Liver Transplants

40

Drugs

Extra Equipment (*institutional variation, often run by perfusionist) (Table 40.1)

1. Belmont Machine
2. Arterial Blood Gas analyzer/iSTAT

Blood Products

1. Designated fridge in the OR for blood (Tables 40.3 and 40.4)
2. Verify with OR RN that hospital blood bank has been notified of liver transplant.
3. Double check that PRBCs, FFP, and platelets (10 + 10 + 2) will be in the room by the time dissection begins.
4. Order cryoprecipitate if needed (not automatically part of the massive transfusion protocol).

Monitors and Lines

1. Routine ASA monitors
2. Radial arterial line ± awake, depends on underlying cardiac and pulmonary function
   (a) Example: severe aortic stenosis, severe pulmonary hypertension
3. Femoral arterial line
4. Right Internal Jugular Vein (IJ) (RIJ) large bore central line, ± left Internal Jugular Vein (IJ) (LIJ) large bore central line
   (a) Option 1: Double stick: 2 × Cordises in R IJ
   (b) Option 2: 1 R IJ Cordis +1 L J Cordis

C. Sampankanpanich Soria et al., *Anesthesiology Resident Manual of Procedures*,
https://doi.org/10.1007/978-3-030-65732-1_40

Table 40.1 Common medications organized by action to have prepared when performing a liver transplant

Narcotics	Midazolam 10 cc Fentanyl 20 cc
Induction agents	Etomidate 10 cc Propofol 20 cc
Paralytic	Succinylcholine 10 cc Rocuronium 10 cc
Steroids	Methylprednisolone 500 mg × 1 (at beginning and end of case)
Antibiotics	Ampicillin-sulbactam 3 g
Uppers (inotropes, pressors)	Ephedrine 10 cc syringe Phenylephrine 10 cc syringe Epinephrine gtt (pre-program to 0.02 mcg/kg/min) Phenylephrine gtt (pre-program to 20 mcg/min) Norepinephrine gtt (pre-program to 1 mg/min)
Downers (antihypertensives)	Nicardipine gtt (pre-program to 1 mg/h) Nitroglycerin gtt (pre-program to 20 mcg/min)
Emergency drugs *Most institutions have a designated "Anesthesia Liver Cart" containing these drugs	Vasopressin 1 unit/ml Epinephrine 10 mcg/ml in 10 cc syringe Epinephrine 1 mg/10 ml in 10 cc syringe Atropine 1 mg/10 ml in 10 cc syringe Lidocaine 100 mg/10 ml in 10 cc syringe *Calcium chloride 1000 mg/10 ml in 10 cc syringe *Sodium bicarbonate 50 meq/50 ml in 50 ml syringe *MULTIPLE boxes stacked on top of the anesthesia cart/machine very close by
Fluids	500 cc bottles of albumin 100 cc and 250 cc bags of normal saline to dilute medications 1 L bags of normal saline spiked and on fluid warmers

   (c) Option 3: 14/16 G PIV + R IJ Cordis
   (d) 1 central line is for Belmont machine
5. ± Swan Ganz catheter
   (a) Risks of PA catheter: atrial or ventricular arrhythmias, clot formation, traumatic placement
   (b) Benefits of catheter: assess hemodynamic changes, volume status, acute RV failure, pulmonary hypertension, prolonged ICU course
6. ± TEE probe
   (a) Caution with esophageal varices. May place TEE probe and not manipulate, leave in mid-esophageal 4 chamber view.
   (b) At least have available in room in case of emergency.
7. Airway
   (a) Largest size possible in case of fiberoptic bronchoscopy, pulmonary edema, suctioning

Preoperative Evaluation

1. Rapid sequence induction
   (a) All full-stomachs
   (b) Ascites
   (c) NPO status: called in from home, not planned
2. Hemodynamic state
   (a) Volume-depleted? Hemorrhaging?
3. Any contraindications to liver transplant?
   (a) Unstable arrhythmias
   (b) Severe pulmonary hypertension
4. Airway exam
   (a) Direct laryngoscopy ok?
   (b) Difficult intubation anticipated? – awake FOB
5. Cardiac function
   (a) Affects type of induction: any variation of etomidate, propofol with narcotic, benzodiazepines
6. Esophageal varices
   (a) Risk of TEE probe causing trauma, bleeding
7. Neurologic: mentation, hepatic encephalopathy
   (a) Hyperalgesia
8. Hematologic: coagulopathic? Prothrombotic? Thrombocytopenic?

Manifestations of Liver Disease and Their Anesthetic Implications

Adelmann et al. [1] (Table 40.2)

1. Neurological
   (a) Hepatic encephalopathy, coma, altered mental status, seizures, asterixis
   (b) In fulminant liver failure --> cerebral edema --> increased intracranial pressure --> herniation, intracerebral hemorrhage
   (c) Most liver failure patients will die of ICH
2. Cardiovascular
   (a) Hyperdynamic heart, high ejection fraction, low systemic vascular resistance, and high cardiac output.
   (b) If the liver disease is due to Wilson's disease which causes a cardiomyopathy, a low ejection fraction can be done.
3. Pulmonary
   (a) Restrictive lung physiology, decreased functional residual capacity due to ascites
   (b) Pulmonary edema, pleural effusions R > L

Table 40.2 Description of key events that occur during the pre-anhepatic, anhepatic, and reperfusion stages of a liver transplant

Phase	Event	Impact
Pre-anhepatic	Abdomen opened Ascites released Loss of tamponade effect on splanchnic vessels	Release ascites Improvement in functional residual capacity (FRC) and lung compliance Hemodynamic changes (hypotension, bradycardia)
	Usually coagulopathic	Surgeon may request pre-emptive fresh frozen plasma (FFP) and platelet transfusion to decrease bleeding during dissection
	Adhesions/scar tissue Portal hypertension Engorged splanchnic vessels	Difficult dissection High risk of traumatic injury to liver or blood vessels with hemorrhage May pre-emptively start pressors or give blood products Check ABG/TEG q20min minimum Keep volume low (low CVP) to decrease IVC distension and improve surgical view
	Lifting of liver	Loss of preload and therefore cardiac output Anticipate by watching surgeons carefully and giving pressors
	Acute vs. chronic liver failure	Acute liver failure: no time for collaterals; volume depleted Chronic liver failure: lots of collaterals
Anhepatic	Clamp vessels	Thrombus formation in IVC Significant drop in preload
	Anhepatic: no liver to make clotting factors or clear toxins	Massive bleeding potential, very high EBL Acidosis: give bicarbonate Coagulopathy: give blood products Frequent ABG/TEG q20min Glucose: hypoglycemia Hypocalcemia: massive transfusion; high citrate leading to calcium chelation Hyperkalemia: hyperventilation, bicarbonate Vasoplegia: loss of arterial waveform, hypotension Cold: Bair hugger on, warmed room; cold temperature worsens coagulopathy
	Waiting for surgeons to anastomose new liver	Organize your workstation Have a couple syringes of epinephrine, bicarbonate, and calcium setup Dilute epinephrine 10 mcg/ml in line ready to bolus Carefully watch TEE, EKG, and arterial lines

Table 40.2 (continued)

Phase	Event	Impact
Reperfusion	Cold, acidotic, hyperkalemic, high lactate, and high citrate blood is reperfused and recirculated Staged reperfusion: surgeons slowly unclamp	This is when bad things happen (cardiac arrest, acute RV failure, MI, etc.) Hypocalcemia → hypotension Hyperkalemia → arrhythmias Cold → arrhythmias, coagulopathy Massive blood loss → coagulopathy Acidosis → arrhythmias, myocardial ischemia/infarction, coagulopathy, hypotension Thrombi → arrhythmias, hypotension, pulmonary hypertension

4. Gastrointestinal
   (a) Ascites, esophageal varices, peptic ulcer disease
   (b) High aspiration risk because ascites, so do rapid sequence induction
   (c) Massive splanchnic vasodilation
5. Renal
   (a) Massive splanchnic vasodilation --> low renal perfusion pressure --> renal vascular urge tries to vasoconstrict by activating the renin-angiotensin-aldosterone system --> salt and water retention
   (b) Diagnosis of exclusion
   (c) Kidneys sense they are underperfused
6. Hematologic
   (a) Hypercoagulable and hypocoagulable
   (b) Even with an elevated INR, a patient's TEG can show hypercoagulability
   (c) Just because a patient has a high INR doesn't mean they have a propensity to bleed, because the INR tests for specific factors only
   (d) Liver makes factors 2, 7, 9, and 10, and proteins C and S, but proteins C and S have shorter half-lives
7. Endocrine
   (a) Impaired glucose homeostasis, decreased gluconeogenesis --> hypoglycemia
8. Infectious Disease
   (a) Prone to infection, bacterial translocation across gut wall
   (b) Everyone always thinks of spontaneous bacterial peritonitis, but the most common infection is actually pneumonia
9. Metabolic
   (a) Electrolyte imbalances, malnourished, chronically hyponatremic (water > sodium), hypokalemia, hypomagnesemia

(b) High volume of distribution – theoretically need higher dosage of induction drugs, but impaired hepatic metabolism of drug, so lasts longer, don't need higher doses in real life

10. Hepatorenal (see above)
11. Hepatopulmonary
    (a) Increased shunting from arterial to venous (right to left) within the intrapulmonary vasculature --> hypoxia
    (b) Do better when lie down because less shunting
    (c) Basically the liver makes and clears VEGF (vascular endothelial growth factor), and in liver failure, VEGF makes it to the pulmonary circulation and creates AVMs
12. Portopulmonary
    (a) Pulmonary hypertension due to portal hypertension (portal to systemic circulation)
    (b) Toxic mediators are not cleared by the failing liver --> systemic circulation --> severe pulmonary artery hypertension

Phases of Liver Transplant

Guidelines for Acute Massive Blood Loss (Table 40.3)

Table 40.3 Management of massive blood loss

Goal	Intervention	Comments
Call for help	Blood Bank OR RN OR Runner Massive Transfusion Protocol	Blood bank mobilizes 45 U packed red blood cells (PRBC), 45 U fresh frozen plasma (FFP), 4–6 U Platelets as soon as possible (ASAP) Blood bank supplies batches of 10 U PRBC, 10 U FFP, 1–2 U plt
Restore Volume	Large bore IV access, Central Line	
	Crystalloid, colloid	Caution w/dilutional anemia Caution w/coagulopathy Monitor CVP
	Blood products	Blood loss is often underestimated Caution w/coagulopathy Caution w/hypothermia Caution w/hypocalcemia
	Maintain normal BP and urine output (UOP)	Pressors, inotropes
Arrest bleeding	Early surgical intervention	
Monitor Labs	CBC, Coags, Fibrinogen, TEG ABG, BMP	

Contents of Blood Products

Blood products are separated into specific components which should be transfused according to the patient's coagulopathy status (Fig. 40.1 and Table 40.4)

- Cryo = factor VIII, factor XIII, vWF, fibrinogen
- 1 unit of FFP = 2 × fibrinogen and 2 × factor VIII in 1 unit of Cryoprecipitate
- 1 pack Cryo = 5 units Cryo
- Typical ratios of transfusion: 2–3: 2–3: 1 of PRBC: FFP: Plt

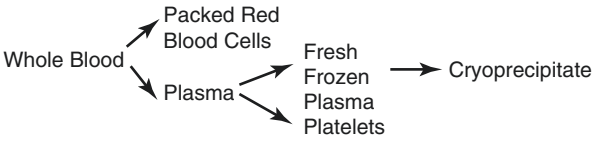

Fig. 40.1 Diagram outlining how whole blood is separated into individual components for blood transfusion

Table 40.4 Options for blood transfusion

Blood product	Special preparation	When to transfuse	How much to transfuse	Expected change
PRBCs	Fresh: <7 days old Washed if patient <1 year old or <10 kg	Hb < 7 Hct < 21 Clinically indicated	10–15 cc/kg	Increases Hb 2–3/Hct 6–9
FFP		½ × blood volume has been replaced w/PRBCs Excessive oozing without known cause	10–15 cc/kg	Increases factors 15–20%
Platelets		EBL > 1–2 × blood volumes Platelet count <100 K w/ further blood loss anticipated	5–10 cc/kg	Increases platelet count 50–100 K
Cryoprecipitate		Extensive blood loss replaced w/PRBC and FFP Clinical/laboratory evidence of coagulopathy Hypofibrinogenemia	5–10 cc/kg	Increases fibrinogen 60–100 mg/dL
Whole blood	<7 days old		Replace blood loss "cc per cc"	
Reconstituted blood	Mix donor-matched PRBCs and FFP Irradiated Washed if >7 days old		Replace blood loss "cc per cc"	

Non-blood Products

- Recombinant factors
- VIII, IX, VIIa, etc.
- K-Centra = PCC = Prothrombin Complex Concentrate = II, VII, IX, X, Protein C + S
- Antifibrinolytics
  - TXA = tranexaminic acid
  - Amicar = aminocaproic acid
- Protamine

Reference

1. Adelmann D, Kronish K, Ramsay MA. Anesthesia for liver transplantation. Anesthesiol Clin. 2017;35:491–508.