LIVER RESECTION

Surgical Specialty:	Hepatology
Authors:	Geovany Siguenza, MD and Philip Pearson, MD; Loma Linda University Children's Hospital, Loma Linda, CA

Background:

- General Considerations
  - Liver resection is performed for pediatric patients with a liver mass with the goals of removing the mass, minimizing blood loss, leaving enough liver for regeneration, and avoiding liver failure.[1,2]
  - The two predominant types of liver masses in pediatric patients are hepatoblastoma and hepatocellular carcinoma.[1]
  - Other types of liver tumors that may need resection include neuroendocrine tumors, mesenchymal hamartomas, and metastatic disease.[1]
- Patient Considerations
  - Disease Specific Considerations
    - Hepatoblastomas usually occur in children under 2 years of age and are not usually associated with ascites, anemia, or jaundice. Liver function is usually normal.[2]
    - The incidence of hepatocellular carcinoma is highest below the age of 4 years and between the ages of 12-14 years. About 5% of these patients will have cirrhosis. [2]
  - Associated Comorbidities/Syndromes
    - Hepatoblastoma is associated with Beckwith-Wiedemann syndrome, familial adenomatous polyposis, and hemihypertrophy.[2]
    - Hepatocellular carcinoma patients have often been subjected to chemotherapy, and the specific protocol should be reviewed prior to surgery.
    - Chemotherapeutic agents should be reviewed for side effects and long-term effects. [1-3]

Anesthetic Planning:

- Pre-Anesthetic Evaluation
  - Additional labs/tests indicated during work-up. [1-3]
    - Complete blood cell count
    - Basic metabolic profile
    - Liver function tests
    - Type and crossmatch

        - Coagulation factors (PT/INR, PTT)
        - Imaging including CT scans and ultrasounds to determine the size and extent of tumor and if the tumor is invading any nearby structures.[2]
    - If patient has received chemotherapy, then appropriate cardiac and/or pulmonary pre-anesthetic evaluation may be necessary to evaluate heart and/or lung function.[1-3]
        - Echocardiogram
        - Electrocardiogram
        - Arterial blood gas (ABG)
        - Chest x-ray
    - Discussions to have with surgeon/family
        - Code status
        - Blood transfusions/consent
        - ECMO candidacy
- Specific or Unique Room Set-Up Requirements
    - Airway
        - Intubate with an oral endotracheal tube.
        - Consider a rapid sequence induction (RSI) if ascites present[1]
    - Drugs/Infusions
        - May need vasopressor (norepinephrine or vasopressin) or inotropes if complete occlusion of blood flow to the liver is anticipated during the surgical procedure.
    - Monitors
        - Standard American Society of Anesthesiologists monitors
        - Intra-arterial catheter[1-3]
        - Consider central venous access for measurements of filling pressures but it may not be reliable with manipulation of the liver. Safer to place in internal jugular or subclavian vein for continued access during vascular clamping [1-3]
        - Depending on the extent of surgery, consider transesophageal echocardiography[1,2]
        - Foley catheter[3]
    - Blood Availability
        - Type and crossmatch prior to surgery
        - Blood products: Packed red blood cells (pRBC) and fresh frozen plasma (FFP) in the operating room, platelets available
        - Intraoperative cell salvage – controversial due to malignancy
    - PICU Bed Availability
        - Discuss with the surgeon regarding the extent of resection.
        - Notify the pediatric intensive care unit (PICU) team about the potential for admission to the PICU.
        - Large resections require ICU level of care.
    - Other Indicated Resources (e.g., ECMO standby)
        - May require cardiopulmonary bypass [4]
            - For liver tumors that may extend into the inferior vena cava (IVC) and right atrium.[4]
            - Allows for complete resection of mass without breaking capsule and prevents tumor fracture/spillage
            - Allows for the reconstruction of IVC and/or right atrium
            - Cannulation:
                - Venous: superior vena cava/right atrium and IVC with clamping IVC above the cannula

  - Arterial: ascending aorta
  - Variations may include adding a cannula to the portal vein or directly into a hepatic vein to drain the liver.

Intraoperative Considerations:

- General
  - Monitor for blood loss, especially during resection of the liver
  - Decrease the risk of blood loss and transfusion by maintaining low central venous pressures (CVP).[5]
  - Obtain large peripheral intravenous (IV) access, preferably in the upper extremities in case of IVC clamping[1-3]
  - Discuss with the surgeon the need for complete vascular occlusion as such techniques may induce hemodynamic instability
- Induction
  - Standard inhalational induction or IV induction
    - Consider an RSI if the patient has ascites
- Positioning
  - Supine
  - Surgeon may request reverse Trendelenburg for improved visualization and to help decrease CVP and hepatic congestion.
- Maintenance
  - Maintain with sevoflurane, opioids, and neuromuscular blockade
  - Consider active warming to maintain body temperature
- Hemodynamic/Physiologic goals
  - CVP < 5 [1-3,5]
    - Although measuring CVP may not be reliable due to changes in CVP with manipulation of liver.
    - Achieved by limiting IV fluids, diuresis if possible, or nitroglycerin. [1-2]
  - Monitor for hemodynamic instability with the following surgical maneuvers
    - Total vascular occlusion (hepatic artery, portal vein, suprahepatic and infrahepatic IVC and biliary duct all occluded)
      - Cross-clamping results in a decrease in venous return and cardiac output. Systemic vascular resistance (SVR) and heart rate increase, but overall, there is a decrease in cardiac index due to the decrease in preload. [2]
      - With unclamping, cardiac index increases and SVR decreases.
    - Pringle maneuver (common hepatic artery and portal vein occlusion) used to minimize bleeding. It can be done continuously or intermittently. [1,5]
    - Intermittent clamping is better tolerated. [2]
    - Selective vascular occlusion of the hepatic artery and portal vein branches can be done, resulting in a more hemodynamically stable patient and avoiding ischemia of the remaining liver that is not being resected. [1,5]
    - When selective occlusion or the Pringle maneuver are employed, SVR increases, thus increasing the mean arterial pressure, with a drop in cardiac output. [1,2]
- Surgical Considerations
  - Maintain muscle relaxation through case
  - Need for meticulous monitoring of blood loss: Serial ABGs, lap/sponge/suction canister/drapes monitoring
- Emergence/Disposition

  - Following a major resection, ICU level of care is required after the surgery
  - If there was significant blood loss requiring massive transfusion, hemodynamic instability requiring vasoactive infusions, or severe acidosis, discuss leaving the patient intubated with the surgical team. [2]
- Post-op Pain
  - Neuraxial: Epidural [1-3]
    - Consider risks and benefits in a patient with possible coagulopathy due to liver disease or if the intraoperative course is expected to be complicated.
    - Discuss with the surgical team and family prior to surgery
    - Removal of the epidural catheter can be complicated by coagulopathy. Monitor PT, PTT, and platelets.
    - Monitor for signs or symptoms of epidural hematoma formation if an epidural catheter is placed.
  - Regional: Consider paravertebral or erector spinae plane blocks[3]
  - Opioids – intermittent bolus or patient-controlled analgesia.[1]
  - Ketamine
  - Acetaminophen[1,3]
    - Safe to use but if resection is extensive, consider withholding.
    - Discuss with the surgical team
  - NSAIDs
    - May want to avoid if pre-existing renal disease is present[1,3]
    - Discuss with the surgical team

Case Specific Complications/Pitfalls

- Hemorrhage[5] – possibility for massive hemorrhage
  - Monitor blood gases intraoperatively
  - Maintain low CVP for the resection portion of surgery[5]
  - Prevent hypothermia and acidosis
  - Intraoperative ultrasound may be used by the surgeon to delineate the mass and anatomic association with vascular structures[5]
  - Surgical technique for preventing hemorrhage is important
    - Pringle maneuver
    - Total vascular occlusion
    - Selective vascular occlusion
  - Prepare for massive transfusion 1:1:1 ratio of pRBC: FFP: Platelets
    - Consider using viscoelastic measurements like TEG or ROTOEM in helping direct blood transfusion
    - Pharmacologic agents like prothrombin complex concentrate, fibrinogen concentrate or factor VIIa may be utilized to aid with hemostasis
    - Serial ABGs to correct electrolyte abnormalities: especially hypocalcemia
- Air embolism – can occur when a hepatic vein is injured. [1]
  - Factors that increase the risk for air embolism include low CVP techniques, surgical techniques, large mass, and proximity to the IVC
  - Transesophageal echocardiography or precordial doppler may help detect air embolism.
  - Initial presentation may be sudden decrease in $EtCO_2$, hypoxemia, and hypercarbia.
  - Management:
    - Trendelenburg position.
    - CVC aspiration.
    - Supportive therapy with fluid resuscitation, vasopressors, and inotropes.

- Hemodynamic instability when Pringle maneuver or total vascular occlusion used.
    - Use vasoactive medications to support patient's hemodynamics.[3]
    - Monitor for acidosis and treat accordingly.
- Hypoglycemia[1-2] – intraoperative or postoperative
    - Monitor blood glucose during the case with ABG/point-of-care glucose measurements
    - Especially important when total vascular occlusion is performed or a large resection is required.[1]
    - May require dextrose infusion[2]
- Postoperative complications include hepatic failure, biliary leak, ascites, respiratory failure, infection, portal or hepatic vein thrombosis, and coagulopathy.[2, 5-6]

References

1.) Mogane P, Motshabi-Chakane P. Anaesthetic considerations for liver resections in paediatric patients. *Southern African Journal of Anaesthesia and Analgesia*. 2013;19(6):290-294.

2.) Hartog A, Mills G. Anaesthesia for hepatic resection surgery. *Continuing Education in Anaesthesia Critical Care & Pain*. 2009;9(1):1-5.

3.) Jacob R. Anaesthesia for biliary atresia and hepatectomy in paediatrics. *Indian Journal of Anaesthesia*. 2012;56(5):479-484.

4.) LaQuaglia MJ, Kim HB, Fynn-Thompson F, Baird C, Vakili K. Resection of hepatic tumors with central venous and right atrial extension using cardiopulmonary bypass. *Journal of Pediatric Surgery Case Reports*. 2018;30:14-18.

5.) Abdelkader HM, Abdel-Latif M, Abdelsattar M, Youssef AA. Hepatic resection in children: Highlighted and revisited steps. *Egyptian Pediatric Association Gazette*. 2019;67(1).

6.) Li K, Jiang F, Aizpuru M, et al. Successful management and technical aspects of major liver resection in children. *Medicine*. 2021;100(6).

Reviewed by:

Reviewer #1: Bridget K. Pearce, M.D., University of Michigan

Reviewer #2: Senthil Packiasabapathy, MD, Indiana University School of Medicine

Reviewer #3: T.J. Lockhart, MD, FASA, University of Nebraska

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