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LIVER (S COTLER AND E KALLWITZ, SECTION EDITORS)

Evaluation and Management of Cirrhotic Patients Undergoing Elective Surgery

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Abstract

Purpose of Review Cirrhotic patients have an increased risk of surgical complications and higher perioperative morbidity and mortality based on the severity of their liver disease. Liver disease predisposes patients to perioperative coagulopathies, volume overload, and encephalopathy. The goal of this paper is to discuss the surgical risk of cirrhotic patients undergoing elective surgeries and to discuss perioperative optimization strategies.

Recent Findings Literature thus far varies by surgery type and the magnitude of surgical risk. CTP and MELD classification scores allow for the assessment of surgical risk in cirrhotic patients.

Summary Once the decision has been made to undergo elective surgery, cirrhotic patients can be optimized pre-procedure with the help of a checklist and by the involvement of a multidisciplinary team. Elective surgeries should be performed at hospital centers staffed by healthcare providers experienced in caring for cirrhotic patients. Further research is needed to develop ways to prepare this complicated patient population before elective surgery.

Keywords Surgery · Cirrhosis · Checklist · Child-Turcotte-Pugh · Portal hypertension · TIPS

Introduction

Patients having chronic liver disease should be formally evaluated for increased perioperative morbidity prior to elective surgeries given their metabolic and synthetic dysfunction and coagulopathy [1, 2]. Depending on the severity of their liver disease, patients are at increased risk of complications that should be considered prior to undergoing elective surgical procedures. Compared with patients having normal liver function, patients with cirrhosis have poorer outcomes (Table 1). Due to the critical role of the liver in the metabolism of many drugs, the elimination of sedatives and narcotics may be prolonged [9•]. In addition, the changes in cardiac output and oxygen uptake that occur during surgeries can lead to decreased perfusion to the liver and thus, complications of hemorrhage, hepatic and renal dysfunction, and hepatic ischemia [2]. This review summarizes current and recent literature on surgical risk assessment, preoperative optimization strategies, and postoperative risk reduction in patients with cirrhosis undergoing elective abdominal surgeries.

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Background of Surgical Risk

The risks of surgery in patients having cirrhosis stem from the altered function of the liver. Given the liver's role in drug metabolism, anesthetic agents used for induction can decrease blood flow to the liver significantly and lead to production of hepatotoxic byproducts. At baseline, cirrhotic patients have low blood pressure, low systemic vascular resistance, and elevated cardiac output, sometimes requiring vasopressors during the induction and maintenance phases of anesthesia [10].

Patients with liver disease have underlying coagulopathies, being at risk for both bleeding and thrombosis. The liver produces many coagulation factors including fibrinogen, thrombin, and factors V, VII, IX, X, and XI. Cirrhotic patients have

Table 1 Mortality after elective and emergent abdominal surgery in patients having cirrhosis, since 2010

	Telem et al., 2010 [3] (*N* = 100)	Neef et al., 2011 [4] (*N* = 138)	Andraus et al., 2015 [5] (*N* = 61)	Salamone et al., 2018 [6] (*N* = 117)	Petro et al., 2019 [7][a] (*N* = 253)
Surgery Type	Cholecystectomy, hernia repairs, appendectomy	Intra-abdominal, abdominal wall	Abdominal wall hernia repair	Hernia repair	Hernia repair
Elective (%)	6	9	3.7	6.6	27
Emergent (%)	25	47	29.4	53.6	60

Adapted from Im et al. [8••]

[a] Total 30-day morbidity and mortality

reduced production and function of these factors. In addition, cirrhotic patients have thrombocytopenia secondary to decreased platelet production, bone marrow suppression, and platelet sequestration in the spleen [11]. This combination increases their risk of both bleeding and clotting in the perioperative period.

There are several contraindications to elective surgery. In patients with alcoholic hepatitis, older studies have shown significantly higher mortality rates for open liver biopsy, exploratory laparotomy, and portosystemic shunts [12–14]. Relative contraindications vary by institution but generally include acute renal failure, acute hepatitis, cardiomyopathy, hypoxemia, and severe coagulopathy [15••]. It is recommended that elective surgeries be delayed for as long as it takes for liver function to improve.

Predictors of Surgical Risk

Given these risks in patients with liver disease, many risk assessment scores have been developed to predict the occurrence of pre- and postoperative surgical complications.

In the past, the Child-Turcotte (CT) and Child-Pugh (CP) scoring systems were used to help assess perioperative morbidity and mortality in patients with cirrhosis. The Child-Turcotte classification involves three classes A, B, and C, based on the five parameters: ascites, total bilirubin, albumin, encephalopathy, and nutritional status. In comparison, the Child-Pugh classification system replaces nutritional status with prothrombin time or INR. Based on points, classes are assigned as follows: score 5–6 class A, 7–9 class B, and 10–15 class C (Table 2). Both scoring systems reflect the degree of decompensation of cirrhosis.

Studies have shown that a higher score corresponds to a worse predicted perioperative morbidity and mortality [18–20]. Patients with Child class A have a 10% risk of inpatient mortality after surgery, 30–31% for class B, and 76–82% for class C [16–19]. More recent studies from 2009 to 2011 have shown relatively similar results, with some suggesting similar outcomes of mortality in class B and C patients. Variation between studies is likely due to differences in center experience, advances in surgical and hepatology management, and differences in the type of surgeries [4, 20, 21]. A 2010 cohort at our institution of cirrhotic patients undergoing hernia surgery showed that CTP correlated with operative morbidity, but also showed a similar 30-day postoperative mortality of 12% in Child B and C classes [20].

The Model for End-Stage Liver Disease (MELD) score is preferred by some clinicians due to limitations of the CTP scoring system. Serum sodium was recently added to create the MELD-Na score to include the known increased morbidity and mortality of hyponatremia in cirrhosis [22]. The MELD score has its limitations as well, as it does not include albumin and thus fails to take into account the nutritional status of the patient. In comparing these scoring systems, the CTP scoring system also has some limitations. Some of the variables are subjective and equally weighted, despite differences in clinical significance of each variable [8••]. While studies have shown that MELD score correlates with CTP score, more recent studies suggest MELD may be a better predictor of postoperative mortality [18, 19, 23]. Both MELD and CTP scores exclude platelet count, which serves as an important surrogate marker for the degree of portal hypertension. A recent meta-analysis by Wu et al. showed that MELD-Na was better at predicting overall surgical mortality after 12 months as compared to CTP and MELD [24]. In addition, MELD has been shown to be a better predictive model of short-term mortality in patients with alcoholic hepatitis as compared to CTP [25]. However, there are scenarios in which the patient will be sicker than their MELD score, when the CTP score is more helpful in assessing the severity of their liver disease and hence their surgical risk [8••]. Some studies have shown that combining the CTP and MELD scoring systems can allow for the best predictive power of mortality [26•]. At our institution, we do not use any one prognostic scoring system and individualize each assessment, examining CTP, MELD-Na, platelet count, nutritional status, and other comorbidities.

In combination with the American Society of Anesthesiologists (ASA) physical status classification, MELD score can be used to predict mortality at 30 and 90 days as well as long term after surgery [27]. The ASA score is a grading system that reflects the preoperative health of surgical patients, ranging from class I (completely health fit patient) to

Table 2 CTP Classification for severity of cirrhosis

	Points		
Parameter	1	2	3
Ascites	None	Mild to moderate	Severe
Hepatic Encephalopathy	None	Mild to moderate (grade 1–2)	Severe (grade 3–4)
Total bilirubin (mg/dL)	< 2	2–3	> 3
Serum albumin (g/dL)	> 3.5	2.8–3.5	< 2.8
International Normalized Ratio	< 1.7	1.7–2.3	> 2.3

Add the score for each parameter to calculate CTP score. 5–6 points: CTP class A. 7–9 points: CTP class B. 10–15 points: CTP Class C [16, 17]

class V (moribund patient not expected to live 24 h with or without surgery) [28]. The Mayo Clinic produced a postoperative mortality risk calculator for patients with cirrhosis that includes ASA score [29•]. The Acute Physiology, Age, and Chronic Health Evaluation System (APACHE III) score predicts survival in patients with cirrhosis that are admitted to intensive care units. It can be used for assessing in-patient mortality but is less relevant in regard to this review given the focus on elective surgeries. Some studies have shown that the addition of preoperative albumin level to a MELD score greater than or equal to 15 can correlate with outcome [20]. With medical and surgical advancements, there is a growing elderly cirrhotic patient population. A recent review found that cirrhosis did not impact outcomes in elderly patients undergoing hepatectomy, suggesting that age itself should not necessarily preclude elective surgical procedures [30].

Risk by Surgery

The risk of morbidity and mortality of elective surgeries in patients with cirrhosis varies by the type of surgery. In general, outcomes are worse in emergent compared to elective surgeries (see Table 1). One recent review found that for hernia repair, there was a 60% total 30-day morbidity and mortality in emergent surgery, compared to 27% with elective surgery [7]. In this review, we will focus solely on intra-abdominal surgeries.

Cholecystectomy

Gallstones are common in cirrhotic patients, with prevalences as high as 29.4% [31]. One study demonstrated that in cirrhotic patients with gallstones, 22% developed jaundice, biliary colic, and cholecystitis. Overall, patients with cirrhosis tend to undergo cholecystectomy for more urgent reasons and have a higher morbidity upwards of 20% [32]. Perioperative mortality for obstructive jaundice is relatively high, upwards of 28% [31]. However, in patients with Child A and B cirrhosis and MELD scores up to 13, studies have shown that cholecystectomy may be safe, with laparoscopic cholecystectomy as the preferred method. A laparoscopic approach compared to open cholecystectomy has been shown to be associated with shorter hospital stays and operative time, reduced wound complications, and faster postoperative physical rehabilitation [33–36]. Some approaches have been developed in an effort to lower morbidity and mortality with perioperative broad-spectrum antibiotics and external biliary drainage via a transhepatic approach when surgery is not possible [37, 38]. ERCP can sometimes be used to obviate surgery in the setting of choledocolithiasis, or on rare occasion via cystic duct stent placement [39, 40]. However, a recent study showed that biliary sphincterotomy in both compensated and decompensated cirrhosis is associated with an increased risk of post-procedural bleeding [41].

Herniorrhaphy

Patients with cirrhosis have a higher incidence of umbilical hernias, up to 20%, which increases in the presence of ascites [42]. Cirrhotic patients also have higher morbidity and mortality with emergency surgical hernia repairs, correlating with increasing severity of the liver disease [5]. Conservative measures should be enacted early on to control ascites, such as paracentesis, appropriate use of diuretics, and dietary limitation of sodium [8••]. Studies suggest that elective repair has better outcomes with lower morbidity and mortality, avoiding the dangers of incarceration and rupture [6, 7, 42, 43]. MELD-Na has recently been shown to be a predictor of postoperative complications in ventral hernia repair, with interval increases in MELD-Na associated with increased overall complications [44•]. Postoperative mortality in umbilical hernia repair in patients with cirrhosis can be estimated by assessing clinical features at presentation: age greater than 65 years, MELD greater than 15, serum albumin less than 3.0 mg/dL, and sepsis being present [45].

Given the concerns of ascites worsening wound healing, increasing the risk of infection, and leading to recurrent hernias, studies have looked at transjugular intrahepatic portosystemic shunt (TIPS) to decrease portal pressures prior to elective umbilical hernia repairs. Multicenter randomized control trials have shown TIPS to be superior to large-volume paracentesis for controlling ascites [3, 8••, 46–48]. Some case

series have shown lower than expected perioperative mortality risk in cirrhotic patients who underwent TIPS before abdominal or cardiothoracic surgery [49]. Preoperative TIPS has been shown to improve operability of cirrhotic patients with portal hypertension [50•]. However, TIPS effectively reduces ascites in only about 75–80% of cases and the change may take up to 4–6 weeks to occur, potentially delaying elective surgeries [51]. Overall, TIPS is not routinely recommended based on recent AGA guidelines, but further research is needed to evaluate the benefits of this procedure in specific cases [52••]. Inguinal hernias repairs do not have appreciably higher perioperative complications in patients with cirrhosis. In addition, there is no increase in complications related to severity of liver disease based on Child Class [53].

Liver Resection

Cirrhotic patients are at increased risk of hepatocellular cancer with screening allowing for earlier detection and curative resection [54, 55, 56•]. The limited regenerative capability of a cirrhotic liver, coagulopathy, and portal hypertension can contribute to worse outcomes. Patients who can be considered for liver resection include patients with Child A cirrhosis, MELD score less than 9–10, normal bilirubin and albumin levels, and in the absence of portal hypertension [57]. Platelet count can be used as a surrogate marker for portal hypertension in cirrhotic patients [58]. Pre- and postoperative thrombocytopenia is a risk factor for liver failure after hepatectomy [59]. The size and location of the lesion also affects the surgical decision. More amenable lesions are smaller in size and are located at the surface of the liver or in the peripheral segments away from major vessels [60]. Hepatic venous pressure gradient (HVPG) can be used to assess portal hypertension prior to resection for HCC. Some studies suggest that HVPG < 10 mmgHg suggests an absence of clinically significant portal hypertension [52••, 61].

To improve outcomes, several methods have been employed before and during surgery. For patients undergoing hemi-liver resection, percutaneous portal vein embolization (PVE) of the lobe planned for resection reduces postoperative morbidity secondary to liver failure [62]. With PVE, the embolized lobe atrophies and the contralateral lobe should hypertrophy. During surgery, priorities are to limit hypotension to minimize altered hemodynamics to the liver, to maintain a low central venous pressure to minimize bleeding during parenchymal dissection, and for the placement of appropriate drains to avoid infections and to aid in draining ascites. Laparoscopic liver resection compared to open resection has been shown to result in less blood loss, shorter hospital length of stay, and a lower complication rate [63–65]. Predictors of worse survival include older age, greater severity of liver disease, higher degree of comorbidities, and extent of malignant invasion of the liver [66].

Colorectal Surgery

Colorectal surgeries for cirrhotic patients usually are performed for diverticular disease or colorectal cancer, with worse outcomes for emergent surgeries [67]. Cirrhotic patients are at higher risk of colorectal surgery postoperative morbidity and mortality, with rates as high as 26% in one study [68, 69]. A 2005 US population-based study found an 11-fold increased risk in the adjusted mortality of cirrhotic patients with portal hypertension undergoing elective colorectal surgery compared with non-cirrhotic patients [69]. In patients with inflammatory bowel disease (IBD) complicated by primary sclerosing cholangitis (PSC), colectomy is associated with a high early postoperative morbidity rate [70]. Higher MELD-Na has been shown to be a predictor for anastomotic leak in partial rectal resections [71].

Bariatric Surgery

The incidence of undiagnosed preoperative cirrhosis at the time of bariatric surgery is 2–6% [72]. Some studies have shown increased morbidity and mortality of obese patients after liver transplantation, bringing to light a discussion of the safety of bariatric surgery in obese patients with cirrhosis [73, 74]. There is limited research evaluating bariatric surgery in cirrhosis. Bariatric surgery options include Roux-en-Y gastric bypass (RYGB), gastric banding, and sleeve gastrectomy. Data suggest that sleeve gastrectomy may be the safest option for patients with cirrhosis and portal hypertension; however, there is risk of gastric variceal hemorrhage [74]. Wu et al. reviewed three studies of patients with Child A and B cirrhosis undergoing bariatric surgery, mostly undergoing laparoscopic RYGB, and found a complication rate of 32% [74]. Sleeve gastrectomy performed at the time of liver transplantation may result in better weight loss and metabolic profiles over the short term; however, limited long-term outcome data exist [75].

Other Non-Hepatic Abdominal Surgeries

Many review papers have compared cirrhotic and non-cirrhotic outcomes based on surgery type, all showing increased mortality in cirrhotic patients [76]. The 30-day mortality of open appendectomy in cirrhotic compared to non-cirrhotic patients was 9% vs. 0.7% [77]. Similar to most surgeries, laparoscopic appendectomy has better outcomes than open appendectomy [78]. In pancreatic surgery, morbidity in cirrhotic patients compared to non-cirrhotic patients was shown to be 69% compared to 44% [79]. Transurethral resection of the prostate (TURP) in cirrhotics versus non-cirrhotics carries a 30-day mortality of 6.7% versus 2% [80].

Pre- and Intraoperative Optimization

At our institution, a sequential preoperative liver assessment checklist has been developed to help guide preoperative management of cirrhotic patients (shown in Fig. 1). Other institutions have designed similar checklists [81–83].

The initial assessment of a cirrhotic patient prior to elective surgery should focus on the type, severity, and chronicity of the liver disease, as well as whether there is a history of decompensation. Patients with a history of hepatic encephalopathy should be given postoperative sedation and analgesia with caution, with adequate monitoring for bowel movements and aspiration precautions. Ketorolac is often used postoperatively and as a NSAID may carry a greater risk for precipitating renal failure and GI bleeding in cirrhotic patients [84]. Acetaminophen can safely be used as an analgesic postoperatively up to 2 to 3 g daily [85, 86]. Oral lactulose should be used with a goal of 2 to 4 bowel movements per day, administered with a small-caliber nasogastric tube if necessary. However, large frequent doses of lactulose can lead to an ileus and even a small bowel obstruction with gaseous distention leading to abdominal bloating and stretching of staple lines, so if possible, dosing should be limited.

Anesthesia decreases hepatic blood flow, which in cirrhotic patients who cannot compensate with portal blood flow may lead to further hepatic dysfunction [10, 15••, 87]. Spinal and epidural anesthesia is known to cause reduced hepatic blood flow and are often not ideal given the coagulopathies in cirrhotics [88]. Hepatic resection can also lead to new coagulopathies that can increase the risk of epidural anesthesia. However, there are no studies directly comparing different anesthetic agents in cirrhotic patients. Anesthesia should be chosen based on the individual. Any patient having an absolute contraindication to surgery, such as in the setting of acute-on-chronic liver failure, should have elective surgeries delayed or canceled. Upper endoscopy should be performed to evaluate for varices and to assess the benefit of starting a non-selective beta-blocker preoperatively.

Many patients with cirrhosis suffer from sarcopenia, with a prevalence of greater than 60% in some studies [89, 90]. Nutrition has been shown to be a predictor of mortality in cirrhotic patients [91]. Per 2019 ESPEN recommendations, cirrhotic patients scheduled for elective surgery or listed for transplant should be assessed for malnutrition early on in order to improve body protein status [92•]. Cirrhotic patients have depleted liver glycogen stores; therefore, adequate nutrition is necessary to avoid gluconeogenesis of muscle protein in this protein-depleted patient population. Optimizing nutritional status can reduce poor postoperative outcomes in patients who are moderately or severely malnourished [18]. In patients actively using alcohol, a period of abstinence prior to surgery can prevent the development of withdrawal [93, 94].

In patients with ascites, diagnostic paracentesis should be performed to exclude spontaneous bacterial peritonitis (SBP). With moderate or severe ascites, large-volume paracentesis should be performed with intravenous albumin replacement in order to reduce the risk of wound dehiscence and abdominal wall herniation. At our center, we replace every 1 to 2 L of ascites removed with 12.5 g of 25% albumin. If the patient has diuretic-resistant ascites and MELD less than 15, a preoperative TIPS can be considered. Evidence is mixed regarding the effects of preoperative TIPS on outcomes, so a multidisciplinary discussion should be held regarding its need and timing [95, 96]. At our institution, we do not routinely proceed with TIPS prior to elective surgeries. However, in cases of medically refractory ascites in which abdominal surgery is necessary to perform, i.e., colon resection for colon cancer, preoperative TIPS can be considered in patients having MELD scores less than 15, or in patients having CTP A or early B cirrhosis.

Up to 10% of cirrhotic patients can develop pulmonary complications like hepatopulmonary syndrome, portopulmonary hypertension, and hepatic hydrothorax [97]. Significant pulmonary hypertension is a strict contraindication to any type of surgical procedure, whether a patient has liver disease or not. Preoperative transthoracic echocardiography and chest x-ray should thus be evaluated. Volume overload is a notable concern in cirrhotic patients. Care should be taken in providing fluids or blood products in order to avoid volume overload which can worsen portal hypertension. This must be balanced with the provision of adequate volume replacement for urinary, diarrheal, and interstitial losses in order to lessen the risk for pre-renal azotemia and acute kidney injury.

Liver imaging with abdominal CT or MRI with intravenous contrast is used to screen for hepatic masses and assess vessel patency. If renal function precludes the use of contrast, then a preoperative abdominal ultrasound with Doppler can be performed. Coagulation disorders should be corrected. Routine subcutaneous vitamin K, 10 mg daily, for 3 days can be used to correct INR. Recent AGA Guidelines no longer recommend transfusing to a target INR in cirrhosis [52••]. The data supporting the use of FFP to correct coagulopathy in cirrhosis is limited, and newer products like prothrombin complex concentrate, while more expensive, may offer less complication risk [98–100]. FFP does not necessarily reduce bleeding risk and can increase risk of lung injury and volume overload [99]. Thromboelastography (TEG) can be used, when available, to assess all phases of clot formation and lysis, in order to guide what products should be used [101]. A 2015 randomized controlled trial found that TEG-guided transfusion can lower use of blood products without increasing bleeding complications compared to using routine tests to assess coagulopathy [102•].

Blood should be transfused to a goal hemoglobin of 7 g/dL with a restrictive resuscitation strategy, as over transfusion can increase portal pressures and risk of volume overload [99].

- Emergent or Elective
  - If surgery is potentially life-saving, proceed with surgery with adequate informed consent. Consider non-surgical alternative like ongoing medical therapy or interventional radiologic procedures or palliative care as appropriate.
- Characterize liver disease
  - Determine cause and chronicity of liver disease.
    - If acute viral or alcoholic hepatitis or severe drug-induced injury, postpone surgery until liver function improves.
    - If chronic but mild liver disease, proceed with surgery.
    - If there is evidence of cirrhosis or non-cirrhotic portal hypertension, continue with liver assessment.
- Identify significant comorbid conditions
  - Focus on presence of diabetes, chronic kidney disease, and cardiovascular disease.
  - If moderate or severe malnutrition is present, optimize nutrition by oral, enteral, or even parenteral means before surgery.
- Perform liver imaging
  - MRI or CT are preferred to evaluate for liver appearance, vessel patency, hepatocellular carcinoma, and evidence of portal hypertension (e.g. intra-abdominal varices, spleen size).
  - Ultrasound with Doppler is sufficient if there is contraindication to CT or MRI such as acute kidney injury.
- Obtain history of prior hepatic decompensation
  - Ascites: if yes, consider future impact on wound healing with postoperative recurrence
  - Encephalopathy: if yes, adjust planned sedation and analgesia, monitor for regular bowel movements. Do not restrict dietary protein, give dietary protein 1.2-1.5 g/kg daily.
  - Variceal bleeding: if yes, perform upper endoscopy and initiate variceal hemorrhage prophylaxis
- Evaluate for current hepatic decompensation
  - Ascites: if yes, perform diagnostic paracentesis to evaluate for SBP
    - If moderate or severe, perform LVP before surgery.
    - If diuretic resistant and MELD<15, consider preoperative TIPS, but not routinely recommended.
    - Give 2 g sodium diet, 35-45 kcal/g daily
  - Encephalopathy: if yes, optimize lactulose to achieve 2-4 bowel movements per day (even if NGT needed) and give rifaximin
    - Do not restrict dietary protein, give 1.2-1.5 g/kg protein daily.
    - Order aspiration precautions.
  - Variceal bleeding: if yes, perform upper endoscopy and initial variceal hemorrhage prophylaxis.
  - Hypoxemia or CHF: if yes, consider hepatopulmonary syndrome or portopulmonary hypertension
    - Perform ABG, contrast-enhanced echocardiography
- Estimate liver function and the likelihood of portal hypertension
  - Check serum total bilirubin, albumin, INR, creatinine, platelets, hepatic venous pressure gradient, if available especially with partial hepatectomy.
- Calculate CTP, MELD, and modified MELD for surgery at several time points (all cirrhotics are $\geq$ ASA class III)
  - If Child C or MELD>12 or high risk, consider alternative to surgery or transfer to liver transplant center
  - If Child C or MELD>12 or high risk, consider completing liver transplant evaluation before surgery
- Evaluate coagulopathy and anemia
  - Give subcutaneous vitamin K supplementation leading up to surgery.
  - Give DDAVP/desmopressin if renal insufficiency present.
  - In absence of hemorrhage, do not transfuse platelets if count $\geq 50 \times 10^3$ μL or cryoprecipitate if fibrinogen >50 mg/dL
  - Avoid over-transfusion to correct anemia (use hemoglobin goal 7 g/dL) to avoid increasing portal pressures
- Review medications
  - Avoid hepatotoxic medications like herbal supplements and acetaminophen >2-3 g/day.
  - Avoid nephrotoxic medications like NSAIDs (ie. ketorolac, ibuprofen) or aminoglycosides (ie. gentamicin)
  - Avoid all benzodiazepines for anxiety/insomnia and narcotics or administer those with short half-lives
  - Monitor and correct for electrolyte and acid-base disturbances that may precipitate encephalopathy
  - Avoid prophylactic antibiotics with greater risks of drug-induced liver injury like amoxicillin-clavulanate (augmentin), nitrofurantoin, TMP/SMX (Bactrim), ciprofloxacin, and levofloxacin

◀ **Fig. 1** Preoperative Liver Assessment (POLA) checklist. ABG, arterial blood gas; CHF, congestive heart failure; CT, computed tomography; ddAVP, desamino-D-arginine vasopressin; INR, International Normalized Ratio; LVP, large-volume paracentesis; MRI, magnetic resonance imaging; NGT, nasogastric tube; NSAIDs, non-steroidal anti-inflammatory drugs; SBP, spontaneous bacterial peritonitis; TMP/SMX, trimethoprim/sulfamethoxazole. (Modified from Im et al. 2014 [8••]). Used with permission from Elsevier

Platelets can be transfused if less than 50×10^3 μL. The newly FDA-approved therapy of a thrombopoietin receptor agonist (avatrombopag) can raise platelet counts in patients with chronic liver disease [103•]. Medications should be reviewed to avoid hepatotoxic and nephrotoxic medications, and acetaminophen dosing should be less than 2–3 g/day. Benzodiazepines and narcotics should be avoided or sparingly administered. Cirrhotic patients have QTc prolongation compared to non-cirrhotic patients, so care should be taken with the use of QTc prolonging medications [104]. Electrolytes should be monitored, avoiding hypokalemia which can exacerbate arrhythmias and hepatic encephalopathy. There is an increasing prevalence of *Clostridium difficile* infections (CDIs) in hospitalized cirrhotic patients; therefore, physicians should have a high suspicion for CDI, and antibiotics should be used only when clinically indicated [105].

In addition to the general preoperative liver assessment, there are liver disease-specific concerns to evaluate. Patients with non-alcoholic fatty liver disease are at increased risk of cardiovascular disease and therefore need a careful cardiac evaluation before elective surgery [106]. Patients with Wilson's disease should continue their medications in the perioperative period in order to avoid developing acute-on-chronic liver failure. Holding immunosuppressive medications in patients with autoimmune hepatitis for a couple of days postoperatively should be safe. Clinicians should be aware that after any type of surgical procedure in a patient having chronic liver disease, there may be a transient modest elevation in the aminotransferases that typically rapidly decreases back to baseline.

Overall, patients should be operated on at specialized liver or liver transplant centers that have physicians and surgeons experienced in caring for patients with acute and chronic liver disease. At times before an elective surgery in a high-risk cirrhotic patient, we have pursued a preoperative liver transplant evaluation and listing in lieu of a potential hepatic decompensation. However, the complications arising in the postoperative setting, such as infection, often preclude proceeding with transplantation, at least in the short term. Performance of other surgical procedures at the time of liver transplantation, such as colon, renal, pancreatic, and cardiac surgeries, carry higher degrees of postoperative morbidity, especially in an immunosuppressed patient, and are not favored by the transplant team. If the surgical procedure can be undertaken post-transplantation and allow the patient to safely undergo the transplant, it is always preferable.

Post-Op Risk Reduction

In the postoperative period, risks can be reduced based on surgery type and clinical scenario. If oral and/or enteral intake is inadequate, cirrhotic patients should receive early postoperative parenteral nutrition [92•]. Studies have shown that in cirrhotic patients after abdominal surgery, there is a lower complication rate when postoperative parenteral nutrition is administered rather than just intravenous fluids and electrolytes [107]. Drains should remain less than 5 to 7 days if possible in order to reduce risk of infection. If ascites recurs, early large-volume paracentesis with albumin replacement and diuresis is recommended. If kidney injury precludes this treatment approach, interventional radiology may be able to place an intra-abdominal drain to remove ascites and improve wound healing although this carries added risk for infection.

Postoperative risk reduction measures are similar to preoperative measures, including avoiding narcotics and benzodiazepines, correcting electrolyte or acid-base disturbances, monitoring volume status, and maintaining regular bowel movements to avoid constipation and hepatic encephalopathy. Early mobilization, compression stockings, and/or heparin subcutaneous injections can be used for DVT prophylaxis on an individualized basis. Postoperative portomesenteric venous thrombosis can occur after abdominal surgery, so Doppler ultrasonography should be performed in the setting of worsening ascites, portal hypertension, or liver decompensation. Antiviral medications for HIV or hepatitis B virus treatment should be resumed after surgery.

Conclusion

Patients with liver disease are at high risk of perioperative surgical complications. The earlier identification of the need for surgery can allow for improved management and outcomes as emergent surgery carries high risks of morbidity and mortality. MELD is more accurate then CTP in predicting perioperative mortality; however, there are scenarios in which CTP is more helpful. Surgical risk varies by surgery type. A preoperative checklist can help optimize patients before elective surgery. Surgery should be undertaken at a liver or liver transplant center where the providers and healthcare team have experience in dealing with portal hypertension and patients having liver disease, as well as collaborating with consultative hepatology, surgical subspecialties, and liver anesthesiology. Further research is needed to assess the safety of

TIPS prior to elective surgeries for patients having severe portal hypertension, and to identify further ways to optimize this complicated patient population before elective surgeries.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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•• Of major importance

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