ORGAN PROCUREMENT

Surgical Specialty:	Transplant
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Background:

- General Considerations
  - Organ donation after brain death (DBD) is considered in eligible patients who have experienced irreversible cessation of brain function, including brain stem function, per the Uniform Determination of Death Act.[1,2]
  - It is essential to know which organs are going to be procured so that distinct goals can be set and strategies initiated to improve transplant recipient outcomes.[3]
  - Brain death is associated with loss of vasomotor tone, hormonal support, and hypothermia.[5]
    - The anesthesia team's goal is to maintain homeostasis and adequate organ perfusion pressure.
  - Up to 20% of initially suitable transplant organs are unable to be transplanted due to deterioration during ICU care.[6]
    - The condition of the transplanted organ is of utmost importance for the transplant recipient.[5,7,8]
  - A large thoraco-abdominal incision necessitates the titrated use of neuromuscular blocking agents (NMBA) and/or anesthetics to blunt spinally mediated responses at doses that do not compromise organ perfusion, especially when in conjunction with vasopressors.[1]
    - Intraoperative hypertension can be addressed with the cautious use of vasodilators.[1]
    - Providers should communicate closely with the organ donation program and transplant surgeon(s) regarding anesthetic/pharmacologic preferences, which may vary institutionally and depend on the organs being procured.
- Patient Considerations
  - Disease Specific Considerations
    - With neurologic death and consequent necrosis of parasympathetic nuclei in the medulla oblongata, there is unchallenged sympathetic activity, manifesting as an outpouring of catecholamines.[9]

        - This is termed “autonomic storm” or “hyperdynamic phase” and may happen within minutes after brain death occurs.[9]
        - Within minutes after brain death, the donor will experience hemodynamic compromise due to ischemia of the spinal cord and subsequent hypotension, bradycardia, and decreased inotropy.[9]
            - Associated hypoperfusion is the greatest risk to donor organ viability.
    - Neurogenic pulmonary edema may occur as a result of systemic vasoconstriction of the hyperdynamic phase.[9]
    - Furthermore, the absence of cough/lung protective reflexes and the presence of pharyngeal atony predisposes to atelectasis, aspiration, and ultimately infection.[9, 10]
    - The procurement team may request a hyperoxia test pre-operatively to measure the alveolo-arterial (A-aO_2) gradient in order to assess the quality of the lung graft
    - In the absence of a functioning hypothalamic-pituitary-adrenal axis, donors may develop diabetes insipidus (DI) (40%), rapid decline in free T_3, and lactic acidosis due to a shift to anaerobic metabolism.[9]
    - Coagulopathy may occur due to cerebral insult and hyperdynamic phase.[9]
    - Brain death is not precluded by the presence of abnormal body movements, resulting from intact spinal reflexes.[9]
        - Up to 50% of donors may exhibit these movements, which can prove problematic during organ procurement.[11]

Anesthetic Planning:

- Pre-Anesthetic Evaluation
    - Relative fluid restriction perioperatively may aid in pulmonary edema prevention, especially if lungs are being procured.[10]
    - Assess the donor’s electrolytes and urine output
        - Donors may develop sodium derangements due to diabetes insipidus, SIADH, or cerebral salt wasting.
    - Parenteral feeding, if prescribed, can be continued intraoperatively to aid in glycemic control.[5]
        - Glycemic control may improve outcomes in renal grafts.[12]
        - Institutional NPO guidelines should be followed when determining when to discontinue enteral feeding prior to organ procurement
    - pRBC transfusion to optimize oxygen delivery is restricted/cautiously used due to the effect on the patient's immune system.[5]
        - Coagulopathy is corrected with FFP and platelets.
        - Consult hematology if needed.[5]
    - Exposure to ambient temperature, and IV fluids/blood products can worsen hypothermia.[5]
        - Active warming measures (i.e. heated blankets/fluids/humidifiers) are often required to achieve a goal temperature of 36-38 °C.[9]
        - Hypothermia can result in arrhythmias, hypotension, myocardial depression, hypoxia, hyperglycemia, and coagulopathy.[5]
    - Physical examination should focus on:
        - Airway evaluation to identify barriers to mask ventilation/intubation.
    - Discussions to have with surgeon/family

        - The donor's family may request to accompany their child to the OR during procurement until the transfer of care to the surgical team.[5]
            - If possible, this should be attempted to facilitate the continuation of the family's trust/rapport with the surgical team.
            - Discussion with transplant surgeons and pediatric intensivists is encouraged to discuss preferences in pharmacologic agents for hemodynamic stability.[9]
        - There are often multiple surgeons from different institutions present during organ procurement.
        - The doses of heparin and corticosteroids to be administered should be discussed with the surgeon(s).[13]
            - Several minutes prior to aortic cross-clamping, the anesthesia provider will administer an agreed-upon quantity of heparin which will prepare the organs for infusion of preservative solution.[13]
            - Depsite preoperative serologic testing, the procurement team(s) may request additional blood sampling to verify the donor's blood type, serology, and to perform cross-matches. These additional samples may result in a significant blood volume being drawn, especially in infants or small children.
- Specific or Unique Room Set-up Requirements
    - Airway
        - Reintubation by the anesthesia team may be necessary if lung procurement is anticipated.[1]
            - The lungs should be insufflated with 10 cm of positive airway pressure in a single maneuver and held open with CPAP.[3]
            - Once mechanical ventilation is re-initiated, a lung protective strategy should be implemented with tidal volumes of 6 - 8 cc/kg and a PEEP of 8 – 10 cm H_2O.[4]
            - If lung procurement is planned:
                - The surgical team may want to perform bronchoscopy.
                - Discuss with the surgical team if there is a need to change/upsize the existing ETT.[13]
        - The patient should be intubated with an age-appropriate, cuffed ETT to prevent aspiration, and lung protective ventilation strategies should be employed.[5]
            - TV 6 - 8 cc/kg
            - PEEP 8 - 10 cm H_2O
            - FiO_2 0.40
            - PaO_2 > 100 mmHg
            - $PaCO_2$ 35-45 mmHg[4,9]
                - In general, it is safe to mimic the ICU ventilator settings in the OR.
    - Drugs/Infusions
        - IV Anesthetics (i.e. propofol, etomidate)
            - Almost never used in organ procurement.[11]
        - Inhaled Anesthetics (i.e. sevoflurane, isoflurane, desflurane)
            - Can be used to control sympathetic responses in the patient, per surgical team preferences.[13]
        - Neuromuscular Blocking Agents
            - Rocuronium

        - Vecuronium
    - Vasoactive agents – titrate to hemodynamic goals as agreed upon with surgeon(s)
        - Milrinone IV (0.25 - 0.75 mcg/kg/min), loading dose 50 mcg/kg
            - Hypotension can occur[9]
        - Dopamine IV (2 - 20 mcg/kg/min)
        - Dobutamine IV (2 - 20 mcg/kg/min)
        - Epinephrine IV (0.1 - 1 mcg/kg/min)
        - Norepinephrine IV (0.05 - 2 mcg/kg/min)
        - Phenylephrine IV (0.1 - 0.5 mcg/kg/min), bolus 5 - 20 mcg/kg
        - Vasopressin IV (0.3 - 2 milliunits/kg/min)
            - Limited data in children[9]
            - If a donor is receiving vasopressin, clarify the indication for which it is being used. Vasopressin may also be used to manage diabetes insipidus, in which case, it may need to be continued even in the setting of hypertension.
        - Levothyroxine (T_4)
            - Refractory hypotension/cardiac dysfunction
            - 0 - 6 mo, loading (5 mcg/kg), infusion (1.4 mcg/kg/h)
            - 6 - 12 mo, loading (4 mcg/kg) infusion (1.3 mcg/kg/h)
            - 1 - 5 y, loading (3 mcg/kg), infusion (1.2 mcg/kg/h)
            - 6 - 12 y, loading (2.5 mcg/kg), infusion (1 mcg/kg/h)
            - 12 - 16 y, loading (1.5 mcg/kg), infusion (0.8 mcg/kg/h)
            - >16 y, loading (0.8 mcg/kg), infusion (0.8 mcg/kg/h)[14]
    - Glycemic Control
        - Insulin infusion (0.02 – 0.1 units/kg/hr)[14]
            - Discuss glucose goals with the procurement teams
    - Corticosteroids
        - Methylprednisolone IV
            - (15 - 30 mg/kg/d) - max dose 1,000 mg
            - For immunosuppression[14]
            - May cause fluid retention and glucose intolerance[9]
        - Dexamethasone (0.2 - 1 mg/kg) - max 10 mg
- Monitors
    - Standard ASA monitors
    - Arterial access for continuous blood pressure monitoring – typically placed in the ICU
    - Central venous access for administration of vasoactive medications – typically placed in the ICU
    - Foley catheter for strict I&Os – patients are prone to disruptions in sodium homeostasis including SIADH and DI
- Blood Availability
    - Cross-matched blood products should be available, discuss quantity with the surgical team.[13]

Intraoperative Considerations:

- General
  - Meticulous attention to detail is required by the anesthesia team intraoperatively.
- Induction
  - NMBAs are frequently used to blunt the spinal reflexes and to provide optimal surgical conditions.[3]
  - Volatile anesthetics may enable ischemic preconditioning in cardiac/hepatic procurement, thus administration 30 min prior to aortic clamping sometimes occurs.[11]
- Positioning
  - Supine
- Maintenance
  - Goal is the maintenance of physiologic homeostasis and end-organ perfusion.
    - Drugs and agents as mentioned above.
- Hemodynamic/Physiologic Goals
  - As mentioned above, anesthetics and vasodilators can be used to address hypertension, if allowed by transplant surgeons and organ procurement team.
    - Maintain age-appropriate MAP/SBP
    - Restore and maintain intravascular volume with colloids or crystalloids.[1,9]
  - Direct injury to the myocardium may have occurred during resuscitation (ie. hypoperfusion, chest compressions, metabolic acidosis, epinephrine boluses).[5]
    - Inotropic agents initiated in the PICU are often continued intraoperatively, but increased doses of inotropic agents may be required to maintain age-appropriate mean arterial pressure.[5]
    - Some major pediatric transplant centers recommend reduced doses of epinephrine/norepinephrine and substitution with vasopressin or use in combination.[15]
    - Methylprednisolone, in combination with liothyronine/levothyroxine, for endocrine management can facilitate reduced doses of the inotropes for blood pressure control.[16,17]
    - Blood pressure alone does not indicate adequate end-organ perfusion, thus biomarkers such as lactate should be followed as vasoactive agents are titrated.[9]
- Surgical Considerations
  - Midline laparotomy and sternotomy are used for multiple organ procurement procedures.
    - Procurement and associated dissection can cause excessive blood loss and hemodynamic instability.
    - Maintain hemoglobin > 8 g/dl[1]
- Emergence/Disposition
  - The anesthesia team's role in the case ends at the time of cross-clamp placement on the aortic arch vessels.
    - Organ procurement will continue with the surgeon/nursing team until all donated organs are retrieved.

Case-Specific Complications/Pitfalls

- Brain death leads to the loss of homeostatic mechanisms in virtually all organ systems.[1]
- Death of a child and organ procurement can have a profound psychological effect on nursing/medical staff and appropriate resources/support should be available.[18]
    - Clinical debriefing or Critical Incident Stress Debriefing can be an effective way to mitigate psychological stress imposed on the OR team after organ procurement.[19]
    - When possible, care should be taken to have those team members with children the same age as the donor not be a part of the case; this can cause them additional stress.
        - This is especially true when the patient is an extremely young pediatric organ donor.
    - The OR nurses remain in the room even after the transplant surgeons and organ procurement teams exit.
        - They clean the child and prepare them for transport to the morgue, completing all necessary paperwork to do so.
        - This process is often incredibly saddening, inquiring as to how fellow team members are coping can effectively foster a safe/supportive work environment.
- Organ donation after circulatory death (DCD) is considered in eligible patients as a medically/ethically acceptable approach for those who do not meet death by neurological criteria.[1]
    - DCD is defined as the irreversible or permanent absence of circulation and respiration with a growing global consensus that 5 min of asystole, apnea, and coma is sufficient.[1]
    - There is the presence of a withdrawing physician, but these patients do not routinely require anesthetic management.
    - In some countries, this can be legally done in the context of euthanasia and voluntary organ donation in a patient with an incurable neurologic disease.[20]

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