of BCS cases,[125–130] controls portal hypertensive complications and is associated with good survival (72% overall and TFS).[125–129, 131, 132] Importantly, venoplasty with or without stenting should not preclude subsequent creation of a percutaneous portosystemic shunt in patients who remain symptomatic after initial revascularization (Supplemental Discussion). Finally, in patients with BCS, re-intervention may be needed to maintain or restore TIPS patency as primary patency rates with ePTFE-covered TIPS for BCS varies widely (5-year primary patency, 45–91%).[133, 134]

Cardiopulmonary, Renal and Neurologic Considerations in TIPS

Cardiopulmonary Considerations in TIPS—Cardiac decompensation post-TIPS varies from 1% in one week[135] to 20% in one year.[136] The underlying pathophysiology is multifactorial, involving pre-TIPS subclinical cardiac dysfunction (e.g., cirrhotic cardiomyopathy; CCM) and post-TIPS worsening in hyperdynamic circulation given increased preload and cardiac output (CO) with concomitantly decreased systemic vascular resistance.[137] Recommendations for cardiopulmonary considerations in TIPS are summarized in Table 3.

Q1. What cardiopulmonary testing is indicated prior to elective TIPS?: Cardiac risk assessment prior to TIPS is essential and should incorporate contemporary echocardiographic measurements for left ventricular (LV) and right ventricular (RV) function, with particular attention to the recently updated criteria for CCM (Table S5).[138, 139] Electrocardiogram (ECG) is warranted for evaluation of arrhythmia if tachycardia or bradycardia is noted on pre-procedure assessment.

Q2. Does CCM or diastolic dysfunction confer a risk for post-TIPS heart failure (HF)?: In patients undergoing TIPS creation, evaluating the presence and severity of systolic and/or diastolic dysfunction is an important part of risk stratification for adverse cardiac outcomes. There is limited data regarding TIPS outcomes in patients with LV ejection fraction (LVEF) < 50%. Impaired global longitudinal strain, reflective of subclinical systolic

dysfunction, is associated with poor post-TIPS survival.[140] Older studies have shown conflicting results about the impact of diastolic dysfunction on TIPS outcomes.[141, 142] However, the new diastolic dysfunction criteria[138] have been found to be predictive of increased mortality and cardiac events post-TIPS.[136]

Q3. Can TIPS be safely performed in patients with moderate or severe portopulmonary hypertension (POPH) (i.e., mean Pulmonary Artery Pressure > 35 mmHg, Pulmonary Vascular Resistance > 3 wood units)?: TIPS creation, if pulmonary hypertension is present, has the potential to precipitate right-sided HF and/or be ineffective at lowering portal pressure.[143, 144] There are no published data regarding TIPS in patients with POPH. TIPS acutely increases right atrial pressure (RAP) by 3–5 mmHg in those without POPH.[145–148] One study specifically demonstrated that RAP pre- and post-TIPS of > 14.5 mmHg and > 21.5 mmHg, respectively, was associated with increased post-TIPS mortality, though whether these patients had POPH specifically is unknown.[145] Thus, significant caution should be exercised when considering TIPS in patients with moderate/severe POPH on treatment or elevated RAP.

Q4. Can severe tricuspid regurgitation (TR) be prohibitive of TIPS creation?: TR usually reflects volume overload and/or pressure overload from conditions resulting in pulmonary hypertension in patients with a normal tricuspid valve. Careful assessment of TR etiology is necessary to determine if TIPS risk is prohibitive. When volume overload is suspected, volume optimization is warranted prior to reassessment. In some cases, chronic volume overload results in RV dysfunction and tricuspid annular dilatation, leading to persistent moderate to severe functional TR, which can be prohibitive of TIPS.

Q5. Can TIPS treat HPS?: Given the risks associated with TIPS creation, current evidence does not support routine use of TIPS for treatment of HPS alone (Supplemental Discussion).[149–151]

Q6. Does stent size affect risk for post-TIPS HF in high cardiac risk patients?: A recent study showed that an 8 mm stent was associated with better survival than a 10 mm stent; however, cardiac deaths were not specified.[152] Generally, larger stent size leads to higher cardiac venous return resulting in potentially higher decompensation risk. Thus, in patients with systolic and/or diastolic dysfunction or mild POPH who are undergoing TIPS, the desired PSG must be balanced with the potential risk for worsening cardiac dysfunction.

Q7. Is there a need for post-TIPS echocardiographic surveillance?: There are prompt incremental changes post-TIPS involving CO, cardiac index, RAP as well as LV and RV end diastolic and end systolic volumes.[137, 153–155] These changes peak at 3-months post-TIPS, and tend to resolve within 6–12 months post-TIPS in some, but not all, patients.[153, 156, 157] Surveillance in high-risk patients (e.g., prior HF, elevated RAP, LV dysfunction) may be beneficial to guide pre-emptive interventions (e.g., initiation of HF guideline-directed anti-remodeling therapy).

Renal Considerations in TIPS—The true incidence of acute kidney injury (AKI) or disease (AKD) following TIPS and potential benefit in persons with chronic kidney

disease (CKD) is unknown given a wide spectrum of indication and urgency for TIPS, the heterogeneity in measurement of kidney function (e.g., measured versus estimated glomerular filtration rate (GFR), serum creatinine (sCr)), definitions of AKI or CKD, and patient selection. We suggest considering the primary indication, individualized risk factors, and physiologic goals of the intervention when considering TIPS creation in patients with kidney dysfunction (Table 3).

Q1. What is the best marker to assess kidney function before or after TIPS?: Kidney function should be assessed prior to TIPS either through measurement of sCr or GFR (estimated or measured).[75, 158–162] A change in GFR may best capture changes in kidney function. The limitations of sCr in cirrhosis are well documented (Supplemental Discussion).[163]

Q2. Is there an absolute cutoff for kidney function for which TIPS is contraindicated?: Kidney function (measured by sCr) is included in several predictive models of outcomes after TIPS.[17–22, 164, 165] Elevated sCr is a risk factor for post-TIPS HE.[166] However, there is insufficient evidence to recommend an absolute sCr, CKD stage, or presence/absence of renal replacement therapy where TIPS creation is contraindicated.

Q3. What can be done to prevent kidney complications after TIPS?: Data regarding kidney protection strategies surrounding TIPS are lacking (Supplemental Discussion). Maintenance of intravascular volume with albumin infusion in the setting of LVP if performed with TIPS creation may help prevent kidney dysfunction secondary to circulatory impairment.[1, 167–169] Judicious use of iodinated contrast agents may minimize risk of contrast nephropathy. Development of AKI and progression to AKD and CKD may not be immediately recognized after TIPS. Recognition-Action-Result framework for secondary prevention and follow up based on AKI/AKD severity as outlined by the Acute Disease Quality Initiative may identify those at highest risk for progression and allow for early mitigation.[170]

Q4. What is the role of TIPS for hepatorenal syndrome (HRS)?: Data on TIPS in patients with HRS is limited.[171] The quality of available studies is low due to small sample size and significant heterogeneity (Supplemental Discussion). Larger randomized trials applying the most recent definition of HRS-AKI are needed before TIPS can be recommended for this indication.

HE and TIPS

Q1. What is the risk of overt HE after TIPS and what patient factors contribute to its development?: Incidence of overt HE is estimated between 25%−50% (Supplemental Discussion).[3, 4, 97, 98, 172–174] Notably, most studies excluded patients with a history of recurrent overt HE. Patient factors for development of post-TIPS overt HE includes prior HE, advanced liver dysfunction (CTP Class C, MELD score >18),[4, 97, 98, 175, 176] older age,[166] elevated creatinine,[166] hyponatremia and sarcopenia.[177, 178]

Q2. What social factors should be considered a contraindication to elective TIPS as it relates to overt HE?: Patients and family members should be counseled about the manifestations of overt HE.[179, 180] In patients who have poor social support, and therefore may be at greater risk of harm due to post-TIPS HE, we favor non-TIPS management options. This does not apply to urgent TIPS for variceal bleeding where survival and prevention of rebleeding remains the priority.

Q3. What is the role for formal evaluation for covert or minimal HE prior to elective TIPS?: The diagnosis of covert HE has been associated with a greater risk of post-TIPS HE,[173, 181, 182] and impaired health related quality of life (Supplemental Discussion).[183–185] In patients being considered for elective TIPS, a diagnosis of covert HE should guide discussion of the pros and cons of TIPS creation with patients, family members and clinical teams.

Q4. What TIPS stent diameter should be considered with regards to limiting post-TIPS HE?: Smaller shunts (e.g., 8mm vs. 10mm) may decrease overt HE, but may also be less effective for portal decompression (Supplemental Discussion).[10, 31, 186–188]

Q5a. Is there a role for collateral embolization at the time of TIPS to prevent HE?: In patients undergoing elective TIPS for ascites/HH, embolization of spontaneous portosystemic shunts (SPSS) > 6mm may be considered in order to reduce the risk of post-TIPS HE. Large SPSS have been associated with increased risk of overt HE and mortality in patients with cirrhosis (Supplemental Discussion).[189–192]

Q5b. Is there a role for TIPS with shunt embolization in the management of refractory HE related to presumed portosystemic shunting?: In select patients with large (> 6mm) SPSS and refractory HE, we recommend that shunt embolization be considered. In those who develop portal hypertensive-associated complications after shunt embolization, small caliber TIPS creation could be considered. The prevalence of SPSS approaches 70% among patients with cirrhosis and with persistent overt HE.[193] Evidence on retrograde transvenous obliteration or embolization of SPSS for treatment of overt HE is limited to small series but with success rates of 59–100% free of overt HE.[194–199]

Q6a. What is the role for medical prophylaxis to prevent HE after TIPS?: RCTs using uncovered TIPS stents showed no difference in the incidence of overt HE in a head to head comparison of lactulose, rifaximin, and placebo.[193] A recent RCT with a larger sample size, however, demonstrated significantly reduced incidence of first episode of HE post-TIPS (44.2% vs 59.1%, $p = 0.05$) in patients without a history of overt HE receiving rifaximin versus placebo as prophylaxis prior to TIPS.[200]

Q6b. What is the recommended medical therapy to treat overt HE after TIPS?: Lactulose is recommended for treatment of the first episode of overt HE followed by the addition of rifaximin if there is a subsequent episode of overt HE.[180]

Q6c. What is the role for TIPS stent reduction/occlusion for treatment of persistent or refractory HE?: Severe refractory overt HE that requires shunt reduction occurs in

approximately 8% of TIPS recipients.[166] There is no consensus definition of refractory overt HE; however, shunt reduction should be considered when there is persistent HE refractory to medical therapy or at least three or more episodes of unprovoked HE requiring hospitalization in the past 3 months.[201] Shunt reduction is effective at reducing post-TIPS HE; however, recurrence of portal hypertensive complications are likely.[166, 202–207]

CONCLUSIONS AND FUTURE DIRECTIONS

Tremendous progress has been made in the application of TIPS creation for the management of portal hypertension. With such a rapid evolution of knowledge, practice-based recommendations must also evolve. These North American consensus recommendations reflect multi-disciplinary discussion required around TIPS creation, including consideration of alternatives and best practices to minimize short and long-term complications and maximize benefit. There are multiple knowledge gaps and areas in need of future research regarding the clinical effectiveness and efficacy of TIPS across indications for use (Table 4). Of particular relevance is the notion of personalized TIPS, in which the benefits and risks of TIPS are tailored to the specific needs of the patient. With the advent of new controlled expansion stents, personalized TIPS is the future of precision medicine for the management of portal hypertension. As the field continues to develop and the research questions identified during this process are answered, the recommendations presented herein will evolve in the context of new data.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations (alphabetically)

AKD	Acute Kidney Disease
AKI	Acute kidney injury
ALF	Acute liver failure
ALTA	Advancing Liver Therapeutic Approaches

ACC	American College of Cardiology
AHA	American Heart Association
BCS	Budd-Chiari Syndrome
CCM	Cirrhotic cardiomyopathy
CKD	Chronic kidney disease
CO	Cardiac output
CTP	Child-Turcotte-Pugh
DIPS	Direct intrahepatic portosystemic shunt
ECG	Electrocardiogram
ePTFE	Expanded polytetrafluoroethylene
EVL	Endoscopic variceal ligation
GFR	Glomerular filtration rate
GV	Gastric fundal varices
HE	Hepatic encephalopathy
HF	Heart failure
HH	Hepatic hydrothorax
HPS	Hepatopulmonary syndrome
HRS	Hepatorenal syndrome
INCPH	idiopathic non-cirrhotic portal hypertension
INR	Internationalized normal ratio
IR	Interventional radiology
IVC	Inferior vena cava
LT	Liver transplantation
LV	Left ventricular
LVEF	Left ventricular ejection fraction
LVP	Large volume paracentesis
MELD	Model for End-Stage Liver Disease
POPH	Portopulmonary hypertension
PSG	Portosystemic gradient

PVT	Portal vein thrombosis
RA	Refractory ascites
RAP	Right atrial pressure
RCTs	Randomized controlled trials
RV	Right ventricular
sCr	Serum creatinine
SPSS	Spontaneous portosystemic shunts
TFS	Transplant-free survival
TIPS	Transjugular intrahepatic portosystemic shunt
TR	Tricuspid regurgitation
VHD	Valvular Heart Disease

REFERENCES

1. Runyon BA, Aasld. Introduction to the revised American Association for the Study of Liver Diseases Practice Guideline management of adult patients with ascites due to cirrhosis 2012. Hepatology 2013;57:1651–3. [PubMed: 23463403]
2. Lv Y, Zuo L, Zhu X, et al. Identifying optimal candidates for early TIPS among patients with cirrhosis and acute variceal bleeding: a multicentre observational study. Gut 2019;68:1297–1310. [PubMed: 30415233]
3. Garcia-Pagan JC, Caca K, Bureau C, et al. Early use of TIPS in patients with cirrhosis and variceal bleeding. N Engl J Med 2010;362:2370–9. [PubMed: 20573925]
4. Bureau C, Thabut D, Oberti F, et al. Transjugular Intrahepatic Portosystemic Shunts With Covered Stents Increase Transplant-Free Survival of Patients With Cirrhosis and Recurrent Ascites. Gastroenterology 2017;152:157–163. [PubMed: 27663604]
5. Dhanasekaran R, West JK, Gonzales PC, et al. Transjugular intrahepatic portosystemic shunt for symptomatic refractory hepatic hydrothorax in patients with cirrhosis. Am J Gastroenterol 2010;105:635–41. [PubMed: 19904245]
6. Song T, Rossle M, He F, et al. Transjugular intrahepatic portosystemic shunt for hepatorenal syndrome: A systematic review and meta-analysis. Dig Liver Dis 2018;50:323–330. [PubMed: 29422242]
7. Mezawa S, Homma H, Ohta H, et al. Effect of transjugular intrahepatic portosystemic shunt formation on portal hypertensive gastropathy and gastric circulation. Am J Gastroenterol 2001;96:1155–9. [PubMed: 11316163]
8. Trivedi PS, Rochon PJ, Durham JD, et al. National Trends and Outcomes of Transjugular Intrahepatic Portosystemic Shunt Creation Using the Nationwide Inpatient Sample. J Vasc Interv Radiol 2016;27:838–45. [PubMed: 26965361]
9. Busk TM, Bendtsen F, Poulsen JH, et al. Transjugular intrahepatic portosystemic shunt: impact on systemic hemodynamics and renal and cardiac function in patients with cirrhosis. Am J Physiol Gastrointest Liver Physiol 2018;314:G275–G286. [PubMed: 29074483]
10. Miraglia R, Maruzzelli L, Di Piazza A, et al. Transjugular Intrahepatic Portosystemic Shunt Using the New Gore Viatorr Controlled Expansion Endoprosthesis: Prospective, Single-Center, Preliminary Experience. Cardiovasc Intervent Radiol 2019;42:78–86. [PubMed: 30073477]
11. RiChard J, Thornburg B. New Techniques and Devices in Transjugular Intrahepatic Portosystemic Shunt Placement. Semin Intervent Radiol 2018;35:206–214. [PubMed: 30087525]

12. Brouwers MC, Kho ME, Browman GP, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. Canadian Medical Association Journal 2010;182:E839–E842. [PubMed: 20603348]
13. Dalkey N, Helmer O. An Experimental Application of the DELPHI Method to the Use of Experts. Management Science 1963;9:458–467.
14. Howick J, Chalmers I, Glasziou P, et al. The 2011 Oxford CEBM Levels of Evidence. University of Oxford.: Oxford Centre for Evidence-Based Medicine, 2011.
15. Boyer TD, Haskal ZJ, American Association for the Study of Liver D. The Role of Transjugular Intrahepatic Portosystemic Shunt (TIPS) in the Management of Portal Hypertension: update 2009. Hepatology 2010;51:306. [PubMed: 19902484]
16. Dariushnia SR, Haskal ZJ, Midia M, et al. Quality Improvement Guidelines for Transjugular Intrahepatic Portosystemic Shunts. J Vasc Interv Radiol 2016;27:1–7. [PubMed: 26614596]
17. Gaba RC, Couture PM, Bui JT, et al. Prognostic capability of different liver disease scoring systems for prediction of early mortality after transjugular intrahepatic portosystemic shunt creation. J Vasc Interv Radiol 2013;24:411–20, 420.e1–4; quiz 421. [PubMed: 23312989]
18. Kim WR, Biggins SW, Kremers WK, et al. Hyponatremia and mortality among patients on the liver-transplant waiting list. N Engl J Med 2008;359:1018–26. [PubMed: 18768945]
19. Moreau R, Jalan R, Gines P, et al. Acute-on-chronic liver failure is a distinct syndrome that develops in patients with acute decompensation of cirrhosis. Gastroenterology 2013;144:1426–37, 1437 e1–9. [PubMed: 23474284]
20. Pugh RN, Murray-Lyon IM, Dawson JL, et al. Transection of the oesophagus for bleeding oesophageal varices. Br J Surg 1973;60:646–9. [PubMed: 4541913]
21. Schepke M, Roth F, Fimmers R, et al. Comparison of MELD, Child-Pugh, and emory model for the prediction of survival in patients undergoing transjugular intrahepatic portosystemic shunting. American Journal of Gastroenterology 2003;98:1167–1174. [PubMed: 12809844]
22. Wiesner R, Edwards E, Freeman R, et al. Model for end-stage liver disease (MELD) and allocation of donor livers. Gastroenterology 2003;124:91–96. [PubMed: 12512033]
23. Al Sibae MR, Cappell MS. Accuracy of MELD Scores in Predicting Mortality in Decompensated Cirrhosis from Variceal Bleeding, Hepatorenal Syndrome, Alcoholic Hepatitis, or Acute Liver Failure As Well As Mortality After Non-transplant Surgery or TIPS. Digestive Diseases and Sciences 2011;56:977–987. [PubMed: 20844956]
24. Alessandria C, Gaia S, Marzano A, et al. Application of the model for end-stage liver disease score for transjugular intrahepatic portosystemic shunt in cirrhotic patients with refractory ascites and renal impairment. Eur J Gastroenterol Hepatol 2004;16:607–12. [PubMed: 15167164]
25. Ascha M, Hanouneh M, M SA, et al. Transjugular Intrahepatic Porto-Systemic Shunt in Patients with Liver Cirrhosis and Model for End-Stage Liver Disease >/=15. Dig Dis Sci 2017;62:534–542. [PubMed: 27154510]
26. Allegretti AS, Frenk NE, Li DK, et al. Evaluation of model performance to predict survival after transjugular intrahepatic portosystemic shunt placement. PLoS One 2019;14:e0217442. [PubMed: 31120995]
27. Ferral H, Gamboa P, Postoak DW, et al. Survival after elective transjugular intrahepatic portosystemic shunt creation: prediction with model for end-stage liver disease score. Radiology 2004;231:231–6. [PubMed: 14990811]
28. Li Y, Wang F, Chen X, et al. Short outcome comparison of elderly patients versus nonelderly patients treated with transjugular intrahepatic portosystemic stent shunt: A propensity score matched cohort study. Medicine (Baltimore) 2017;96:e7551. [PubMed: 28723777]
29. Suraweera D, Jimenez M, Viramontes M, et al. Age-related Morbidity and Mortality After Transjugular Intrahepatic Portosystemic Shunts. J Clin Gastroenterol 2017;51:360–363. [PubMed: 27159421]
30. Trebicka J, Gu W, Ibáñez-Samaniego L, et al. Rebleeding and mortality risk are increased by ACLF but reduced by pre-emptive TIPS. Journal of Hepatology 2020;73:1082–1091. [PubMed: 32339602]

31. Wang Q, Lv Y, Bai M, et al. Eight millimetre covered TIPS does not compromise shunt function but reduces hepatic encephalopathy in preventing variceal rebleeding. J Hepatol 2017;67:508–516. [PubMed: 28506905]
32. Miraglia R, Maruzzelli L, Tuzzolino F, et al. Transjugular Intrahepatic Portosystemic Shunts in Patients with Cirrhosis with Refractory Ascites: Comparison of Clinical Outcomes by Using 8- and 10-mm PTFE-covered Stents. Radiology 2017;284:281–288. [PubMed: 28121521]
33. Rudnick MR, Goldfarb S, Wexler L, et al. Nephrotoxicity of ionic and nonionic contrast media in 1196 patients: a randomized trial. The Iohexol Cooperative Study. Kidney Int 1995;47:254–61. [PubMed: 7731155]
34. Cigarroa RG, Lange RA, Williams RH, et al. Dosing of contrast material to prevent contrast nephropathy in patients with renal disease. Am J Med 1989;86:649–52. [PubMed: 2729314]
35. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA Guideline for the Management of Heart Failure. Journal of the American College of Cardiology 2013;62:e147–e239. [PubMed: 23747642]
36. Otto CM, Nishimura RA, Bonow RO, et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation 2021;143:e72–e227. [PubMed: 33332150]
37. Martin P, DiMartini A, Feng S, et al. Evaluation for liver transplantation in adults: 2013 practice guideline by the American Association for the Study of Liver Diseases and the American Society of Transplantation. Hepatology 2014;59:1144–1165. [PubMed: 24716201]
38. Society of Interventional Radiology Standards of Practice Committee. American College of Radiology (ACR)-Society of Interventional Radiology (SIR)-Society for Pediatric Radiology (SPR) Practice Parameter for the Creation of a Transjugular Intrahepatic Portosystemic Shunt (TIPS) - ACR-SIR-SPR TIPS, 2017. available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/TIPS.pdf?la=en. Access date: October 23, 2020.
39. Angeloni S, Merli M, Salvatori FM, et al. Polytetrafluoroethylene-covered stent grafts for TIPS procedure: 1-year patency and clinical results. Am J Gastroenterol 2004;99:280–5. [PubMed: 15046218]
40. Barrio J, Ripoll C, Bañares R, et al. Comparison of transjugular intrahepatic portosystemic shunt dysfunction in PTFE-covered stent-grafts versus bare stents. Eur J Radiol 2005;55:120–4. [PubMed: 15950109]
41. Charon JP, Alaeddin FH, Pimpalwar SA, et al. Results of a retrospective multicenter trial of the Viatorr expanded polytetrafluoroethylene-covered stent-graft for transjugular intrahepatic portosystemic shunt creation. J Vasc Interv Radiol 2004;15:1219–30. [PubMed: 15525740]
42. Hausegger KA, Karnel F, Georgieva B, et al. Transjugular intrahepatic portosystemic shunt creation with the Viatorr expanded polytetrafluoroethylene-covered stent-graft. J Vasc Interv Radiol 2004;15:239–48. [PubMed: 15028808]
43. Otal P, Smayra T, Bureau C, et al. Preliminary results of a new expanded-polytetrafluoroethylene-covered stent-graft for transjugular intrahepatic portosystemic shunt procedures. AJR Am J Roentgenol 2002;178:141–7. [PubMed: 11756108]
44. Perarnau JM, Le Gouge A, Nicolas C, et al. Covered vs. uncovered stents for transjugular intrahepatic portosystemic shunt: a randomized controlled trial. J Hepatol 2014;60:962–8. [PubMed: 24480619]
45. Riggio O, Ridola L, Angeloni S, et al. Clinical efficacy of transjugular intrahepatic portosystemic shunt created with covered stents with different diameters: results of a randomized controlled trial. J Hepatol 2010;53:267–72. [PubMed: 20537753]
46. Tripathi D, Ferguson J, Barkell H, et al. Improved clinical outcome with transjugular intrahepatic portosystemic stent-shunt utilizing polytetrafluoroethylene-covered stents. Eur J Gastroenterol Hepatol 2006;18:225–32. [PubMed: 16462534]
47. Saad WE, Darwish WM, Davies MG, et al. Stent-grafts for transjugular intrahepatic portosystemic shunt creation: specialized TIPS stent-graft versus generic stent-graft/bare stent combination. J Vasc Interv Radiol 2010;21:1512–20. [PubMed: 20801686]

48. Pieper CC, Jansen C, Meyer C, et al. Prospective Evaluation of Passive Expansion of Partially Dilated Transjugular Intrahepatic Portosystemic Shunt Stent Grafts-A Three-Dimensional Sonography Study. J Vasc Interv Radiol 2017;28:117–125. [PubMed: 27553918]
49. Pieper CC, Sprinkart AM, Nadal J, et al. Postinterventional passive expansion of partially dilated transjugular intrahepatic portosystemic shunt stents. J Vasc Interv Radiol 2015;26:388–94. [PubMed: 25541420]
50. Northup PG, Garcia-Pagan JC, Garcia-Tsao G, et al. Vascular Liver Disorders, Portal Vein Thrombosis, and Procedural Bleeding in Patients With Liver Disease: 2020 Practice Guidance by the American Association for the Study of Liver Diseases. Hepatology 2020;n/a.
51. De Pietri L, Bianchini M, Montalti R, et al. Thrombelastography-guided blood product use before invasive procedures in cirrhosis with severe coagulopathy: A randomized, controlled trial. Hepatology 2016;63:566–73. [PubMed: 26340411]
52. Napolitano G, Iacobellis A, Merla A, et al. Bleeding after invasive procedures is rare and unpredicted by platelet counts in cirrhotic patients with thrombocytopenia. Eur J Intern Med 2017;38:79–82. [PubMed: 27989373]
53. Tripodi A, Mannucci PM. The coagulopathy of chronic liver disease. N Engl J Med 2011;365:147–56. [PubMed: 21751907]
54. Tripodi A, Salerno F, Chantarangkul V, et al. Evidence of normal thrombin generation in cirrhosis despite abnormal conventional coagulation tests. Hepatology 2005;41:553–8. [PubMed: 15726661]
55. Segal JB, Dzik WH, Transfusion Medicine/Hemostasis Clinical Trials N. Paucity of studies to support that abnormal coagulation test results predict bleeding in the setting of invasive procedures: an evidence-based review. Transfusion 2005;45:1413–25. [PubMed: 16131373]
56. Navaratnam AM, Grant M, Banach DB. Endotipsitis: A case report with a literature review on an emerging prosthetic related infection. World journal of hepatology 2015;7:710–716. [PubMed: 25866608]
57. Mizrahi M, Adar T, Shouval D, et al. Endotipsitis-persistent infection of transjugular intrahepatic portosystemic shunt: pathogenesis, clinical features and management. Liver Int 2010;30:175–83. [PubMed: 19929905]
58. Kao SD, Morshedi MM, Narsinh KH, et al. Intravascular Ultrasound in the Creation of Transhepatic Portosystemic Shunts Reduces Needle Passes, Radiation Dose, and Procedure Time: A Retrospective Study of a Single-Institution Experience. J Vasc Interv Radiol 2016;27:1148–53. [PubMed: 27052948]
59. Pillai AK, Andring B, Faulconer N, et al. Utility of Intravascular US-Guided Portal Vein Access during Transjugular Intrahepatic Portosystemic Shunt Creation: Retrospective Comparison with Conventional Technique in 109 Patients. J Vasc Interv Radiol 2016;27:1154–9. [PubMed: 27363298]
60. Ripoll C, Groszmann R, Garcia-Tsao G, et al. Hepatic venous pressure gradient predicts clinical decompensation in patients with compensated cirrhosis. Gastroenterology 2007;133:481–8. [PubMed: 17681169]
61. D'Amico G, Garcia-Tsao G, Pagliaro L. Natural history and prognostic indicators of survival in cirrhosis: a systematic review of 118 studies. J Hepatol 2006;44:217–31. [PubMed: 16298014]
62. Silva-Junior G, Turon F, Baiges A, et al. Timing Affects Measurement of Portal Pressure Gradient After Placement of Transjugular Intrahepatic Portosystemic Shunts in Patients With Portal Hypertension. Gastroenterology 2017;152:1358–1365. [PubMed: 28130066]
63. Casado M, Bosch J, Garcia-Pagan JC, et al. Clinical events after transjugular intrahepatic portosystemic shunt: correlation with hemodynamic findings. Gastroenterology 1998;114:1296–303. [PubMed: 9609767]
64. La Mura V, Abraldes JG, Berzigotti A, et al. Right atrial pressure is not adequate to calculate portal pressure gradient in cirrhosis: a clinical-hemodynamic correlation study. Hepatology 2010;51:2108–16. [PubMed: 20512998]
65. Castellani P, Campan P, Bernardini D, et al. Is transjugular intrahepatic portosystemic shunt really deleterious for liver transplantation issue? A monocentric study on 86 liver transplanted patients. Transplant Proc 2001;33:3468–9. [PubMed: 11750484]

66. Menegaux F, Baker E, Keeffe EB, et al. Impact of transjugular intrahepatic portosystemic shunt on orthotopic liver transplantation. World J Surg 1994;18:866–70; discussion 870–1. [PubMed: 7846910]

67. Matsushima H, Fujiki M, Sasaki K, et al. Can pretransplant TIPS be harmful in liver transplantation? A propensity score matching analysis. Surgery 2020;168:33–39. [PubMed: 32268937]

68. Millis JM, Martin P, Gomes A, et al. Transjugular intrahepatic portosystemic shunts: impact on liver transplantation. Liver Transpl Surg 1995;1:229–33. [PubMed: 9346571]

69. Antonini M, Della Rocca G, Pugliese F, et al. Hemodynamic and metabolic effects of transjugular intrahepatic portosystemic shunt (TIPS) during anesthesia for orthotopic liver transplantation. Transpl Int 1996;9:403–7. [PubMed: 8819278]

70. Engstrom BI, Horvath JJ, Suhocki PV, et al. Covered transjugular intrahepatic portosystemic shunts: accuracy of ultrasound in detecting shunt malfunction. AJR Am J Roentgenol 2013;200:904–8. [PubMed: 23521468]

71. Owen JM, Gaba RC. Transjugular Intrahepatic Portosystemic Shunt Dysfunction: Concordance of Clinical Findings, Doppler Ultrasound Examination, and Shunt Venography. J Clin Imaging Sci 2016;6:29. [PubMed: 27563495]

72. Manatsathit W, Samant H, Panjawatanan P, et al. Performance of ultrasound for detection of transjugular intrahepatic portosystemic shunt dysfunction: a meta-analysis. Abdom Radiol (NY) 2019;44:2392–2402. [PubMed: 30905044]

73. Garcia-Tsao G, Abraldes J, Berzigotti A, et al. Portal Hypertensive Bleeding in Cirrhosis: Risk Stratification, Diagnosis and Management - 2016 Practice Guidance by the American Association for the Study of Liver Diseases. Hepatology 2017;65:310–335. [PubMed: 27786365]

74. Thornburg B, Desai K, Hickey R, et al. Pretransplantation Portal Vein Recanalization and Transjugular Intrahepatic Portosystemic Shunt Creation for Chronic Portal Vein Thrombosis: Final Analysis of a 61-Patient Cohort. J Vasc Interv Radiol 2017;28:1714–1721.e2. [PubMed: 29050854]

75. Lebrec D, Giuily N, Hadengue A, et al. Transjugular intrahepatic portosystemic shunts: comparison with paracentesis in patients with cirrhosis and refractory ascites: a randomized trial. French Group of Clinicians and a Group of Biologists. J Hepatol 1996;25:135–44. [PubMed: 8878773]

76. Rössle M, Ochs A, Gülberg V, et al. A comparison of paracentesis and transjugular intrahepatic portosystemic shunting in patients with ascites. N Engl J Med 2000;342:1701–7. [PubMed: 10841872]

77. Ginès P, Uriz J, Calahorra B, et al. Transjugular intrahepatic portosystemic shunting versus paracentesis plus albumin for refractory ascites in cirrhosis. Gastroenterology 2002;123:1839–47. [PubMed: 12454841]

78. Sanyal AJ, Genning C, Reddy KR, et al. The North American Study for the Treatment of Refractory Ascites. Gastroenterology 2003;124:634–41. [PubMed: 12612902]

79. Salerno F, Merli M, Riggio O, et al. Randomized controlled study of TIPS versus paracentesis plus albumin in cirrhosis with severe ascites. Hepatology 2004;40:629–35. [PubMed: 15349901]

80. Narahara Y, Kanazawa H, Fukuda T, et al. Transjugular intrahepatic portosystemic shunt versus paracentesis plus albumin in patients with refractory ascites who have good hepatic and renal function: a prospective randomized trial. J Gastroenterol 2011;46:78–85. [PubMed: 20632194]

81. Deltenre P, Mathurin P, Dharancy S, et al. Transjugular intrahepatic portosystemic shunt in refractory ascites: a meta-analysis. Liver Int 2005;25:349–56. [PubMed: 15780061]

82. D'Amico G, Luca A, Morabito A, et al. Uncovered transjugular intrahepatic portosystemic shunt for refractory ascites: a meta-analysis. Gastroenterology 2005;129:1282–93. [PubMed: 16230081]

83. Albillos A, Bañares R, González M, et al. A meta-analysis of transjugular intrahepatic portosystemic shunt versus paracentesis for refractory ascites. J Hepatol 2005;43:990–6. [PubMed: 16139922]

84. Salerno F, Cammà C, Enea M, et al. Transjugular intrahepatic portosystemic shunt for refractory ascites: a meta-analysis of individual patient data. Gastroenterology 2007;133:825–34. [PubMed: 17678653]

85. Bai M, Qi XS, Yang ZP, et al. TIPS improves liver transplantation-free survival in cirrhotic patients with refractory ascites: an updated meta-analysis. World J Gastroenterol 2014;20:2704–14. [PubMed: 24627607]

86. Saab S, Nieto JM, Lewis SK, et al. TIPS versus paracentesis for cirrhotic patients with refractory ascites. Cochrane Database Syst Rev 2006:Cd004889. [PubMed: 17054221]

87. Spencer EB, Cohen DT, Darcy MD. Safety and efficacy of transjugular intrahepatic portosystemic shunt creation for the treatment of hepatic hydrothorax. J Vasc Interv Radiol 2002;13:385–90. [PubMed: 11932369]

88. Young S, Bermudez J, Zhang L, et al. Transjugular intrahepatic portosystemic shunt (TIPS) placement: A comparison of outcomes between patients with hepatic hydrothorax and patients with refractory ascites. Diagn Interv Imaging 2019;100:303–308. [PubMed: 30522911]

89. Siegerstetter V, Deibert P, Ochs A, et al. Treatment of refractory hepatic hydrothorax with transjugular intrahepatic portosystemic shunt: long-term results in 40 patients. Eur J Gastroenterol Hepatol 2001;13:529–34. [PubMed: 11396532]

90. Wilputte JY, Goffette P, Zech F, et al. The outcome after transjugular intrahepatic portosystemic shunt (TIPS) for hepatic hydrothorax is closely related to liver dysfunction: a long-term study in 28 patients. Acta Gastroenterol Belg 2007;70:6–10. [PubMed: 17619531]

91. Gordon FD, Anastopoulos HT, Crenshaw W, et al. The successful treatment of symptomatic, refractory hepatic hydrothorax with transjugular intrahepatic portosystemic shunt. Hepatology 1997;25:1366–9. [PubMed: 9185754]

92. Saad WE, Darwish WM, Davies MG, et al. Transjugular intrahepatic portosystemic shunts in liver transplant recipients for management of refractory ascites: clinical outcome. J Vasc Interv Radiol 2010;21:218–23. [PubMed: 20123207]

93. King A, Masterton G, Gunson B, et al. A case-controlled study of the safety and efficacy of transjugular intrahepatic portosystemic shunts after liver transplantation. Liver Transpl 2011;17:771–8. [PubMed: 21714062]

94. Saad WE, Darwish WM, Davies MG, et al. Transjugular intrahepatic portosystemic shunts in liver transplant recipients: technical analysis and clinical outcome. AJR Am J Roentgenol 2013;200:210–8. [PubMed: 23255764]

95. Wong F, Sniderman K, Liu P, et al. The mechanism of the initial natriuresis after transjugular intrahepatic portosystemic shunt. Gastroenterology 1997;112:899–907. [PubMed: 9041252]

96. Monescillo A, Martinez-Lagares F, Ruiz-del-Arbol L, et al. Influence of portal hypertension and its early decompression by TIPS placement on the outcome of variceal bleeding. Hepatology 2004;40:793–801. [PubMed: 15382120]

97. Lv Y, Yang Z, Liu L, et al. Early TIPS with covered stents versus standard treatment for acute variceal bleeding in patients with advanced cirrhosis: a randomised controlled trial. Lancet Gastroenterol Hepatol 2019;4:587–598. [PubMed: 31153882]

98. Garcia-Pagan JC, Di PM, Caca K, et al. Use of early-TIPS for high-risk variceal bleeding: results of a post-RCT surveillance study. J. Hepatol 2013;58:45–50. [PubMed: 22940408]

99. Rudler M, Cluzel P, Corvec TL, et al. Early-TIPSS placement prevents rebleeding in high-risk patients with variceal bleeding, without improving survival. Aliment. Pharmacol. Ther 2014;40:1074–1080. [PubMed: 25230051]

100. Bucsics T, Schoder M, Goeschl N, et al. Re-bleeding rates and survival after early transjugular intrahepatic portosystemic shunt (TIPS) in clinical practice. Dig Liver Dis 2017;49:1360–1367. [PubMed: 28869158]

101. Hernández-Gea V, Procopet B, Giráldez Á, et al. Preemptive-TIPS Improves Outcome in High-Risk Variceal Bleeding: An Observational Study. Hepatology 2019;69:282–293. [PubMed: 30014519]

102. Lakhoo J, Bui JT, Lokken RP, et al. Transjugular Intrahepatic Portosystemic Shunt Creation and Variceal Coil or Plug Embolization Ineffectively Attain Gastric Variceal Decompression or Occlusion: Results of a 26-Patient Retrospective Study. J Vasc Interv Radiol 2016;27:1001–11. [PubMed: 27106732]

103. Yu J, Wang X, Jiang M, et al. Comparison of transjugular intrahepatic portosystemic shunt (TIPS) alone and combined with embolisation for the management of cardiofundal varices: a retrospective study. Eur Radiol 2019;29:699–706. [PubMed: 30039223]
104. Liu J, Yang C, Huang S, et al. The combination of balloon-assisted antegrade transvenous obliteration and transjugular intrahepatic portosystemic shunt for the management of cardiofundal varices hemorrhage. Eur J Gastroenterol Hepatol 2020;32:656–662. [PubMed: 32175982]
105. Xiao T, Chen L, Chen W, et al. Comparison of transjugular intrahepatic portosystemic shunt (TIPS) alone versus TIPS combined with embolotherapy in advanced cirrhosis: a retrospective study. J Clin Gastroenterol 2011;45:643–50. [PubMed: 21301360]
106. Biecker E, Roth F, Heller J, et al. Prognostic role of the initial portal pressure gradient reduction after TIPS in patients with cirrhosis. Eur J Gastroenterol Hepatol 2007;19:846–52. [PubMed: 17873607]
107. Rössle M, Siegerstetter V, Olschewski M, et al. How much reduction in portal pressure is necessary to prevent variceal rebleeding? A longitudinal study in 225 patients with transjugular intrahepatic portosystemic shunts. Am J Gastroenterol 2001;96:3379–83. [PubMed: 11774952]
108. Morrison JD, Mendoza-Elias N, Lipnik AJ, et al. Gastric Varices Bleed at Lower Portosystemic Pressure Gradients than Esophageal Varices. J Vasc Interv Radiol 2018;29:636–641. [PubMed: 29352698]
109. Lakhoo J, Bui JT, Zivin SP, et al. Root Cause Analysis of Rebleeding Events following Transjugular Intrahepatic Portosystemic Shunt Creation for Variceal Hemorrhage. J Vasc Interv Radiol 2015;26:1444–53. [PubMed: 26239896]
110. Qi X, Liu L, Bai M, et al. Transjugular intrahepatic portosystemic shunt in combination with or without variceal embolization for the prevention of variceal rebleeding: a meta-analysis. J Gastroenterol Hepatol 2014;29:688–96. [PubMed: 24117967]
111. Tesdal IK, Filser T, Weiss C, et al. Transjugular intrahepatic portosystemic shunts: adjunctive embolotherapy of gastroesophageal collateral vessels in the prevention of variceal rebleeding. Radiology 2005;236:360–7. [PubMed: 15955858]
112. Chen S, Li X, Wei B, et al. Recurrent variceal bleeding and shunt patency: prospective randomized controlled trial of transjugular intrahepatic portosystemic shunt alone or combined with coronary vein embolization. Radiology 2013;268:900–6. [PubMed: 23657891]
113. Gaba RC, Omene BO, Podczerwinski ES, et al. TIPS for treatment of variceal hemorrhage: clinical outcomes in 128 patients at a single institution over a 12-year period. J Vasc Interv Radiol 2012;23:227–35. [PubMed: 22178037]
114. Shi Y, Tian X, Hu J, et al. Efficacy of transjugular intrahepatic portosystemic shunt with adjunctive embolotherapy with cyanoacrylate for esophageal variceal bleeding. Dig Dis Sci 2014;59:2325–32. [PubMed: 24748182]
115. Brensing KA, Hörsch M, Textor J, et al. Hemodynamic effects of propranolol and nitrates in cirrhotics with transjugular intrahepatic portosystemic stent-shunt. Scand J Gastroenterol 2002;37:1070–6. [PubMed: 12374234]
116. Vinet E, Perreault P, Bouchard L, et al. Transjugular intrahepatic portosystemic shunt before abdominal surgery in cirrhotic patients: a retrospective, comparative study. Can J Gastroenterol 2006;20:401–4. [PubMed: 16779457]
117. Tabchouri N, Barbier L, Menahem B, et al. Original Study: Transjugular Intrahepatic Portosystemic Shunt as a Bridge to Abdominal Surgery in Cirrhotic Patients. J Gastrointest Surg 2019;23:2383–2390. [PubMed: 30820792]
118. Hibi T, Nishida S, Levi DM, et al. When and why portal vein thrombosis matters in liver transplantation: a critical audit of 174 cases. Ann Surg 2014;259:760–6. [PubMed: 24299686]
119. Rodrigues SG, Sixt S, Abraldes JG, et al. Systematic review with meta-analysis: portal vein recanalisation and transjugular intrahepatic portosystemic shunt for portal vein thrombosis. Aliment Pharmacol Ther 2019;49:20–30. [PubMed: 30450634]
120. Valentin N, Korrapati P, Constantino J, et al. The role of transjugular intrahepatic portosystemic shunt in the management of portal vein thrombosis: a systematic review and meta-analysis. Eur J Gastroenterol Hepatol 2018;30:1187–1193. [PubMed: 30074506]

121. Regnault D, d'Alteroche L, Nicolas C, et al. Ten-year experience of transjugular intrahepatic portosystemic shunt for noncirrhotic portal hypertension. Eur J Gastroenterol Hepatol 2018;30:557–562. [PubMed: 29324586]

122. Lv Y, Li K, He C, et al. TIPSS for variceal bleeding in patients with idiopathic non-cirrhotic portal hypertension: comparison with patients who have cirrhosis. Aliment Pharmacol Ther 2019;49:926–939. [PubMed: 30820990]

123. Bissonnette J, Garcia-Pagan JC, Albillos A, et al. Role of the transjugular intrahepatic portosystemic shunt in the management of severe complications of portal hypertension in idiopathic noncirrhotic portal hypertension. Hepatology 2016;64:224–31. [PubMed: 26990687]

124. Valla DC. Budd-Chiari syndrome/hepatic venous outflow tract obstruction. Hepatol Int 2018;12:168–180. [PubMed: 28685257]

125. Amarapurkar DN, Punamiya SJ, Patel ND. Changing spectrum of Budd-Chiari syndrome in India with special reference to non-surgical treatment. World J Gastroenterol 2008;14:278–85. [PubMed: 18186568]

126. Attwell A, Ludkowski M, Nash R, et al. Treatment of Budd-Chiari syndrome in a liver transplant unit, the role of transjugular intrahepatic porto-systemic shunt and liver transplantation. Aliment Pharmacol Ther 2004;20:867–73. [PubMed: 15479358]

127. Darwish Murad S, Plessier A, Hernandez-Guerra M, et al. Etiology, management, and outcome of the Budd-Chiari syndrome. Ann Intern Med 2009;151:167–75. [PubMed: 19652186]

128. Plessier A, Sibert A, Consigny Y, et al. Aiming at minimal invasiveness as a therapeutic strategy for Budd-Chiari syndrome. Hepatology 2006;44:1308–16. [PubMed: 17058215]

129. Shalimar Kumar A, Kedia S, et al. Hepatic venous outflow tract obstruction: treatment outcomes and development of a new prognostic score. Aliment Pharmacol Ther 2016;43:1154–67. [PubMed: 27060876]

130. Zahn A, Gotthardt D, Weiss KH, et al. Budd-Chiari syndrome: long term success via hepatic decompression using transjugular intrahepatic porto-systemic shunt. BMC Gastroenterol 2010;10:25. [PubMed: 20193077]

131. Seijo S, Plessier A, Hoekstra J, et al. Good long-term outcome of Budd-Chiari syndrome with a step-wise management. Hepatology 2013;57:1962–8. [PubMed: 23389867]

132. Eldorry A, Barakat E, Abdella H, et al. Outcome of non surgical hepatic decompression procedures in Egyptian patients with Budd-Chiari. World J Gastroenterol 2011;17:906–13. [PubMed: 21412499]

133. Hayek G, Ronot M, Plessier A, et al. Long-term Outcome and Analysis of Dysfunction of Transjugular Intrahepatic Portosystemic Shunt Placement in Chronic Primary Budd-Chiari Syndrome. Radiology 2017;283:280–292. [PubMed: 27797679]

134. Mukund A, Mittal K, Mondal A, et al. Anatomic Recanalization of Hepatic Vein and Inferior Vena Cava versus Direct Intrahepatic Portosystemic Shunt Creation in Budd-Chiari Syndrome: Overall Outcome and Midterm Transplant-Free Survival. J Vasc Interv Radiol 2018;29:790–799. [PubMed: 29705227]

135. Modha K, Kapoor B, Lopez R, et al. Symptomatic Heart Failure After Transjugular Intrahepatic Portosystemic Shunt Placement: Incidence, Outcomes, and Predictors. Cardiovasc Intervent Radiol 2018;41:564–571. [PubMed: 29181605]

136. Billey C, Billet S, Robic MA, et al. A Prospective Study Identifying Predictive Factors of Cardiac Decompensation After Transjugular Intrahepatic Portosystemic Shunt: The Toulouse Algorithm. Hepatology 2019;70:1928–1941. [PubMed: 31512743]

137. Rodríguez-Laiz JM, Bañares R, Echenagusia A, et al. Effects of transjugular intrahepatic portasystemic shunt (TIPS) on splanchnic and systemic hemodynamics, and hepatic function in patients with portal hypertension. Preliminary results. Dig Dis Sci 1995;40:2121–7. [PubMed: 7587778]

138. Izzy M, VanWagner LB, Lin G, et al. Redefining Cirrhotic Cardiomyopathy for the Modern Era. Hepatology 2020;71:334–345. [PubMed: 31342529]

139. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and

the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2015;28:1–39.e14. [PubMed: 25559473]

140. Jansen C, Schröder A, Schueler R, et al. Left Ventricular Longitudinal Contractility Predicts Acute-on-Chronic Liver Failure Development and Mortality After Transjugular Intrahepatic Portosystemic Shunt. Hepatol Commun 2019;3:340–347. [PubMed: 30984902]
141. Cazzaniga M, Salerno F, Pagnozzi G, et al. Diastolic dysfunction is associated with poor survival in patients with cirrhosis with transjugular intrahepatic portosystemic shunt. Gut 2007;56:869–75. [PubMed: 17135305]
142. Shounak M, Vimal R, Colin S, et al. A retrospective analysis of the impact of diastolic dysfunction on one-year mortality after transjugular intrahepatic porto-systemic shunt, liver transplantation and non-transplant abdominal surgery in patients with cirrhosis. Ann Gastroenterol 2015;28:385–390. [PubMed: 26129720]
143. Krowka MJ, Fallon MB, Kawut SM, et al. International Liver Transplant Society Practice Guidelines: Diagnosis and Management of Hepatopulmonary Syndrome and Portopulmonary Hypertension. Transplantation 2016;100:1440–52. [PubMed: 27326810]
144. DuBrock HM, Krowka MJ. The myths and realities of portopulmonary hypertension. Hepatology 2020.
145. Parvinian A, Bui JT, Grace Knuttinen M, et al. Right atrial pressure may impact early survival of patients undergoing transjugular intrahepatic portosystemic shunt creation. Annals of Hepatology 2014;13:411–419. [PubMed: 24927612]
146. Filì D, Falletta C, Luca A, et al. Circulatory response to volume expansion and transjugular intrahepatic portosystemic shunt in refractory ascites: Relationship with diastolic dysfunction. Dig Liver Dis 2015;47:1052–8. [PubMed: 26427586]
147. Busk TM, Bendtsen F, Henriksen JH, et al. Effects of transjugular intrahepatic portosystemic shunt (TIPS) on blood volume distribution in patients with cirrhosis. Dig Liver Dis 2017;49:1353–1359. [PubMed: 28729141]
148. Ascha M, Abuqayyas S, Hanouneh I, et al. Predictors of mortality after transjugular portosystemic shunt. World J Hepatol 2016;8:520–9. [PubMed: 27099653]
149. Tsauo J, Weng N, Ma H, et al. Role of Transjugular Intrahepatic Portosystemic Shunts in the Management of Hepatopulmonary Syndrome: A Systemic Literature Review. J Vasc Interv Radiol 2015;26:1266–71. [PubMed: 26074026]
150. Tsauo J, Zhao H, Zhang X, et al. Changes in arterial oxygenation after portal decompression in Budd-Chiari syndrome patients with hepatopulmonary syndrome. Eur Radiol 2019;29:32733280.
151. Zhao H, Liu F, Yue Z, et al. Clinical efficacy of transjugular intrahepatic portosystemic shunt in the treatment of hepatopulmonary syndrome. Medicine (Baltimore) 2017;96:e9080. [PubMed: 29245324]
152. Trebicka J, Bastgen D, Byrtus J, et al. Smaller-Diameter Covered Transjugular Intrahepatic Portosystemic Shunt Stents Are Associated With Increased Survival. Clin Gastroenterol Hepatol 2019;17:2793–2799 e1. [PubMed: 30940552]
153. Kovacs A, Schepke M, Heller J, et al. Short-term effects of transjugular intrahepatic shunt on cardiac function assessed by cardiac MRI: preliminary results. Cardiovasc Intervent Radiol 2010;33:290–6. [PubMed: 19730936]
154. Saugel B, Mair S, Meidert AS, et al. The effects of transjugular intrahepatic portosystemic stent shunt on systemic cardiocirculatory parameters. J Crit Care 2014;29:1001–5. [PubMed: 25220530]
155. Pudil R, Praus R, Hulek P, et al. Transjugular intrahepatic portosystemic shunt is associated with significant changes in mitral inflow parameters. Ann Hepatol 2013;12:464–70. [PubMed: 23619264]
156. Lotterer E, Wengert A, Fleig WE. Transjugular intrahepatic portosystemic shunt: short-term and long-term effects on hepatic and systemic hemodynamics in patients with cirrhosis. Hepatology 1999;29:632–9. [PubMed: 10051460]
157. Merli M, Valeriano V, Funaro S, et al. Modifications of cardiac function in cirrhotic patients treated with transjugular intrahepatic portosystemic shunt (TIPS). Am J Gastroenterol 2002;97:142–8. [PubMed: 11808939]

158. Anderson CL, Saad WE, Kalagher SD, et al. Effect of transjugular intrahepatic portosystemic shunt placement on renal function: a 7-year, single-center experience. J Vasc Interv Radiol 2010;21:1370–6. [PubMed: 20691610]

159. Quiroga J, Sangro B, Núñez M, et al. Transjugular intrahepatic portal-systemic shunt in the treatment of refractory ascites: effect on clinical, renal, humoral, and hemodynamic parameters. Hepatology 1995;21:986–94. [PubMed: 7705810]

160. Allegretti AS, Ortiz G, Cui J, et al. Changes in Kidney Function After Transjugular Intrahepatic Portosystemic Shunts Versus Large-Volume Paracentesis in Cirrhosis: A Matched Cohort Analysis. Am J Kidney Dis 2016;68:381–91. [PubMed: 26994685]

161. Brensing KA, Textor J, Strunk H, et al. Transjugular intrahepatic portosystemic stent-shunt for hepatorenal syndrome. Lancet 1997;349:697–8. [PubMed: 9078203]

162. Hamel B, Guillaud O, Roman S, et al. Prognostic factors in patients with refractory ascites treated by transjugular intrahepatic porto-systemic shunt: From the liver to the kidney. Dig Liver Dis 2014;46:1001–7. [PubMed: 25096966]

163. Cholongitas E, Shusang V, Marelli L, et al. Review article: renal function assessment in cirrhosis - difficulties and alternative measurements. Aliment Pharmacol Ther 2007;26:969–78. [PubMed: 17877504]

164. Malinchoc M, Kamath PS, Gordon FD, et al. A model to predict poor survival in patients undergoing transjugular intrahepatic portosystemic shunts. Hepatology 2000;31:864–71. [PubMed: 10733541]

165. Khabbaz RC, Lokken RP, Chen YF, et al. Albumin-Bilirubin and Platelet-Albumin-Bilirubin Grades Do Not Predict Survival After Transjugular Intrahepatic Portosystemic Shunt Creation. Cardiovasc Intervent Radiol 2018.

166. Riggio O, Angeloni S, Salvatori FM, et al. Incidence, natural history, and risk factors of hepatic encephalopathy after transjugular intrahepatic portosystemic shunt with polytetrafluoroethylene-covered stent grafts. Am J Gastroenterol 2008;103:2738–46. [PubMed: 18775022]

167. Gines P, Tito L, Arroyo V, et al. Randomized comparative study of therapeutic paracentesis with and without intravenous albumin in cirrhosis. Gastroenterology 1988;94:1493–502. [PubMed: 3360270]

168. Sola-Vera J, Minana J, Ricart E, et al. Randomized trial comparing albumin and saline in the prevention of paracentesis-induced circulatory dysfunction in cirrhotic patients with ascites. Hepatology 2003;37:1147–53. [PubMed: 12717396]

169. Pozzi M, Osculati G, Boari G, et al. Time course of circulatory and humoral effects of rapid total paracentesis in cirrhotic patients with tense, refractory ascites. Gastroenterology 1994;106:709–19. [PubMed: 8119542]

170. Kashani K, Rosner MH, Haase M, et al. Quality Improvement Goals for Acute Kidney Injury. Clin J Am Soc Nephrol 2019;14:941–953. [PubMed: 31101671]

171. Sturgis TM. Hepatorenal syndrome: resolution after transjugular intrahepatic portosystemic shunt. J Clin Gastroenterol 1995;20:241–3. [PubMed: 7797835]

172. Bureau C, carlos Garcia-Pagan J, Otal P, et al. Improved clinical outcome using polytetrafluoroethylene-coated stents for TIPS: results of a randomized study. Gastroenterology 2004;126:469–475. [PubMed: 14762784]

173. Masson S, Mardini HA, Rose JD, et al. Hepatic encephalopathy after transjugular intrahepatic portosystemic shunt insertion: a decade of experience. Qjm 2008;101:493–501. [PubMed: 18440957]

174. Yang Z, Han G, Wu Q, et al. Patency and clinical outcomes of transjugular intrahepatic portosystemic shunt with polytetrafluoroethylene-covered stents versus bare stents: a meta-analysis. J Gastroenterol Hepatol 2010;25:1718–1725. [PubMed: 21039832]

175. Bai M, Qi X, Yang Z, et al. Predictors of hepatic encephalopathy after transjugular intrahepatic portosystemic shunt in cirrhotic patients: a systematic review. J Gastroenterol Hepatol 2011;26:943–951. [PubMed: 21251067]

176. Casadaban LC, Parvinian A, Minocha J, et al. Clearing the Confusion over Hepatic Encephalopathy After TIPS Creation: Incidence, Prognostic Factors, and Clinical Outcomes. Dig Dis Sci 2015;60:1059–66. [PubMed: 25316553]

177. Nardelli S, Lattanzi B, Torrisi S, et al. Sarcopenia Is Risk Factor for Development of Hepatic Encephalopathy After Transjugular Intrahepatic Portosystemic Shunt Placement. Clin Gastroenterol Hepatol 2017;15:934–936. [PubMed: 27816756]

178. Praktiknjo M, Clees C, Pigliacelli A, et al. Sarcopenia Is Associated With Development of Acute-on-Chronic Liver Failure in Decompensated Liver Cirrhosis Receiving Transjugular Intrahepatic Portosystemic Shunt. Clin Transl Gastroenterol 2019;10:e00025–e00025. [PubMed: 30939488]

179. Bajaj JS, Lauridsen M, Tapper EB, et al. Important Unresolved Questions in the Management of Hepatic Encephalopathy: An ISHEN Consensus. Official journal of the American College of Gastroenterology | ACG 2020;115.

180. Vilstrup H, Amodio P, Bajaj J, et al. Hepatic encephalopathy in chronic liver disease: 2014 practice guideline by AASLD and EASL. Hepatology 2014;60:715–735. [PubMed: 25042402]

181. Berlioux P, Robic MA, Poirson H, et al. Pre-transjugular intrahepatic portosystemic shunts (TIPS) prediction of post-TIPS overt hepatic encephalopathy: the critical flicker frequency is more accurate than psychometric tests. Hepatology 2014;59:622–629. [PubMed: 24620380]

182. Nardelli S, Gioia S, Pasquale C, et al. Cognitive Impairment Predicts The Occurrence Of Hepatic Encephalopathy After Transjugular Intrahepatic Portosystemic Shunt. Am J Gastroenterol 2016;111:523–528. [PubMed: 26925879]

183. Amodio P, Campagna F, Olianas S, et al. Detection of minimal hepatic encephalopathy: Normalization and optimization of the Psychometric Hepatic Encephalopathy Score. A neuropsychological and quantified EEG study. Journal of Hepatology 2008;49:346–353. [PubMed: 18602716]

184. Montagnese S, Bajaj JS. Impact of Hepatic Encephalopathy in Cirrhosis on Quality-of-Life Issues. Volume 79: Springer International Publishing, 2019:11–16.

185. Patidar KR, Thacker LR, Wade JB, et al. Covert Hepatic Encephalopathy Is Independently Associated with Poor Survival and Increased Risk of Hospitalization. American Journal of Gastroenterology 2014;109:1757–1763. [PubMed: 25178701]

186. Luo X, Wang X, Zhu Y, et al. Clinical Efficacy of Transjugular Intrahepatic Portosystemic Shunt Created with Expanded Polytetrafluoroethylene-Covered Stent-Grafts: 8-mm Versus 10-mm. Cardiovasc Intervent Radiol 2019;42:737–743. [PubMed: 30643936]

187. Schepis F, Vizzutti F, Garcia-Tsao G, et al. Under-dilated TIPS Associate With Efficacy and Reduced Encephalopathy in a Prospective, Non-randomized Study of Patients With Cirrhosis. Clin Gastroenterol Hepatol 2018;16:1153–1162.e7. [PubMed: 29378312]

188. Sauerbruch T, Mengel M, Dollinger M, et al. Prevention of Rebleeding From Esophageal Varices in Patients With Cirrhosis Receiving Small-Diameter Stents Versus Hemodynamically Controlled Medical Therapy. Gastroenterology 2015;149:660–8.e1. [PubMed: 25989386]

189. Praktiknjo M, Simón-Talero M, Römer J, et al. Total area of spontaneous portosystemic shunts independently predicts hepatic encephalopathy and mortality in liver cirrhosis. Journal of Hepatology 2020;72:1140–1150. [PubMed: 31954206]

190. Simón-Talero M, Roccarina D, Martínez J, et al. Association Between Portosystemic Shunts and Increased Complications and Mortality in Patients With Cirrhosis. Gastroenterology 2018;154:1694–1705.e4. [PubMed: 29360462]

191. He C, Lv Y, Wang Z, et al. Association between non-variceal spontaneous portosystemic shunt and outcomes after TIPS in cirrhosis. Dig Liver Dis 2018;50:1315–1323. [PubMed: 29960900]

192. Leng X, Zhang F, Zhang M, et al. Comparison of transjugular intrahepatic portosystemic shunt for treatment of variceal bleeding in patients with cirrhosis with or without spontaneous portosystemic shunt. Eur J Gastroenterol Hepatol 2019;31:853–858. [PubMed: 30633039]

193. Riggio O, Masini A, Efrati C, et al. Pharmacological prophylaxis of hepatic encephalopathy after transjugular intrahepatic portosystemic shunt: a randomized controlled study. Journal of hepatology 2005;42:674–679. [PubMed: 15826716]

194. An J, Kim KW, Han S, et al. Improvement in survival associated with embolisation of spontaneous portosystemic shunt in patients with recurrent hepatic encephalopathy. Alimentary pharmacology & therapeutics 2014;39:1418–1426. [PubMed: 24754260]

195. Laleman W, Simon-Talero M, Maleux G, et al. Embolization of large spontaneous portosystemic shunts for refractory hepatic encephalopathy: a multicenter survey on safety and efficacy. Hepatology 2013;57:2448–2457. [PubMed: 23401201]

196. Lee EW, Saab S, Kaldas F, et al. Coil-Assisted Retrograde Transvenous Obliteration (CARTO): An Alternative Treatment Option for Refractory Hepatic Encephalopathy. American Journal of Gastroenterology 2018;113:1187–1196. [PubMed: 29899437]

197. Lynn AM, Singh S, Congly SE, et al. Embolization of portosystemic shunts for treatment of medically refractory hepatic encephalopathy. Liver Transplantation 2016;22:723–731. [PubMed: 26970243]

198. Naeshiro N, Kakizawa H, Aikata H, et al. Percutaneous transvenous embolization for portosystemic shunts associated with encephalopathy: Long-term outcomes in 14 patients. Hepatol Res 2014;44:740–749. [PubMed: 23745735]

199. Philips CA, Kumar L, Augustine P. Shunt occlusion for portosystemic shunt syndrome related refractory hepatic encephalopathy—A single-center experience in 21 patients from Kerala. Indian Journal of Gastroenterology 2017;36:411–419. [PubMed: 29124669]

200. Bureau C, Thabut D, Jezequel C, et al. The Use of Rifaximin in the Prevention of Overt Hepatic Encephalopathy After Transjugular Intrahepatic Portosystemic Shunt : A Randomized Controlled Trial. Ann Intern Med 2021.

201. Riggio O, Nardelli S, Moscucci F, et al. Hepatic encephalopathy after transjugular intrahepatic portosystemic shunt. Clin Liver Dis 2012;16:133–146. [PubMed: 22321469]

202. Chung HH, Razavi MK, Sze DY, et al. Portosystemic pressure gradient during transjugular intrahepatic portosystemic shunt with Viatorr stent graft: what is the critical low threshold to avoid medically uncontrolled low pressure gradient related complications? J Gastroenterol Hepatol 2008;23:95–101. [PubMed: 18171347]

203. Cookson DT, Zaman Z, Gordon-Smith J, et al. Management of transjugular intrahepatic portosystemic shunt (TIPS)-associated refractory hepatic encephalopathy by shunt reduction using the parallel technique: outcomes of a retrospective case series. Cardiovasc Intervent Radiol 2011;34:92–99. [PubMed: 21057793]

204. Fanelli F, Salvatori FM, Rabuffi P, et al. Management of refractory hepatic encephalopathy after insertion of TIPS: long-term results of shunt reduction with hourglass-shaped balloonexpandable stent-graft. AJR Am J Roentgenol 2009;193:1696–1702. [PubMed: 19933667]

205. Kochar N, Tripathi D, Ireland H, et al. Transjugular intrahepatic portosystemic stent shunt (TIPSS) modification in the management of post-TIPSS refractory hepatic encephalopathy. Gut 2006;55:1617–1623. [PubMed: 16571635]

206. Maleux G, Heye S, Verslype C, et al. Management of transjugular intrahepatic portosystemic shunt induced refractory hepatic encephalopathy with the parallel technique: results of a clinical follow-up study. J Vasc Interv Radiol 2007;18:986–92; quiz 993. [PubMed: 17675616]

207. Maleux G, Verslype C, Heye S, et al. Endovascular shunt reduction in the management of transjugular portosystemic shunt-induced hepatic encephalopathy: preliminary experience with reduction stents and stent-grafts. AJR Am J Roentgenol 2007;188:659–664. [PubMed: 17312051]

208. Schrier RW, Arroyo V, Bernardi M, et al. Peripheral arterial vasodilation hypothesis: a proposal for the initiation of renal sodium and water retention in cirrhosis. Hepatology (Baltimore, Md.) 1988;8:1151–1157.

209. Wadei HM, Mai ML, Ahsan N, et al. Hepatorenal syndrome: pathophysiology and management. Clin J Am Soc Nephrol 2006;1:1066–79. [PubMed: 17699328]

210. Gines P, Schrier RW. Renal failure in cirrhosis. N Engl J Med 2009;361:1279–90. [PubMed: 19776409]

211. Rossle M, Gerbes AL. TIPS for the treatment of refractory ascites, hepatorenal syndrome and hepatic hydrothorax: a critical update. Gut 2010;59:988–1000. [PubMed: 20581246]

212. Guevara M, Ginès P, Bandi JC, et al. Transjugular intrahepatic portosystemic shunt in hepatorenal syndrome: effects on renal function and vasoactive systems. Hepatology 1998;28:416–22. [PubMed: 9696006]

213. Umgelter A, Reindl W, Geisler F, et al. Effects of TIPS on global end-diastolic volume and cardiac output and renal resistive index in ICU patients with advanced alcoholic cirrhosis. Ann Hepatol 2010;9:40–5. [PubMed: 20308721]

214. Stadlbauer V, Wright GA, Banaji M, et al. Relationship between activation of the sympathetic nervous system and renal blood flow autoregulation in cirrhosis. Gastroenterology 2008;134:111–9. [PubMed: 18166350]

215. Somberg KA, Lake JR, Tomlanovich SJ, et al. Transjugular intrahepatic portosystemic shunts for refractory ascites: assessment of clinical and hormonal response and renal function. Hepatology 1995;21:709–16. [PubMed: 7875668]

216. Gerbes AL, Gülberg V, Waggershauser T, et al. Renal effects of transjugular intrahepatic portosystemic shunt in cirrhosis: comparison of patients with ascites, with refractory ascites, or without ascites. Hepatology 1998;28:683–8. [PubMed: 9731559]

217. Wong F, Sniderman K, Liu P, et al. Transjugular intrahepatic portosystemic stent shunt: effects on hemodynamics and sodium homeostasis in cirrhosis and refractory ascites. Ann Intern Med 1995;122:816–22. [PubMed: 7741365]

218. Jalan R, Redhead DN, Thomas HW, et al. Mechanisms of changes in renal handling of sodium following transjugular intrahepatic portal systemic stent-shunt (TIPSS). European journal of gastroenterology & hepatology 1996;8:1111–1116. [PubMed: 8944375]

219. Jalan R, Forrest EH, Redhead DN, et al. Reduction in renal blood flow following acute increase in the portal pressure: evidence for the existence of a hepatorenal reflex in man? Gut 1997;40:664–670. [PubMed: 9203948]

220. Michl P, Gulberg V, Bilzer M, et al. Transjugular intrahepatic portosystemic shunt for cirrhosis and ascites: Effects in patients with organic or functional renal failure. Scandinavian Journal of Gastroenterology 2000;35:654–658. [PubMed: 10912668]

221. Wong W, Liu P, Blendis L, et al. Long-term renal sodium handling in patients with cirrhosis treated with transjugular intrahepatic portosystemic shunts for refractory ascites. Am J Med 1999;106:315–22. [PubMed: 10190381]

222. Stanley AJ, Redhead DN, Bouchier IA, et al. Acute effects of transjugular intrahepatic portosystemic stent-shunt (TIPSS) procedure on renal blood flow and cardiopulmonary hemodynamics in cirrhosis. The American Journal of Gastroenterology 1998;93:2463–2468. [PubMed: 9860410]

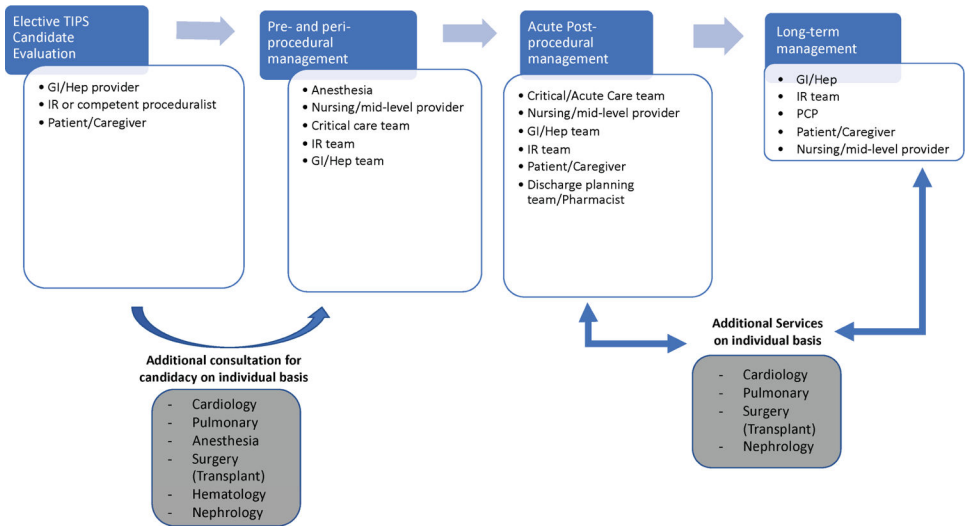

Figure 1. Team-Based Approach to TIPS Care.

A team-based approach to TIPS is of critical importance in all stages of TIPS planning and management. Initial consideration for decision on TIPS candidacy should involve the patient and corresponding caregiver as well as a gastroenterologist or hepatologist and a proceduralist with competency in TIPS. Complex cases should include consultation with additional specialties (e.g., cardiology, pulmonology, transplant surgery, hematology, nephrology) as appropriate. Once a patient is determined to meet criteria for TIPS creation, longitudinal care includes a spectrum of multi-specialty (e.g., anesthesia, critical care, IR, GI/hepatology, primary care provider), multi-practitioner (e.g., nursing, physician, pharmacy, mid-level providers) providers. Abbreviations: GI, gastroenterologist; IR, interventional radiologist; PCP, primary care provider; TIPS, transjugular intrahepatic portosystemic shunt.

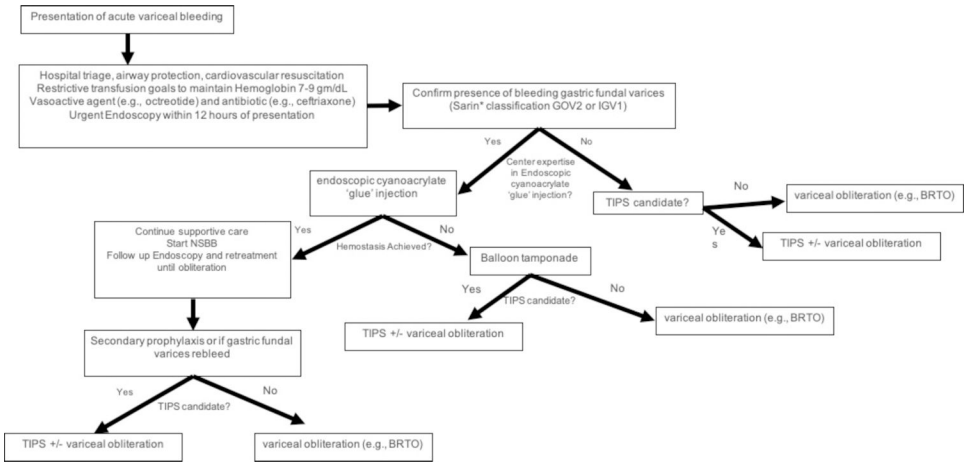

Figure 2. Proposed Approach to Gastric Fundal Variceal Bleeding in Cirrhosis

Management of gastric fundal variceal bleeding depends on the admitting center's expertise as well as the patient's portal vascular anatomy and severity of their liver disease. Initial management is similar to the approach for all patients presenting with acute gastrointestinal bleeding, particularly in the setting of known portal hypertension. Once gastric varices (GV) are confirmed as the bleeding source, use of endoscopic therapy with "glue" injection can be considered depending on proceduralist's expertise. If hemostasis is not achieved, TIPS evaluation +/− variceal obliteration should then be considered. In addition, TIPS +/− variceal obliteration should be considered for secondary prophylaxis or if there is GV rebleeding. Abbreviations: BRTO, balloon-occluded retrograde transvenous obliteration; GOV, gastroesophageal varices; IGV, isolated gastric varices; NSBB, nonselective beta-blocker; TIPS, transjugular intrahepatic portosystemic shunt. *Sarin SK, Lahoti D, Saxena SP, Murthy NS, Makwana UK. Prevalence, classification and natural history of gastric varices: a long-term follow-up study in 568 portal hypertension patients. Hepatology 1992 Dec;16(6):1343–9. doi: 10.1002/hep.1840160607.

Table 1.

Clinical consensus statements for TIPS planning, procedural best practices and care of the TIPS recipient independent of indication for TIPS

Question	Statement	Level of Evidence
PRE-TIPS CONSIDERATIONS		
Q1. Who should be involved in the decision to place a TIPS and what other preprocedure consultations are recommende d?	Prior to TIPS creation, we recommend that a gastroenterologist or hepatologist should be involved in the initial decision to place an emergent or nonemergent TIPS with subsequent consultation by an interventional radiologist or other proceduralist with competency in TIPS. If center expertise is not available, we recommend referral to an expert center. Additional specialty consultations (e.g., Transplant Surgery, Cardiology, Critical Care, Hematology, Nephrology) may be considered on a case-bycase basis.	5
Q2. What services should be readily available at centers where TIPS is performed and what referral pathways should be established for a higher level of care?	For all patients undergoing TIPS creation, we recommend that TIPS should occur at a center with available Interventional Radiology (IR), Gastroenterology/ Hepatology, Cardiology, Pulmonary Surgery, Hematology, Nephrology and Critical Care services in order to provide an adequate level of support for patient management before and after TIPS. In patients requiring a higher level of care, such as possible liver transplant candidates, or in whom the need for further IR expertise is indicated (e.g., extensive portal vein thrombosis), we recommend referral to centers with adequate experience in these areas.	5
Q3. Is there a MELD threshold above which elective TIPS should not be considered?	In patients with cirrhosis undergoing TIPS, a multidisciplinary approach, rather than an absolute MELD cutoff, is recommended to assess TIPS candidacy.	2a
Q4. What imaging and/or preprocedural evaluation is required prior to TIPS creation?	Q4a. In patients undergoing elective TIPS, we recommend: • Contrast-enhanced multiphasic cross-sectional imaging (CT/MRI) to assist with TIPS planning. • Comprehensive echocardiography to assess for abnormalities in cardiac structure, function, and right ventricular systolic pressure.	2a
	Q4b. In patients with cirrhosis undergoing emergent TIPS, best clinical judgement should be applied – we suggest at least a liver ultrasound with doppler to evaluate the patency of the portal venous system and consideration of a limited (bedside) echocardiogram, evaluating left ventricular ejection fraction and right ventricular systolic pressure.	3
Q5. What are absolute contraindicati ons (medical and anatomical) to elective TIPS creation?	The absolute contraindications to elective TIPS include: • severe congestive heart failure (ACC/AHA Stage C or D HF) • severe untreated valvular heart disease (AHA/ACC stage C or D VHD) • moderate-severe pulmonary hypertension (based on invasive measurements) despite medical optimization • uncontrolled systemic infection • refractory overt HE • unrelieved biliary obstruction • lesions (e.g., cysts) or tumors in the liver parenchyma that preclude TIPS creation	2a
Q6. Should all patients being considered for TIPS undergo evaluation for liver transplantation prior to TIPS creation?	In patients with cirrhosis undergoing elective or emergent TIPS, there is insufficient evidence to recommend universal pre-procedure liver transplant evaluation.	5
TIPS PROCEDURAL CONSIDERATIONS		
Q7: Who should perform TIPS creation?	We recommend that TIPS creation should be performed by a credentialed, board certified Interventional Radiologist OR a certified provider with equivalent training and procedural competency *.	5
Q8. What type of stent is recommended for TIPS creation?	For patients undergoing TIPS placement, we recommend the use of an ePTFE lined stent graft (1b) with controlled expansion which allows the operator to tailor the amount of portosystemic shunting based on the indication, target gradient and patient comorbidities (2b).	1b and 2b
Q9. Should coagulopathy be corrected prior to TIPS placement?	Due to insufficient evidence, we do not recommend a specific target INR or platelet threshold when placing a TIPS in a patient with cirrhosis.	2b
Q10. Should periprocedur al antibiotics be routinely used in TIPS creation?	There are no studies to show that the routine use of antibiotics during TIPS placement decreases infectious complications and their use should depend on patient and local risk factors.	5

Question	Statement	Level of Evidence
Q11. Should TIPS creation be performed using general anesthesia or is deep or conscious sedation appropriate?	The use of general anesthesia, deep sedation, or conscious sedation may all be appropriate for TIPS placement and their use will vary depending on the patient risk factors and local practices.	5
Q12. Is the use of intravascular ultrasound recommended to assist with the portal vein puncture?	For patients undergoing TIPS creation, while there is insufficient evidence to recommend the universal use of intravascular ultrasound guidance, it may facilitate efficient portal access in certain situations. Its use will depend on equipment availability and operator preference.	3b
Q13. What is the optimal location from which to measure the systemic venous pressure at the time of TIPS creation (hepatic vein, IVC, right atrium)?	We recommend the use of the free hepatic vein or IVC pressure as the systemic pressure when measuring the portosystemic gradient before and after TIPS placement.	2a
Q14. Are there specific technical factors that should be considered to ensure that TIPS placement does not adversely influence liver transplant candidacy?	Q14a. In patients undergoing TIPS placement who are potentially eligible for liver transplant, we recommend positioning the stent as to not interfere with the portal and hepatic vein anastomoses, presuming that this does not detrimentally affect TIPS function or patency. This positioning includes leaving a segment of unstented main portal vein and not extending the TIPS stent into the right atrium.	5
	Q14b. Liver Transplant candidacy should not be impacted by placement of TIPS.	2a
CARE OF THE POST-TIPS PATIENT		
Q15. What is the recommende d duration of intensive postprocedure monitoring?	Following TIPS creation, we recommend that all patients undergo inhospital overnight observation at minimum. The level of care during postTIPS observation should be dictated by the patient's condition, indication for TIPS, and intraprocedural technical complexity.	5
Q16. What early laboratory testing and/or imaging is recommended following TIPS creation and at what interval?	Q16a. In all patients undergoing TIPS creation, routine labs (complete blood count, comprehensive metabolic panel, and PT/INR) should be obtained on the day following TIPS creation. Hemoglobin/hematocrit labs may be obtained on the same day of TIPS creation, depending on institution and/or operator discretion.	5
	Q16b. Pre-discharge imaging is not indicated in most patients undergoing TIPS creation.	5
Q17. Should TIPS venography and intervention be based on ultrasound, clinical findings, or both?	Q17a. In patients who have undergone TIPS creation for management of varices, either Doppler ultrasound findings suggesting TIPS dysfunction, or persistence or recurrence of portal hypertensive complications should prompt TIPS venography and manometry +/− intervention. Ultrasound findings suggesting TIPS dysfunction include alterations in intrahepatic portal vein direction of flow, abnormal flow velocities within the TIPS, and persistent (e.g., > 6 weeks post-TIPS) or recurrent ascites.	2b
	Q17b. In patients who have undergone TIPS creation for management of ascites and/or hepatic hydrothorax, persistence or recurrence of portal hypertensive complications should prompt TIPS venography and manometry +/− intervention. Medical decision-making should be individualized in patients with well-controlled ascites and/or hepatic hydrothorax and ultrasound findings suggesting TIPS dysfunction.	2b
	Q17c. In select patients, scheduled TIPS venography with intervention is suggested in the early (1–2 months) post-TIPS period. An example of such a scenario would be TIPS creation in a patient with portal vein thrombosis.	5
Q18. What are the optimal techniques for increasing or decreasing TIPS flow when intervention is required?	Q18a. In patients in whom further decrease in portal pressure is desired, we recommend stepwise dilatation of TIPS to its maximum diameter. If it is already at maximum diameter, other interventions to decrease portal pressure (e.g., nonselective beta-blockers, parallel TIPS creation) should be evaluated.	5
	Q18b. In patients in whom an increase in portal pressure desired, there is insufficient evidence to recommend a specific technique to reduce portosystemic shunting through a TIPS.	5
Q19. Who should see patients with TIPS in follow up?	In patients who have undergone TIPS creation, we recommend that a gastroenterologist or hepatologist and a competent proceduralist (e.g., interventional radiologist) should follow the patient to ensure ongoing management of chronic liver disease, post-procedural complications and to determine any need for potential device revision.	5

Abbreviations: ACC, American College of Cardiology; AHA, American Heart Association; CT, computed tomography; ePTFE, Polytetrafluoroethylene; HF, heart failure; INR, internationalized normal ratio; IVC, inferior vena cava; MELD, Model for End-Stage Liver

Disease; MRI, magnetic resonance imaging; NYHA, New York Heart Association; PT, prothrombin time; TIPS, transjugular intrahepatic portosystemic shunt; VHD, valvular heart disease

*According to radiology professional society guidelines, TIPS placement must be performed by a physician with board certification or accredited training as well as sufficient experience with TIPS procedures. In the absence of certification or accredited training, TIPS placement can be performed by a competent proceduralist defined as one who has performed a sufficient number of TIPS procedures under supervision (minimum threshold = 5), in addition to other endovascular techniques (i.e., minimum of 100 angiograms, 50 angioplasties, 10 stent placements, and 5 embolizations), has achieved expected procedure completion thresholds, and has obtained appropriate privileges at their center.[38]

Table 2.

Clinical Consensus Statements for TIPS by Indication

Question	Statement	Level of Evidence
TIPS IN ASCITES OR HEPATIC HYDROTHORAX (HHT)		
Q1. What is the optimal technical approach to TIPS creation among patients with cirrhosis and refractory ascites?	Q1a. For patients with cirrhosis and diuretic refractory or resistant ascites undergoing elective TIPS, we recommend the use of an ePTFE-covered controlled expansion stent.	2b
	Q1b. For patients with cirrhosis and diuretic refractory or resistant ascites undergoing elective TIPS, we recommend a staged approach to TIPS creation with an initial procedural stent dilation to 8mm followed by clinical assessment, and then subsequent progressive stent dilation to 9mm and then 10 mm at 6-week intervals if needed to optimize clinical response.	2b
Q2. Is TIPS associated with better outcomes (mortality, ascites control) than serial large volume paracentesis for the treatment of refractory ascites?	Q2a. For carefully selected patients with cirrhosis and refractory ascites, TIPS is recommended over LVP to prevent recurrent ascites.	1a
	Q2b. For carefully selected patients with cirrhosis and refractory ascites, TIPS is recommended over LVP to improve transplant-free survival.	1a
Q3. Is there a threshold of liver dysfunction above which TIPS for refractory ascites should be contraindicat ed and how should it be defined?	Among patients with cirrhosis and refractory ascites, elevated bilirubin, elevated MELD score and CTP class C cirrhosis are associated with increased post-TIPS complications including mortality. There is insufficient evidence to recommend a cutoff above which any of these measures should be considered a contraindication to TIPS.	1a
Q4. What is the impact of age on candidacy for TIPS for refractory ascites?	Among patients with cirrhosis and refractory ascites, advanced age is significantly associated with post-TIPS complications including severe hepatic encephalopathy and death. There is insufficient evidence to recommend an age cutoff that should be considered a contraindication to TIPS.	1a
Q5. What is the role of TIPS in patients with ascites that is not refractory?	In patients not fulfilling a strict definition of refractory ascites but requiring at least 3 large volume paracenteses for tense ascites in a year despite optimal medical therapy, we recommend that TIPS creation should be considered.	1a
Q6. What is the role of TIPS in HHT? Is patient selection similar for patients with ascites vs patients with HHT?	For patients with HHT requiring recurrent thoracentesis, we recommend that TIPS should be considered.	2b
Q7. Is prior liver transplantati on a contraindicat ion to TIPS for refractory ascites? Is TIPS a better treatment than surgical shunt, serial LVP or splenic artery embolization in liver transplant recipients with refractory ascites?	Unlike TIPS for ascites and HHT in cirrhosis, there is insufficient evidence to support any recommendation regarding therapy (TIPS and other modalities) in liver transplant recipients with refractory ascites.	2b
Q8. What is the expected timeline for the TIPS to be effective for reduction of Ascites/ HHT?	In the setting of TIPS creation for ascites or hepatic hydrothorax, we recommend using a staged approach by starting with the TIPS stent with the smallest diameter with concomitant use of diuretics as tolerated. Reassessment for need to further dilate the TIPS stent should be performed every 6 weeks.	2b
TIPS IN VARICEAL BLEEDING		
Q1. When is TIPS indicated in Acute Variceal Hemorrhage?	For acute variceal hemorrhage, we recommend TIPS creation in the following scenarios: • Pre-emptive TIPS in patients who have been successfully banded but who meet high-risk criteria for rebleeding. High-risk criteria are CTP Class C (10–13 points) or CTP Class B >7 points with active bleeding at endoscopy. TIPS should be performed within 72 hours of admission in patients without contraindications to TIPS.	1c
	• Rescue TIPS in patients who have been successfully banded but who rebleed at any time during admission (after endoscopy).	2a
	• Salvage TIPS should be performed emergently for patients in whom endoscopic band ligation cannot be performed because of profuse bleeding or bleeding persists at endoscopy despite endoscopic band ligation.	2b

Question	Statement	Level of Evidence
Q2. When should TIPS be used in the management of bleeding gastric fundal varices or prevention of rebleeding?	Q2a. We recommend that the initial management of bleeding gastric-fundal varices should be based on center expertise. Variceal obliteration/ embolization with or without TIPS should be considered for bleeding gastric-fundal varices if unable to be managed endoscopically.	5
	Q2b. For rebleeding gastric-fundal varices after endoscopic therapy, we recommend variceal obliteration with or without TIPS creation.	2b
Q3. What are the procedural consideratio ns in TIPS creation for variceal hemorrhage?	Q3a. When placing a TIPS for variceal hemorrhage, we recommend a goal PSG of <12 mmHg or 50–60% decrease from initial. We do not recommend using shunt diameter as a procedural endpoint.	2b
	Q3b. In cases of TIPS creation for variceal hemorrhage, we recommend concurrent obliteration of varices.	1b
Q4. How should patients be monitored after TIPS creation for variceal hemorrhage?	Q4a. In the setting of TIPS creation for variceal bleeding, we recommend surveillance with Doppler ultrasonography three months after TIPS creation and every six months thereafter in order to monitor for post TIPS stenosis or occlusion.	5
	Q4b. If TIPS stenosis/occlusion is suspected or if patient rebleeds after TIPS creation, TIPS venogram with pressure measurements is indicated with consideration of TIPS revision.	2b
NOVEL INDICATIONS FOR TIPS		
Q1. Does preoperative TIPS creation in patients with portal hypertension reduce operative complication and/or improve perioperativ e outcomes following nontransplant abdominal surgery?	Q1a. In patients with portal hypertension requiring non-transplant surgery, there is insufficient evidence to recommend that preoperative TIPS prevents bleeding complications or the need for blood transfusion during or after invasive non-transplant surgical procedures.	1b
	Q1b. In patients with cirrhosis without clinically significant ascites, there is insufficient evidence to recommend pre-operative TIPS in abdominal surgery to prevent complications of ascites. In patients with cirrhosis with clinically significant ascites requiring abdominal surgery, a multidisciplinary team approach (hepatology and hepatobiliary surgery) is recommended to individualize the surgical/medical management.	3b
	Q1c. There is no evidence that preoperative TIPS has an impact on postoperative mortality after invasive non-transplant surgical procedures.	3b
Q2. Does TIPS creation in patients with cirrhosis and portal vein obstruction facilitate listing for liver transplantati on and/or improve outcomes after liver transplantati on?	Q2a. In patients with cirrhosis and chronic, complete portal vein thrombosis, portal vein recanalization and TIPS creation could be considered to facilitate transplant eligibility.	3b
	Q2b. Patients with cirrhosis and complete portal vein thrombosis otherwise being considered for liver transplantation or denied listing due to technical challenges associated with complete portal vein obstruction, should be considered for portal-vein reconstruction and TIPS. Referral to a center with specialized expertise may be necessary.	5
Q3. Does TIPS creation prevent or reduce portal hypertensive complication s in patients with noncirrhotic portal hypertension due to extrahepatic portal vein obstruction?	Q3a. In patients with non-cirrhotic portal hypertension and acute portal vein thrombosis, we recommend immediate anticoagulation. In those who fail or have a poor response to anticoagulation, we recommend that portal vein thrombectomy/thrombolysis using a transjugular approach with or without small caliber TIPS creation should be considered.	4
	Q3b. In patients with acute non-cirrhotic portal vein thrombosis who are not critically ill, evidence is insufficient to recommend TIPS versus anticoagulation alone. We recommend that a trial of anticoagulation be considered initially given the reported rates of venous recanalization.	2b
	Q3c. In patients with chronic portal hypertension secondary to non-cirrhotic extrahepatic portal vein obstruction that is not responsive to anticoagulation, TIPS may be considered for the same indications as cirrhotic portal hypertension.	5
Q4. Does TIPS creation in patients with non-cirrhotic portal hypertension and without extrahepatic portal vein obstruction prevent or reduce portal hypertensive complication s?	In patients with chronic idiopathic portal hypertension/porto-sinusoidal vascular disease TIPS may be considered for the same indications as cirrhotic portal hypertension.	5
Q5. Does TIPS creation improve outcomes in patients with Budd-Chiari Syndrome?	Q5a. Patients with Budd-Chiari syndrome should be evaluated and managed at centers with experience and expertise in hematological evaluation, clinical management, and percutaneous intervention in this patient population. Ideally	5

Question	Statement	Level of Evidence
	the center will also have expertise in liver transplantation, should this be warranted at initial evaluation or during subsequent follow-up. If these resources are not available at the presenting institution, strong consideration of transfer to such an institution should be given while medical management is initiated.	
	Q5b. In patients with Budd-Chiari syndrome who remain symptomatic or without improving liver function after initiation of appropriate medical therapy and who are not candidates for percutaneous revascularization of the hepatic venous outflow tract (short segment obstruction), creation of a percutaneous portosystemic shunt, either TIPS or direct intrahepatic portosystemic shunt (DIPS), should be strongly considered.	2b
	Q5c. In patients with Budd-Chiari syndrome undergoing TIPS, we recommend close clinical monitoring and imaging follow-up.	4

Abbreviations: PFTE, polytetrafluoroethylene; LVP, large volume paracentesis; MELD, Model for End-Stage Liver Disease; CTP, ChildTurcotte-Pugh; RCT, randomized controlled trial; HHT, hepatic hydrothorax; ePTFE, Polytetrafluoroethylene; PSG, portosystemic gradient; DIPS, direct intrahepatic portosystemic shunt; TIPS, transjugular intrahepatic portosystemic shunt

Table 3.

Cardiopulmonary, Renal and Neurologic Considerations in TIPS

Question	Statement	Level of Evidence
CARDIOPULMONARY CONSIDERATIONS IN TIPS		
Q1. What cardiopulmonary testing is indicated prior to elective TIPS?	Q1a. In patients undergoing elective TIPS creation, we recommend comprehensive echocardiographic evaluation incorporating, in addition to the assessment of left ventricular ejection fraction (LVEF), measurement of left ventricular global longitudinal strain, when feasible, and the contemporary surrogates of left ventricular diastolic function.	2b
	Q1b. In patients undergoing elective TIPS creation, we recommend assessment of right ventricular function using tricuspid annular plane systolic excursion (TAPSE) and right ventricular systolic pressure (RVSP). Right ventricular strain has not become standard of care in most centers but should be measured if available.	5
	Q1c. In patients undergoing TIPS creation who have a right ventricular systolic pressure (RVSP) exceeding 45 mmHg or TAPSE less than 1.6 cm, we recommend referral to cardiology for consideration of right heart catheterization to evaluate for RV dysfunction and pulmonary hypertension prior to TIPS creation.	5
	Q1d. In patients undergoing TIPS creation, who have tachycardia or bradycardia on physical examination, we recommend pre-TIPS electrocardiographic assessment to evaluate for arrhythmia.	5
Q2. Does cirrhotic cardiomyopathy or diastolic dysfunction confer a risk for post-TIPS heart failure?	Q2a. In patients undergoing elective TIPS creation, we recommend considering the presence of systolic and/or diastolic dysfunction, which may suggest cirrhotic cardiomyopathy in the absence of other cardiac history, a significant risk factor for post-TIPS heart failure.	2b
	Q2b. In patients undergoing evaluation for elective TIPS, we recommend avoiding TIPS if LVEF is < 50% or if there is grade III diastolic dysfunction, given the risk of post-TIPS cardiac decompensation.	5
Q3. Can TIPS be safely performed in patients with moderate or severe portopulmonary hypertension?	Q3a. In patients with moderate or severe portopulmonary hypertension (POPH) on treatment (i.e., mean pulmonary artery pressure (mPAP) > 35 mmHg, pulmonary vascular resistance (PVR) > 3 wood units), we recommend significant caution when considering TIPS insertion as it may precipitate right-sided heart failure.	5
	Q3b. In patients undergoing elective TIPS who do not have evidence of POPH on screening, we recommend measuring the right atrial pressure at the time of planned TIPS insertion and if > 14 mmHg, we recommend considering right heart catheterization prior to TIPS creation to exclude POPH based on the clinical situation.	5
Q4. Can tricuspid regurgitation severity be prohibitive of TIPS creation?	In patients being considered for elective TIPS who have moderate or severe tricuspid regurgitation despite optimization of volume overload, we recommend evaluation for the underlying cardiopulmonary etiology, which can prohibit proceeding with TIPS.	5
Q5. Can TIPS treat hepatopulmonary syndrome (HPS)?	We do not recommend TIPS as a therapy for HPS, but it may be considered in patients with HPS who have an established indication for TIPS.	4
Q6. Does stent size affect risk for post-TIPS HF in high cardiac risk patients?	In patients with systolic and/or diastolic dysfunction or mild POPH who are undergoing TIPS, we recommend balancing the desired portosystemic gradient with potential worsening of cardiac function by initially deploying the endoprosthesis to 8 mm diameter. If the desired gradient is achieved, no additional dilatation of the shunt should be pursued.	5
Q7. Is there a need for postTIPS echocardiographic surveillance?	In patients with systolic and/or diastolic dysfunction, pulmonary hypertension, or moderate to severe valvular disease, we recommend echocardiographic surveillance at 3 months post-TIPS or earlier, if indicated. Surveillance beyond 3 months can be considered if there is echocardiographic worsening at 3 months (compared to baseline) or if there is clinical indication.	5
RENAL CONSIDERATIONS IN TIPS		

Question	Statement	Level of Evidence
Q1. What is the best marker to assess kidney function before or after TIPS?	Q1a. In patients with cirrhosis undergoing TIPS, kidney function should be assessed prior to the procedure either through measurement of serum creatinine or glomerular filtration rate (GFR, estimated or measured). A change in GFR may better capture changes in kidney function, though there is insufficient evidence to recommend one equation over another.	5
	Q1b. The optimal method to assess kidney function in cirrhosis patients with sarcopenia or chronic kidney disease is not known.	5
Q2. Is there an absolute cutoff for kidney function for which TIPS is contraindicated?	There is insufficient evidence to recommend an absolute serum creatinine, CKD stage, or presence/absence of renal replacement therapy where TIPS creation is contraindicated.	5
Q3. What can be done periprocedurally to reduce the incidence of kidney complications after TIPS? What secondary or tertiary preventive measures can be considered to avoid AKI, acute kidney disease, or de Novo or progressive CKD after TIPS?	Q3a. In patients undergoing TIPS creation for ascites, albumin infusion should be considered in all patients undergoing concurrent paracentesis, and especially for those in whom >5L are removed, to prevent paracentesis-induced circulatory dysfunction and AKI.	1a
	Q3b. LVP Large volume paracentesis with albumin infusion may be performed either within 24hrs prior to, or concomitantly during TIPS creation.	5
	Q3c. Adequate hydration and judicious use of iodinated contrast are rational strategies to help reduce the risk of contrast related injury.	2b
	Q3d. In patients with AKI/CKD prior to TIPS or in those that develop AKI after TIPS creation, kidney function should be closely followed within 1 week of discharge after TIPS creation.	5
Q4. What is the role of TIPS for hepatorenal syndrome (HRS)?	Q4a. There is insufficient evidence to recommend for or against the use of TIPS for treatment of hepatorenal syndrome; however, presence of HRS is not an absolute contraindication for TIPS creation in the presence of other indications (e.g., refractory ascites, variceal bleeding).	2a
	Q4b. Mortality in patients with HRS undergoing TIPS appears to be driven by liver function (i.e., serum bilirubin, INR), therefore, careful patient selection is recommended.	4
HEPATIC ENCEPHALOPATHY AND TIPS		
Q1. When counseling patients, what is the overall risk of overt hepatic encephalopathy after TIPS and what patient specific factors contribute to development of overt HE?	We recommend counseling patients that TIPS is associated with a risk of overt HE in approximately 25–50% of recipients (1b). Patient specific risk factors for development of post-TIPS overt HE include prior history of overt HE, advanced age, advanced liver dysfunction (CTP Class C), hyponatremia, renal dysfunction and sarcopenia (2a).	1b, 2a
Q2. What social factors should be considered a contraindication to elective TIPS as it relates to overt HE?	We recommend avoiding elective TIPS in patients with cognitive impairment and limited family or social support.	3
Q3. What is the role for formal evaluation for covert or minimal HE prior to elective TIPS?	In patients being considered for elective TIPS, testing for covert or minimal HE could be considered for prognostication and discussion with the patient.	2
Q4. What TIPS stent diameter should be considered with regards to limiting post-TIPS HE?	In patients undergoing elective TIPS for ascites, we recommend starting with a smaller diameter controlled-expansion stent to potentially reduce rates of HE.	4
Q5a. Is there a role for collateral embolization at the time of TIPS?	In patients undergoing elective TIPS for ascites and/or hepatic hydrothorax, embolization of spontaneous portosystemic shunts (SPSS) >6mm may be considered in order to reduce the risk of post-TIPS hepatic encephalopathy.	4
Q5b. Is there a role for TIPS with shunt embolization in the management of refractory HE related to presumed clinically significant portosystemic shunting?	In select patients with large (>6mm) SPSS and refractory HE, we recommend that shunt embolization be considered. For select patients who develop portal hypertensive-associated complications (ascites, varices) after shunt embolization, we recommend that small caliber TIPS creation could be considered.	4
Q6a. What is the role for medical prophylaxis to prevent HE after TIPS?	In patients without a history of overt HE undergoing TIPS, we do not recommend medical prophylaxis to prevent HE after TIPS.	3
Q6b. What is the recommended medical therapy to treat overt HE after TIPS?	We recommend medical management of post-TIPS overt HE based on current guidelines with the use of lactulose and rifaximin.	1

Question	Statement	Level of Evidence
Q6c. What is the role for TIPS stent reduction/ occlusi on as the treatment of persistent or refractory HE?	We recommend consideration of TIPS stent diameter reduction in patients with persistent or refractory HE post-TIPS.	2b

Abbreviations: CTP, Child-Turcotte-Pugh; LVEF, left ventricular ejection fraction; TAPSE, tricuspid annular plane systolic excursion; HF, heart failure; RVSP, right ventricular systolic pressure; mPAP, mean pulmonary artery pressure; PVR, pulmonary vascular resistance; POPH, portopulmonary hypertension; HPS, hepatopulmonary syndrome; GFR, glomerular filtration rate; CKD, chronic kidney disease; AKI, acute kidney injury; LVP, large volume paracentesis; HRS, hepatorenal syndrome; INR, internationalized normal ratio; HE, hepatic encephalopathy; SPSS spontaneous portosystemic shunt; TIPS, transjugular intrahepatic portosystemic shunt

Table 4.

Future Research Directions Related to TIPS

Area	Knowledge Gap/Future Research
Standard setting in TIPS	• Prospective data are needed to establish threshold INR and platelet levels for safe TIPS creation as well as to investigate the role of fibrinogen and thromboelastography in the assessment of procedural bleeding risk. • Prospective data could validate societal recommendations regarding the use of periprocedural antibiotics. Currently these recommendations are based on expert consensus rather than studies demonstrating improved outcomes or decreased infectious complications. • Prospective data are needed to assess whether the use of intravascular ultrasound to assist with the portal vein puncture leads to decreased complications or improved survival. • Is there a MELD threshold for TIPS? Future studies require a large size, diverse geographic regions/multi-center studies, increased representation of populations with ascites, higher MELD scores, and standardized procedural techniques. • Prospective data are needed to determine and assess quality indicators throughout the course of TIPS planning and for long-term management of post-TIPS patients.
Ascites/Hepatic Hydrothorax	• Better refinement of parameters of liver function, such as MELD or total bilirubin, that should be utilized in risk stratification or as a contraindication to elective TIPS creation is needed. • The role of TIPS creation in patients with ascites that is not refractory requires further study in prospective randomize controlled trials. • Prospective data are needed to determine whether there is a clinical benefit to universal post-TIPS surveillance doppler ultrasound to monitor for TIPS stenosis in patients who undergo TIPS for refractory ascites. • A better understanding of the role of TIPS creation in transplant recipients with ascites is needed, including refinement of candidate selection criteria and comparison to other therapeutic strategies.
Variceal Bleeding	• Prospective data are needed to further refine criteria for preemptive TIPS, particularly studies which include a range of CTP Class and stratify by etiology of cirrhosis. • The timing of rescue TIPS creation and futility (or not) of the procedure in advanced CTP Class C cirrhosis (score 14–15) remains to be established. • The timing of TIPS creation in patients with PVT diagnosed at the time of variceal hemorrhage needs to be established. • Prospective data are needed on endoscopic therapy vs covered TIPS with/without variceal obliteration vs variceal obliteration alone to prevent GV rebleeding. • Prospective data are needed to establish whether use of a small diameter covered TIPS stent with and without variceal obliteration to control bleeding is efficacious in order to reduce HE. • Prospective data are needed to determine predictors of GV rebleeding and HE after TIPS both with and without variceal obliteration. • Data are needed to support standardization of surveillance protocols after GV treatment. • Prospective data are needed to identify the target PSG after intervention in order to prevent GV rebleeding. • Data are needed to determine the optimal frequency of surveillance for TIPS stenosis/occlusion. • Prospective data are needed to determine whether long term use of non-selective beta blockers after TIPS reduces risk for recurrent variceal hemorrhage.
Novel Indications for TIPS	• Multicenter studies, ideally controlled, evaluating portal hypertensive complications and post-liver transplant outcomes in patients with portal vein obstruction pre-LT who undergo portal vein reconstruction and TIPS creation prior to LT. • Multicenter controlled studies evaluating safety and efficacy of medical and invasive interventions (including TIPS) in patients with symptomatic non-cirrhotic portal hypertension due to extrahepatic portal vein obstruction. • Budd-Chiari Syndrome o In the minority of patients in whom anticoagulation alone improves liver function and results in resolution of portal hypertensive complications, does a risk for progressive liver failure persist? If so, can this be avoided by earlier percutaneous intervention? o Over what timeframe and based on what specific criteria should progression between stepwise management progress? o What factors predict failure of anticoagulation alone, such that a patient presenting with BCS would proceed to venoplasty/stenting or TIPS (based on anatomy) immediately? o In which patients should transjugular portosytemic shunting be avoided and urgent liver transplantation be the primary nonmedical therapy employed? • Long-term PV Access o Safety and efficacy of creating TIPS as an easily accessible intermediate or long-term route for portal infusion therapy (i.e., portal chemoperfusion)
Cardiopulmonary Considerations	• Utility of new cardiac imaging modalities (e.g., MRI and PET) in pre-TIPS cardiac risk assessment and post-TIPS cardiac surveillance • Post TIPS changes in cirrhotic cardiomyopathy, its components, and severity • Evolution of after TIPS in patients with mild portopulmonary hypertensionright heart function and pulmonary vascular hemodynamics • Role of cardiac biomarkers in post TIPS surveillance • Impact of post TIPS echocardiographic surveillance on cardiac decompensation and survival • Effect of TIPS on cardiac function after the first year post TIPS • The interplay between stent size and cardiac function post TIPS • Impact of valvular heart disease on TIPS outcomes

Area	Knowledge Gap/Future Research
Renal Considerations	• What drivers of MELD or MELD-Na dictate outcomes? For the same MELD/MELD-Na score, does a creatinine predominant MELD or MELD-Na have different outcomes compared to other drivers of MELD/MELD-Na score? • What is the role of novel biomarkers in prediction of kidney outcomes after liver transplantation? • What is the of role of TIPS in patients with CKD, and those with sarcopenia? • What is the role of peri-procedure vasoconstrictor use to prevent kidney dysfunction?
Hepatic Encephalopathy and TIPS	• Objective metrics beyond patient characteristics and laboratory values are needed to better predict post-TIPS HE. • Future studies investigating the effect of medically controlled covert HE on post-TIPS OHE are necessary. • Future prospective RCTs are needed to investigate the role for medical prophylaxis to prevent post-TIPS OHE. • The indication of TIPS for embolization of large portosystemic shunts in the management of uncontrolled OHE requires further study.

Abbreviations: GV, gastric varices; MRI, magnetic resonance imaging; OHE, occult hepatic encephalopathy; PET, positron emission tomography; pTIPS, preemptive TIPS; PSG, portosystemic gradient; PVT, portal vein thrombosis; RCT, randomized controlled trial; TIPS, transjugular portosystemic shunt