Pediatric Transplantation:
Liver, Intestinal and/or Multivisceral
GUH – Department of Anesthesia

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GENERAL POLICY:

A. Please refer to **Peds – Updated Pediatric Transplant Set-Up** in New Innovations under Curriculum

B. Equipment Set-Up/Positioning/Monitoring/Access: Appendix 1

C. Blood bank set up as in Appendix 2. A perfusionist will be present for every liver case with cell saver for blood washing as necessary.

D. Other Medications/Lab testing/ and TEG protocol as in Appendix 3.

E. A pediatric transplant anesthesia attending will be present for all pediatric liver cases < 12 years old. Adult transplant anesthesia attending will be present for > 12 years old depending on their comfort, communications with the pediatric transplant attending and the situation at hand. (CCS – Comfort, Communications and Situation)

LIVER, LIVER/BOWEL and MULTIVISCERAL TRANSPLANT

The most common indications for liver transplantation in children include congenital biliary atresia (patient may have had a Kasai procedure before), liver based inborn metabolic errors and cirrhosis (primary biliary and cryptogenic). Other indications include hepatic vein thrombosis, sclerosing cholangitis, primary hepatic malignancy, fulminant hepatic failure (FHF) and failure of a primary liver graft. Priority for transplantation is based on a model of End-Stage Liver Disease (ESLD) in Pediatrics (PELD). The PELD score assesses the risk of dying within 3 months, and is calculated from serum bilirubin, serum albumin, INR, age (points if < age 1 when first listed for Tx) and growth delay (points if > 2 SD below mean).

PELD calculator : http://medcalc3000.com/UNOSPeld.htm

The formula is: 10 x the following, rounded to the nearest integer:
+ 0.436 (if age <1yr when listed)
- 0.687 loge albumin g/dl
+ 0.480 loge Tbili mg/dl
+ 0.1857 loge INR
+ 0.667 (if growth >2SD below mean)

Patients with transplant-requiring malformations or tumors are handled separately, and their synthetic functions may remain intact despite the need for transplant. By comparison, adults are stratified by the MELD score, which utilizes bilirubin, INR and serum creatinine.

Since many of the pediatric patients have been identified with diseases known to progress to cirrhosis, transplants are usually done before decompensation has advanced. Thus, pediatric patients as a whole tend to be less ill than adult OLT patients. As well, the use of living donors preclude the need to wait until liver function has deteriorated enough to warrant a high priority listing for a cadaveric donor. Thus, bleeding in primary OLT in children may be modest, ranging from 10% to 100% of circulating blood volume. Indeed, it is not unusual for primary liver transplants to proceed with no transfusions at all. On the other hand, patients presenting with

FHF or with primary graft failure may be severely coagulopathic, oliguric, and hemodynamically unstable, creating major challenges in fluid and blood product management.

When the transplant is from a living donor, the recipient's surgery is scheduled to begin later in the morning. Because of the need to prepare the donor segment, surgery may take 8-12 hours.

Patients presenting with combined small bowel and liver transplants pose unique and special challenges all of their own. These patients often are ex-premies, tend to be < 1 year of age, have several co-existing conditions and in general tend to be sicker. They may have underlying chronic lung disease, exacerbating preoperative hypoxemia from ESLD, HTN with LVH, renal dysfunction from renal causes and IV access is challenging in these patients.

I. PREOPERATIVE EVALUATION

Obtain and review the pre-op evaluation of all organ systems as follows:

1. Cardiovascular
    a. Patients usually have a hyperdynamic circulation with increased heart rate, stroke volume and cardiac output, and decreased SVR and arterial BP.
    b. A history of supraventricular tachyarrythmias or an underlying cardiomyopathy, valvular heart lesion and occasionally right or biventricular failure are seen in some conditions causing childhood liver failure
    c. Obtain reports of EKG and echocardiogram on all patients

2. Pulmonary
    a. Portopulmonary Hypertension resulting in preoperative hypoxemia and right heart dysfunction may be present in some patients. Check results of echocardiogram.
    b. Preoperative Hypoxemia may be present because of intrapulmonary arteriovenous shunting, V/Q mismatch, restrictive lung disease resulting from ascites and increased intra-abdominal pressure, decreased pulmonary diffusing capacity, and a rightward shift in the oxyhemoglobin dissociation curve.
    c. URI and Chronic Lung Disease may be present in ex-premies resulting in preoperative hypoxemia

3. Renal
    a. The etiology of renal dysfunction in patients with ESLD is multifactorial, including hepatorenal syndrome, prerenal azotemia or renal tubular dysfunction (ATN).
    b. Be aware of preoperative renal function (BUN/Creatinine, creatinine clearance), especially in patient with total bilirubin exceeding 30 mg/dl. Be aware that in small infants, normal BUN/Cr levels are normally low since their muscle mass is low. A normal BUN/Cr may not rule out renal dysfunction as these patients are usually on low protein diets and have additional decreased muscle mass. Attempt to delineate ATN vs chronic renal insufficiency vs Hepato-Renal Syndrome. Consultation with pediatric nephrologist is warranted under these circumstances.
    c. It may be important to consider plasmapheresis in patients with total bilirubin > 30 mg/dl or CVVH for patients with significant renal dysfunction, especially patients with FHF. CVVH needs to be continued intraoperatively.

4. CNS
    a. CNS dysfunction may vary from mild changes in personality and intellect to hepatic coma
    b. In patients with FHF and grade III-IV coma, ICP may be elevated and needs to be followed.

5. Hematologic
    a. Anemia resulting from nutritional deficiencies, variceal bleeding, or coagulation abnormalities. Make note of preoperative HCT and WBC. If WBC is elevated or patient is febrile, the cause must be known as active infection precludes transplantation
    b. The degree of coagulopathy (platelets, PT/INR and preop TEG if available must be appreciated.
    c. Attempt to correct some of the coagulopathy prior to arrival in the OR

6. Electrolyte Disorders
    a. Most common disorders present are hyponatremia, hypokalemia, hyperphosphatemia, hypocalcemia and hypomagnesemia. Hypoglycemia is common in patients with FHF. As glycogen stores are depleted and neoglucogenesis is impaired or non-existent. TPN dependant patients are prone to hypoglycemia. During transplantation, run D10 at ½ to 2/3 normal maintenance rate either via central line or via volume line that is not being used to transfuse blood products. Adjust infusion based on ABG's. D10 may need to be tapered after solumedrol is given.
    b. Both alkalosis and acidosis can develop; alkalosis due to hyperventilation, hyperaldosteronism, or chronic diuretic therapy; metabolic acidosis due to poor peripheral perfusion, liver necrosis, or renal tubular acidosis from underlying errors in metabolism or from immunosuppressants. Giving a lot of NS during the case either with fluid or Albumin solution may result in hyperchloremic acidosis which should be corrected.

II. MAJOR THEMES

A. Volume shifts, coagulopathic bleeding, hyperkalemia, ± renal and cardiac dysfunction.

B. There are three distinct phases to the surgery: pre-anhepatic, anhepatic and reperfusion and neohepatic stage. All three are characterized by ongoing blood losses (especially if coags are abnormal), and the need to balance fluid administration against the problem with bowel edema, and low SVR characteristic of ESLD. Persistent hypoxemia may be caused by intrapulmonary shunting. The intensity of metabolic disarray depends on the patient's preoperative state.

C. The single complication most frequently leading to graft failure in children is hepatic artery thrombosis. Thus, another major theme is to tolerate a mild "coagulopathy" after reperfusion of the graft. Perioperative treatment of coagulopathy is dictated by clinical assessment, rather than the "numbers" alone.

D. Besides the transplant itself, these patients may have many other occasions for anesthetic management. Prior to transplantation, these patients may require line placements, abdominal surgery for lengthening of the bowel, correction of colostomies, ileostomies, especially in patients requiring small bowel with the liver transplants. Re-operation on POD's 1-5 is sometimes required to explore persistent bleeding, arterial thrombectomy, or repair of biliary leakage. Late biliary stricture may require stenting by the invasive radiologist.

III. INDUCTION AND MAINTENANCE

A. After placing SpO2, EKG, and BP, Pre-oxygenate. Broviac catheter may be used for induction and intraoperatively for infusing D10 solution. The broviac catheter is often removed postoperatively, so another central line is definitely warranted. Modified rapid sequence induction with cricoid pressure is used prior to induction of anesthesia. Induce

anesthesia with (ketamine, or propofol) followed by muscle relaxant (rocuronium, vecuronium or pancuronium) dependant on patients hemodynamic status, ventilate and intubate. FiO2 should then be maintained at 0.5-1 as needed with Air-O2 with PEEP of 5 cm H2O. Tidal volumes are set at 7-10 ml/kg with age appropriate RR adjusted to maintain PaCO2 levels of 35-40 mm Hg.

B. Anesthesia maintained primarily with isoflurane and fentanyl. Fentanyl total dose may be 10-30 mcg/kg during the case titrated to effect. Fentanyl infusion of 1-2 mcg/kg/hr should be used for maintenance analgesia after a loading dose of 3-5 mcg/kg. Midazolam/Lorazepam, 0.05-0.2 mg/kg should be used for amnesia initially, and can be redosed after reperfusion if necessary. Isoflurane should be discontinued if hemodynamic instability exists. Muscle relaxants as required.

C. Completion of invasive monitoring and large-bore access (Please refer to **Peds – Updated Pediatric Transplant Set-Up** in New Innovations under Curriculum) Wait to place the central line only after the PIV's and A-line are secured, as access is limited in children to be able to start all 3 lines at the same time. Make sure all lines are secured properly with tape, tegaderm and suture A-line, EJ line, Mid-line catheter and central line. Routine use of PA catheters is unnecessary secondary to technical difficulties and migration by surgical maneuvers, however, the use of PA catheter should be considered in patients who have concurrent cardiac disease or portopulmonary hypertension or are moribund. 5F PA catheters are available with the CVP port 10 cm from the tip (as opposed to the standard 5F that has the CVP port 15 cm from the tip) from the PICU and can be used even on the smallest of the infants. TEE pediatric probe, if available would help evaluate cardiac function in patients with cardiac disease and for detection of pulmonary emboli.

D. Place defibrillator pads after all the lines are placed and before prepping the patient

   a. Infant pads for < 10 kg
   b. Adult pads for > 10 kg

E. Give following drugs at start of case (Table 2)
   - Zosyn IV 100 mg/kg (max 3.375 gms), for PCN allergy, use Aztreonam IV 30 mg/kg (max 2gm) or Vancomycin IV 10-12.5 mg/kg (max 500mg)
   - Fluconazole IV 10 mg/kg (max 400 mg)
   - Ganciclovir IV 5 mg/kg (max 300 mg)

F. Follow CVP measurements throughout the case and use heart rate, systemic diastolic blood pressure readings, CVP, ABG's and urine output to guide fluid replacement.

   Important: Use crystalloids sparingly throughout the liver case. Since large volume of crystalloid lead to bowel and liver congestion, colloid volume expansion is generally preferred (as FFP or albumin). Excess crystalloid is an especial problem for the oliguric patient. Hypotonic solutions should not be used at all. **Remember you have large volume access lines with large bore extension sets. It is very easy to give large volumes, but that is only when needed. If there is no bleeding, the lines should be kept at KVO and fluids given as necessary measured by 20 ml syringes ("push-pull" method) and in small boluses.**

G. Send baseline labs: Gemstat and follow TEG protocol as in Table 3.
   - Use a transplant flow sheet to record all labs (available in cabinet in Room 4)

   - Plan lab testing q 1 hr without fail, and q 15-30 minutes during rapid blood transfusion
   - Plan lab testing q 15-30 minutes during anhepatic phase, and 10 minutes prior to, and q 5 minutes after reperfusion.

- Coags need to be sent only at the beginning and after reperfusion.
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H. Follow TEG protocol according to Table 3

I. Temperature regulation is necessary though often times quite difficult. Attempt to maintain core temperature about 36 degrees C, but certainly > 34 degrees C. Remember, significant platelet dysfunction occurs below 33 degrees C, and arrythmias < 32 degrees C.

III. INTRAOPERATIVE MANAGEMENT

STAGE 1 – PREANHEPATIC: RECIPIENT HEPATECTOMY

A. There are three strategies for managing vena caval flow during hepatectomy

1. "Clamp and Go". The portal vein, suprahepatic and infrahepatic IVC and hepatic artery are cross-clamped and the liver is removed en-bloc. A trial clamping of the IVC before hepatectomy determines if the child can tolerate significant reduction in preload and compensate with increased heart rate and SVR to maintain an acceptable mean pressure. Volume infusions may be needed to provide adequate preload. Dopamine or other pressors may be required. Most common strategy in kids.

2. "Piggyback". The liver is dissected from the IVC, which is left intact. An IVC anastomosis is created with a partial clamp of the IVC.

3. Venovenous bypass is rarely used in children.

B. The preanhepatic stage is the most common time for blood loss. Adhesions from prior surgery are lysed, the hepatic vessels clamped and the liver removed. Previous major perihepatic procedures and other intrabdominal procedures , especially the Kasai procedure and surgery for necrotizing enterocolitis creates adhesions and subsequently increases the blood loss and duration of the preanhepatic phase. Vascular compression of the IVC from a large amount of ascetic fluid and may cause a precipitous drop in blood pressure on relief of the tamponade, complicating hemodynamic management.

C. Replace intravascular volume secondary to initial drainage of ascites, third space losses, surgical bleeding and continued formation of ascites. Maintain "full" volume status in anticipation of IVC clamping and removal of liver. Because of difficulty in obtaining reliable blood loss measurements, hemodynamic variables, urine output, laboratory values and inspection of surgical field guide intraoperative fluid, blood and blood product administration throughout the procedure. It is easiest to administer blood products as reconstituted whole blood. Check to make sure the the first 5 PRBC units are less than 5 days old in patients less than 5 years old in order to minimize the storage defect, especially the potassium load. By mixing PRBC's (HCT = 55) with FFP, the final product will have a HCT in the low 30's, thus avoiding excessive swings in HCT while dealing with large swings in blood volume.

D. Because the portal vein will be clamped, bowel congestion may be a real problem. During Stage I, keep fluids reasonably restricted, replacing blood as needed. Colloid is useful for volume expansion. Excess crystalloid may lead to bowel and liver congestion, as well as extensive third spacing. Since there will be 2-4 IV lines, meticulous attention to each IV line is essential. Don't let your IV's "run away".

E. If used, infusions of Octreotide and Aprotinin are started early in this phase, and will be discontinued with reperfusion (do not set these up unless it has been discussed with the attending anesthesiologist and the surgeon).

Doses: Aprotinin

Test Dose ½-1 cc (1cc = 10,000KIU)
Load: 3cc/kg = 4.2 mg/kg = 30,000 KIU/kg
Infuse: 0.7 cc/kg/hr = 1 mg/kg/hr = 7,000 KIU/kg/hr
Octreotide: 1-2 U/kg/hr

F. Urine output should be kept > 1 ml/kg/hr. Adequate intravascular volume should be assured as the first therapeutic maneuver; however, Dopamine 2-3 mcg/kg/min, lasix or mannitol (as long as the patient has some urine output) may be required.

G. As stated above: Send baseline labs: Gemstat and follow TEG protocol as in Table 3.
- Use a transplant flow sheet to record all labs
- Plan lab testing q 1 hr without fail, but q 15-30 minutes during rapid blood transfusion
- Plan lab testing q 15-30 minutes during anhepatic phase, and 10 minutes prior to, and q 5 minutes after reperfusion.
- Coags need to be sent only at the beginning and after reperfusion.
- Follow TEG protocol as in Table 3

H. Correction of Metabolic and Coagulation Changes during the procedure

1. Ionized calcium levels must be kept between 0.95 and 1.15 at all times, and must be replaced aggressively. A unit dose of 20 mg/kg is given to correct hypocalcemia. (Remember FFP contains more citrate then PRBC's)
2. Potassium should be kept < or 4.0 mEq/L prior to reperfusion. Hyperkalemia (K > 4.0) should be aggressively treated with:
   Hyperventilation
   CaCl2 20 mg/kg
   NaHCO3 1-2 MEq/kg, and start
   Glucose/Insulin 0.5 G/kg glucose with 0.2 U/Kg regular insulin/hour (1000cc D10W with 40 U regular insulin, run at 5 cc/kg/hr)
3. Serum glucose should be > 40 mg/dL at all times. Use D10 at ½-2/3 maintenance rate until reperfusion of the liver. TPN dependant patients may need to be continued on D10 unless otherwise dictated by ABG's. D10 may need to be tapered after the solumedrol dose.
4. pH should never drop below 7.32-7.35. Correct acidosis in accord with ABG's, (mEq of NaHCO3 = Base deficit x wt x 0.3), leaving a mild base deficit of – 3 to –5, since correction to normal will yield metabolic alkalosis postoperatively and difficulty to wean from the ventilator). Depending on the patient's serum sodium, hyperventilation, NaHCO3 8.4% and/or THAM (remember 3 x the volume of THAM is necessary compared to NaHCO3 for equivalent buffering capacity) may be used. Giving large volumes of NS compared to Normosol may result in hypernatremic, hyperchloremic acidosis, compounding the problem. Neonatal NaHCO3 4.2% contains less sodium and may be used instead.
5. Coagulation problems and "oozing" should be corrected with FFP. However, FFP may not readily correct abnormal coags*. It is best to keep the patient slightly anticoagulated, so as to avoid graft thrombosis. Platelets are not given routinely, but platelet depletion (e.g. the cut edge of the donor liver) may warrant a dose of 1U/5 kg (which should raise the count by 30-50,000). Don't treat the numbers, but consult with the surgeon about the degree of constant oozing.
   (for e.g. 1 cc of plasma contains 1 U of factor 8; Since 1U/kg will raise level by about 2%, then to raise factor 8 level by 50%, one would have to give 25 cc/kg, or about 1/3 of the circulating blood volume in FFP)

   Rarely, cryoprecipitate, amicar, protamine, or DDAVP is needed based on TEG evaluation and inspection of the field.

6. Keep in mind that as ionized calcium levels fall, so do ionized magnesium levels, both due to citrate chelation; therefore, consider supplementation with MgSO4 25-50 mg/kg (over 5-10 minutes) prior to reperfusion.

STAGE 2 – ANHEPATIC PHASE

A. The order of anastomosis is: supahepatic cava, infrahepatic cava, and portal vein. The hepatic artery and bile duct are completed after reperfusion. If the piggyback technique is used, there will only be 1 caval anastamosis followed by portal vein prior to reperfusion.

B. Follow the adult protocol if venovenous bypass is used

C. Labs and TEG'S as stated above. Understand that the liver is now totally out of the system; therefore, lactic acidosis, citrate intoxication with ionized hypocalcemia and hypomagnesemia, hypoglycemia, and coagulopathy can become rapidly accentuated. Treat hypocalcemia, and acidosis aggressively in anticipation of reperfusion. Continue D10 as needed to prevent hypoglycemia. Correct acidosis as stated above to base deficit of –3 to –5, based on correction of base deficit (Base deficit x wt x 0.3)

D. Give solumedrol (methlyprednisolone) (20 mg/kg, maximum 1 gm, during completion of portal vein anastomosis after checking with the surgeon. In addition, if octreotide is being used, it should be stopped during this period.

E. Give Simulect (Basiliximab) 10 mg if < 35 kg, all others 20 mg 30 minutes before reperfusion. Check with surgeon prior to administration. For intestinal cases only, repeat Simulect at end of case.

F. The portal and hepatic veins are anastomosed. Just before unclamping the IVC, the surgeon will "flush" the liver by allowing it to bleed via the IVC freely into the field, so be prepared to keep up with this controlled (but rapid and substantial) blood loss. Typically this is 100-200 cc over 2-3 minutes. Based on ABG's, administer CaCl2 at the same time as rapid blood infusion. If calcium has not been given recently, give 20 mg/kg. Give (mEq of NaHCO3 = Base defecit x wt x 0.3) or NaHCO3 1-2 mEq/kg to correct acidosis to base deficit of –3 to –5 as stated above.

G. Consider starting Dopamine 2-4 mcg/kg/min during this phase, prior to reperfusion if warranted, based on hemodynamics or poor urine output.

H. One minute prior to reperfusion, perform the following checklist

- 100% O2
- Epinephrine (0.5-2 mcg/kg) is the pressor/ionotropic agent of choice
- Blood sample syringes x 3 ready
- Ionized calcium and acid/base status should be corrected prior to reperfusion based on "lab" work as stated above. Avoid routine "prophylactic" use of calcium, as supranormal calcium levels can lead to increased mitochondrial uptake during ischemia, the final event in cell death.

I. As preload will rapidly be restored upon unclamping the infrahepatic and suprahepatic vena cava and as part of the post-perfusion syndrome mentioned below, the right heart may become quite distended. For this reason, limit the volume administration towards the end of Stage 2. In practice, aim for low-normal filling pressures (CVP 8-10). For liver bowel and multivisceral transplants, aim for a slightly higher CVP of 10-12.

J. Reperfusion:

1. Abrupt hemodynamic changes may occur on reperfusion due to an acute influx of hyperkalemic, acidotic and cold preservation solution as well as from vasoactive substances released from the grafted liver and ischemic splanchnic bed. Within 5 minutes, the "post-perfusion syndrome" can occur, consisting of progressive bradyarrythmias, hypotension, high filling pressures, and decreased SVR. Epinephrine is the agent of choice for resuscitation. Other abnormalities (acidosis, hypocalcemia, etc.) should be corrected based on the lab work 5 minutes prior to reperfusion. Be prepared for full-scale CPR if necessary.
2. Unusual causes of hypotension include the systemic infusion of thorazine or prostaglandin E1 from the preservation solution, an inadvertent hole in the IVC with or without air embolism, unrecognized laceration of renal vessels or spleenic injury, torsion of the donor liver on its vascular pedicle, hyperacute rejection with fibrinolysis and DIC, septic shock in a patient with unrecognized intraabdominal sepsis, anaphylactic reaction to the drugs used, and hyperkalemia from abdominal examination before anesthetic induction.
3. Pulmonary edema may contribute to hypoxemia. As before, continue vigilance against a high CVP, which may lead to graft congestion and distension of slanchnic vessels (bleeding). Remember, the CVP is the pressure against which the liver and gut will be perfused via the portal veins. However, adequate filling pressures must be maintained (CVP 10-12) to ensure adequate cardiac output and thus oxygen delivery to the newly grafted organ. Use dopamine and epinephrine as vasopressure support as needed.
4. Fibrinolysis may exacerbate coagulopathy. However, children differ from adults in the incidence and severity of coagulopathy and reperfusion fibrinolysis seen intraoperatively. TEG is not essential in children for monitoring blood coagulability, and rarely is pharmacologic therapy such as Amicar and or protamine sulphate required. However, if perfusionist is available, TEG should be followed. If bleeding is a significant clinical problem, therapy should be initiated and only with consultation with the surgeon.

STAGE 3 – NEOHEPATIC STAGE

A. Once reperfusion is complete, the hepatic arterial flow is accomplished through a simple end-to-end (hepatic artery-to-hepatic artery or hepatic-to-celiac artery) anastomosis, a branch patch technique or an aortic conduit , and an iliac artery interposition graft. Temporary clamping of the aorta is needed in 15-20% of cases. In 75% of the children, the bile duct-to-duct construction is difficult since the recipient's bile duct is absent or too small. The most common procedure is duct-to-jejunum anastomosis after the construction of a Roux limb. The patient should stabilize dramatically. Vasopressors if used should be weaned off as tolerated. If vasopressors are needed, discontinue the use of isoflurane and proceed with a narcotic technique.
B. It may be desirable to avoid blood products after reperfusion to minimize the risk of hepatic artery thrombosis.
C. Maintain hepatic O2 delivery by maintaining age appropriate perfusion pressure, HCT 28-30%, SaO2 > 97% and avoidance of vasoactive agents, if possible.
D. Assuming the liver is good, no further calcium, glucose or NaHCO3 supplementation should be necessary. Acidosis and coagulopathy should also improve. Lactate levels should begin to decrease.
    1. Metabolic alkalosis may become evident with the metabolism of lactate and citrate to NaHCO3.

2. If the liver is not working, be ready for continued instability and the need to take over all the functions of the liver. Further, if this continues, the patient may need an emergency re-transplant.

E. Closure of the abdominal cavity may decrease cardiac filling pressures, potentially increase airway pressures and decrease BP, particularly if the grafted liver is large.

F. Administer additional narcotics and benzodiazepines as necessary prior to transport to PICU.

Appendix 1

EQUIPMENT SET-UP FOR PEDIATRIC TRANSPLANTATION POSITIONING/MONITORING/ACCESS

Please refer to:
Peds – Updated Pediatric Transplant Set-Up in New Innovations under Curriculum

A. Be Neat,
B. Avoid clutter
C. Set up takes into consideration the needs for different sizes of infants and children
D. Make sure the "Gem-Stat" is available and has a currently active cartridge
E. Anesthesia gas machine with compressed air supply. Multiple channel vital signs monitor
F. Capnography and Nellcor or Masimo pulse oximetry
G. Pediatric liver/small bowel transplant cart (green in color)
H. Pediatric line cart with various sizes of arterial, intravenous and central venous catheters
I. Pediatric liver/small bowel drug cart from pharmacy
J. Airway: Set up cuffed ETT, 2 sizes styletted and ready to go, oral airway, suction catheters for ETT and for O/P suctioning
K. 2 Ultrasounds for locating vessels – 1) GE Logic™ L10-22 and 2) Sonosite S-Nerve L25 13-6 MHz
L. Warming Devices:
   For all patients:
   - Fluid Warmer x 2 (2 rangers)
   - Warming mattress on the bed,
   - **Age < 2**, Pediatric Infant Underbody Bair Hugger
   - **Age > 2,** Pediatric Large Underbody Bair hugger

   In addition;
   - Keep Level-1 ready to go if there is any indication of excessive bleeding once surgery starts, for e.g. in patients "at risk" for significant bleeding, for e.g. advanced ESLD with marked coagulopathy, no matter what size of the patient.
   - Consider Belmont RIS FMS 2000 for patients > 20 KG
M. Set up blood products (Table 2) appropriate for age
N. BP cuff on the upper arm. May start with cuff on the leg but switch to the upper arm before making incision.
O. O/G tube, combined esophageal/temperature probe well lubricated
P. Indwelling urinary catheter
Q. Pediatric line and CVP kits do not come with towels, gauze, sutures, etc…. Therefore you need to keep the following items listed below ready:
   - Guide wires of 2 different sizes. Set up sterile towels, chlorohexidine prep solution, sterile packet of 4 x 4 gauze, arm boards and 4.0 Silk with curved needle, needle driver and scissors x 2.
U. Remember to secure and suture all arterial and CVP catheters. Secure all IV catheters with proper tape (chevron), tegaderm, and arm boards. Be sure all lines are well labeled and tightly secured
V. Size of CVP catheters as listed below:

APPROXIMATE DEPTH OF INSERTION FOR CENTRAL VENOUS CATHETERS

From: Andropoulos et al. Anesth Analg 2001; 93: 883-6

Patient Weight (kg)	2-3	3-5	5<7	7-<10	10-<13	13-<20	20-<30	30-<40	40-<50
Length of line Insertion	4	5	6	7	8	9	10	11	12

Catheters are inserted in the RIJ at the midpoint of a line from the mastoid process to the sternal notch; or in the RSCV 1-2 cm lateral to the midpoint to the right clavicle

Appendix 2

To be provided for by perfusionist:

- TEG machine must be turned on and ready at least 30 minutes prior to beginning of the case
- Cell Saver standby, ready for old PRBC to be washed prior to transfusion

To be provided for by nursing:

- Cardiac Defibrillator for use with age appropriate defibrillator pads
- Warming Blanket
- Flowtron boots for older children

Blood products from Blood Bank:

- In batches; Blood bank stays one batch ahead.
- Blood products are ordered in PICU and sent directly to the OR. The amounts of blood products ordered will be at the discretion of the surgical and PICU staff.
- More blood and FFP and platelets may be ordered than the order below if a lot of bleeding is expected
    - In general:
- 5-6 units PRBC's , 5-6 units FFP, of which
- 5 units of washed PRBC or fresh PRBC < 5 days old will be sent from blood bank for children < 20 kg and/or < 5 years age.
- More than 5-6 units may be set up for liver transplants where a lot of bleeding is expected, in children > 5 years of age and for isolated bowel and combined liver/bowel transplant.
- A perfusionist will be available in the operating room for every liver case with a cell saver for blood washing as necessary if more PRBC then the 5 units of fresh or washed PRBC's are needed.
- Platelets and Cryoprecipitate must be requested specifically from blood bank. (Note: Platelets are not commonly used, but if used, 1U/5kg of platelet transfusion will raise platelet count by 10,000

Appendix 3

OTHER MEDICATIONS FOR PEDIATRIC TRANSPLANTATION

Pediatric Code Sheets:

- For all other vasopressors, use the pediatric code sheets in the patient's charts. Get familiar with the drugs and how they are mixed.
- For all other drugs refer to the pediatric drug card:

Immunosupressants and Antibiotics: (Please make sure they are sent with the patient from *PICU or C51)*

Check package inserts for rate of infusions

At start of case:

- Zosyn IV 100 mg/kg (max 3.375 gms), for PCN allergy, use Aztreonam IV 30 mg/kg (max 2gm) or Vancomycin IV 10-12.5 mg/kg (max 500mg)
- Fluconazole IV 10 mg/kg (max 400 mg)
- Ganciclovir IV 5 mg/kg (max 300 mg)

60 minutes before reperfusion, during completion of portal vein anastomosis (check with surgeon)

- Methylprednisolone 20 mg/kg (max 1 gm)

30 minutes before reperfusion (check with surgeon)

- Simulect (Basiliximab) 10 mg if < 35 kg, all others 20 mg, repeat in 6 hours if high intra-operative blood loss
- Intestinal cases only; repeat Simulect at end of case (during surgical closure) Surgeon may ask you to give patient
- Thymoglobulin IV 1.5mg/kg to run over 6 hours (instead of Simulect)

LAB TESTING

- Use a transplant flow sheet to record all labs
- Plan lab testing q 1 hr, but q 15-30 minutes during rapid blood transfusion
- Plan lab testing q 15-30 minutes during anhepatic phase, and 10 minutes prior to, and q 5 minutes after reperfusion.
- Coags need to be sent only at the beginning and after reperfusion.
- TEGS are done according to protocol as described below

TEG PROTOCOL

- In general TEGS are not routinely followed in pediatric patients, however,
- Consider doing TEGS if massive blood transfusion anticipated in patients with severe coagulopathy and if perfusionist is available to help

1) Baseline + Labs
2) Every 60 minutes thereafter (if baseline abnormal or excessive bleeding)
3) 5 minutes after reperfusion (3 channels – natural, amicar, protamine) + labs
4) At least one 30 minutes after reperfusion, and repeat as indicated

- TEGS may be done anytime in addition to the above protocol (natural or with amicar or protamine) as clinically indicated
- Proper maintenance and operation is essential to ensure accurate and timely results
- Normal TEG operation involves an ample supply of clean cups and pins. Natural TEG's require 0.36 mls of blood placed in a cup. Amicar and Protamine channels require 0.33 mls of blood _ 0.03 mls 0f either amicar (10mg/ml) or protamine (0.48 mg/ml).

INTESTINAL TRANSPLANT

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In children, the leading indication of intestinal transplantation is the short-gut syndrome leading to TPN dependance and its attendant complications such as liver cholestasis and fibrosis, IV access problems and recurrent line-related sepsis. The most common causes in childhood include some neonatal and childhood catastrophe, inclusive of midgut volvulus, malrotation, necrotizing enterocolitis, combined jejuno-ileal atresia, gastroschisis and ruptured omphalocele. In some pediatric patients, bowel lengthening and tapering procedures are recommended instead of transplantation. Associated liver failure may require combined liver transplantation.

GENERAL POLICY:

A. Please refer to **Peds – Updated Pediatric Transplant Set-Up** in New Innovations under Curriculum.

B. Set up for Intestinal Pediatric Transplant is same as for Updated Pediatric Transplant Set-Up

C. Equipment Set-Up/Positioning/Monitoring/Access: Appendix 1

D. Blood bank set up as in Appendix 2. A perfusionist will be present for every liver/bowel and multivisceral case with cell saver for blood washing as necessary.

E. Other Medications/Lab testing/ and TEG protocol as in Appendix 3.

F. A pediatric transplant anesthesia attending will be present for all pediatric transplant cases < 12 years old. Adult transplant anesthesia attending will be present for > 12 years old depending on their comfort, communications with the pediatric transplant attending and the situation at hand. (CCS – Comfort, Communications and Situation)

I. PREOPERATIVE EVALUATION

A. Most patients will require a thorough work up on admission to determine:

- Remaining GI function, GI studies, history of TPN dependant pancreatitis, length and caliber of remaining intestine
- Nutritional status, growth failure documented by anthropomorphic and biochemical data, patient's ability to eat
- Degree of jaundice, portal dysfunction and synthetic liver dysfunction
- Renal function, BUN/creatinine levels, 24 hour urine creatinine.
- Cardiovascular function may be compromised if congenital jejuno-ileal atresia is associated with cardiac anomalies. Ex-premies may have patent PDA present. Anemia will lead to a hyperdynamic circulation. LV function may be compromised with severe nutritional deficiencies and volume load from anemia. Hypovolemia and hypotension may be present preoperatively. Renal HTN may be present in ex-premies requiring adequate control preoperatively.
- Pulmonary function may be compromised in ex-premies with chronic lung disease and preoperative hypoxemia worsened from sepsis and ESLD if present.
- Assessment of available venous access documented by MRV. Portal vein patency is assessed by abdominal MRV and duplex assessment.
- Hematologic evaluation in patients with associated liver disease and thrombotic disorders. Anemia resulting from nutritional deficiencies. If WBC is elevated, look for active source of infection as active infection precludes transplantation

- Electrolyte and acid-base disorder. Hypoglycemia is common in TPN dependant patients requiring continuation of dextrose infusion intraoperatively.

Obtain all lab work including EKG, echocardiogram, CXR, MRV studies, CBC, electrolyte, renal and liver function panel, coags.

II. MAJOR THEMES

A. Difficulty with venous access;
B. Volume shifts as for major intra-abdominal case; maintenance of electrolyte, metabolic, acid-base status, and adequate liver perfusion;
C. Clamping and unclamping of IVC and aorta for vascular anastomosis.
D. Avoid vasoconstrictors except those that maintain cardiac output since perfusion to the graft may be compromised.
E. Maintain strict sterility when using existing central lines and when inserting new central and arterial lines.
F. Massive bowel edema may occur after reperfusion.

III. INDUCTION AND MAINTENANCE

Same as for liver transplant. Place monitors, induce anesthesia and establish IV access and invasive monitoring. Maintain temperature as for liver transplants.

a. This a lengthy operation. Be prepared for a large amount of third space and insensible losses. Since majority of these patients have had bowel surgery before, the likelihood of increased bleeding from adhesions is very high. Give volume and blood guided by systemic blood pressure, heart rate, CVP measurements, urine output and ABG's.
b. - Use a transplant flow sheet to record all labs
   - Plan lab testing q 1 hr, and q 15-30 minutes during rapid blood transfusion
   - Plan lab testing q 15-30 minutes during anastomotic phase, and 10 minutes prior to, and q 5 minutes after reperfusion.
   - Coags need to be sent only at the beginning and after reperfusion.
   - TEGS are done according to Table 2 for combined liver transplant
c. Correction of metabolic and coagulation changes as in the liver transplant case
d. Immunosupressants and Antibiotics**:** (They will be sent with the patient from PICU or C51)
   Check package inserts for rate of infusions

   At start of case:
   - Zosyn IV 100 mg/kg (max 3.375 gms), for PCN allergy, use Aztreonam IV 30 mg/kg (max 2gm) or Vancomycin IV 10-12.5 mg/kg (max 500mg)
   - Fluconazole IV 10 mg/kg (max 400 mg)
   - Ganciclovir IV 5 mg/kg (max 300 mg)
   - SDD suspension via OG tube ---------- if not previously done in PICU

   60 minutes before reperfusion, during completion of portal vein anastomosis (check with surgeon)
   - Methylprednisolone 20 mg/kg (max 1 gm)
   30 minutes before reperfusion (check with surgeon)
   - Simulect (Basiliximab) 10 mg if < 35 kg, all others 20 mg, repeat in 6 hours if high intra-operative blood loss
   - Intestinal cases only; repeat Simulect at end of case (during surgical closure)
   Surgeon may ask you to give patient
   - Thymoglobulin IV 1.5mg/kg to run over 6 hours, (instead of Simulect)

e. Vasoconstrictors may compromise perfusion of the graft and should be avoided. When necessary to support cardiac output, dopamine over epinephrine may be considered, but phenylephrine and norepinephrine shoud be avoided.
f. The back-table procedure is used to clean out the blood vessels and in some cases, placement of arterial and venous conduits onto graft vessels will be required. For patients who have demonstrated significant liver cholestasis, fibrosis and ultra-short bowel syndrome, aortic inflow and caval drainage is preferred.
g. The venous anastomosis is to the side of portal vein in piggy-back fashion, end to end to the superior mesenteric vein, or to the IVC end to side as is done in a portocaval shunt. Be prepared for abrupt changes in venous return and blood pressure when IVC is clamped with a side-biting clamp and then removed.
h. The aortic graft is placed with infra-renal cross clamping of the aorta. Watch out for hemodynamic changes during clamping and unclamoing of the aorta as is seen during AAA rerpair.
i. Not unlike the liver transplant, prior to reperfusion, once anastomoses are completed, the arterial inflow is unclamped and the venous outflow allowed to flush 100-200 cc into the field. This acute but controlled blood loss should be anticipated and replaced prior to unclamping of the aorta.
j. Reperfusion: Initial reperfusion may be accompanied by vasodilatation and myocardial depression leading to hypotension. Volume infusion and/or a brief dose of vasopressor may be needed.
    k. Massive bowel edema may occur after reperfusion. Hypovolemia is treated with volume even if edema is present.
    l. Occasionally, bowel edema may preclude abdominal closure, which will then be completed at a later stage.
    m. Pediatric patients are usually left intubated immediately postoperatively.

Updated 4/23/2016

The following shows Mayo Stands properly set up for line placement:

Arterial Line:

Contents:
22 ga Angiocath x 2
24 ga Angiocath x 2
Arterial Line Cather – 2.5 Fr/5 cm or 3 Fr/5 cm
Additional Arterial Line Kit Contents: Needle, Syringe, Wire
Chlorhexadine Sterile Prep Stick
Needle Holder
Scissors
Silk Suture on Curved Needle
Biopatch and Occlusive Dressing
Ultrasound Probe Cover and Gel
4x4s
Sterile Blue Drape Towels

Central Line:

Contents:
Appropriate Kits: Introducer and multilumen central line in (discuss size with attending)
Sterile Drape included in kit
Biopatch
Occlusive Dressing
Needle Holder
Scissors
Silk Suture on Curved Needle
Ultrasound Probe Cover and Gel
4x4s
Sterile Blue Towels