CATH LAB (DIAGNOSTIC)

Surgical Specialty:	Interventional Cardiology
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Background:

- General Considerations
  - Diagnostic catheterizations have been decreasing over time because of the availability of echocardiography and magnetic resonance imaging, which provide data without ionizing radiation or iodinated contrast exposure. However, there has been an increase in the portion of interventional catheterizations[1]
  - A wide range of diagnoses may warrant diagnostic catheterization, which dictates the anesthetic approach.
  - Conversion from diagnostic to interventional catheterization is always a possibility.
  - Occupational exposure to radiation requires the anesthesia team to don appropriate radiation protection, along with a radiation dosimeter for cumulative exposure tracking.
  - Access to the patient is often impaired, due to the necessary positioning of Anteroposterior and Lateral X-ray cameras. Unanticipated movement may lead to unplanned extubation or discontinuation of vascular access.
- Patient Considerations
  - Cath patients may be healthy or they may be progressing toward transplant.
  - A multitude of diagnoses include congenital or acquired heart disease
  - Some CHD is associated with syndromes which may further complicate anesthetic plans.

Anesthetic Planning:

- Pre-Anesthetic Evaluation
  - Labs/tests indicated during work-up
    - A preoperative echocardiogram is indicated to demonstrate cardiac structure and function although an echocardiogram under anesthesia may be done in conjunction with the cath
    - CT or MRI may reveal vascular abnormalities that dictate the location/placement of standard ASA monitors (such as the presence of an aberrant right subclavian artery, coarctation, or subclavian stenosis from prior shunts)
    - Baseline coagulation studies preoperatively if the patient is chronically anticoagulated.
  - Preoperative discussions to have with surgeon/family
    - Code Status and ECMO Candidacy

        - Perioperative cardiac arrest in the cardiac catheterization laboratory has an incidence that ranges from 0.7 to 1.6% of diagnostic or interventional catheterizations.[2] It is imperative to know both the code status and ECMO candidacy
        - With abnormal vasculature including stenoses or occlusions, the cannulation strategy in the event of an emergency must be known and communicated prior to induction of anesthesia.
        - Availability of a surgical team for central ECMO cannulation should be established prior to induction of anesthesia in select patients.
    - Discussion with family regarding the need for "flat-time," typically four hours to avoid femoral vascular hematoma, which may include prolonged sedation and/or parental involvement
- Specific or Unique Room Set-up Requirements
    - Airway
        - Many diagnostic catheterizations or interventional procedures may be undertaken with natural airway and intravenous sedation.
        - It's useful to determine baseline hemodynamics with the patient breathing room air. Nasal cannula or facemask may be used only for capnography or supplemental oxygen may be titrated in as needed with closed loop communication with the cardiologists.
            - Monitoring and normalization of end-tidal carbon dioxide is essential as it helps to ensure normal acid-base status so that hemodynamic values are accurate.
            - Prevention of airway obstruction also allows for interventional cardiologists to correctly analyze invasive waveforms. In patients with significant OSA, utilization of LMA or ETT with 21% FiO2 may be necessary.
        - In cases with a high likelihood of intervention, an anesthesiologist may opt to secure the airway with an endotracheal tube for several reasons:
            - Complications of interventions may yield frank pulmonary hemorrhage, reperfusion injury to the lung, or cardiac/vascular injuries requiring immediate cardiac surgery
            - Catheterizations may require long anesthetics, prohibitive of sedation
            - Some catheterizations with balloon intervention yield complete obstruction of cardiac output. Endotracheal tube placement is preferred in these cases.
    - Drugs/Infusions
        - Heparin
            - Heparinization with an initial bolus of 100Units/kg is frequently required when wires or catheters are placed in the systemic/arterial circulation. Heparin practices may be institution-dependent.
            - Heparin can be a lifesaving intervention in the event of shunt thrombosis. Heparin should be available in all interstage patients undergoing diagnostic catheterization.
        - Pressors and Inotropes
            - Normalization of underlying cardiac physiology often requires continuous vasopressor infusion when volatile anesthetics are utilized.
            - In patients with impaired cardiac function, the availability of inotropes is important.

        - Communication with the proceduralist when titrating any vasoactive medications is paramount for the accurate interpretation of catheterization data.
    - Inhaled Nitric Oxide
        - In patients with pulmonary hypertension or patients undergoing a pulmonary hypertension study, inhaled nitric oxide should be available for treatment or assessment of response to therapy.
- Monitors
    - Standard ASA Monitors
    - When the left heart is not being interrogated but an arterial sheath is placed for the procedure, the anesthesiologist will have live arterial pressure waveforms for most of the case.
    - In patients who require constant beat-to-beat blood pressure monitoring throughout the procedure, a peripheral arterial line is often placed by the anesthesia team prior to catheterization.
    - Monitoring of neuromuscular blockade is paramount, especially in the setting where patients are often run "light" to preserve baseline hemodynamics.
    - Core temperature monitoring along with appropriate temperature management devices as indicated (forced-air warming, radiant warmers), given that patients are often widely exposed, such as in the case of access of both neck and groin.
- Blood Availability
    - A type and screen is almost always indicated.
    - If an intervention is discussed or planned, immediate availability of blood or blood products is warranted.
- Intensive Care Unit Bed Availability
    - Patient substrate and possible intervention will dictate the need for a postoperative ICU bed.
- Other Indicated Resources (ex. ECMO standby)
    - ECMO and/or CV Surgical Standby are often required for patients in extremis or for high-risk cases
        - Examples are right heart failure, supra-systemic pulmonary hypertension, failed single-ventricle palliation including interstage patients, cardiomyopathy or myocarditis, high arrhythmia burden, and transplant evaluation.
        - CV Surgery is present, by definition, for combined procedures such as hybrid single ventricle palliation (unlikely in a diagnostic catheterization)

Intraoperative Considerations:

- General
    - Implications of Anesthesia on the Catheterization Procedure
        - A patient's baseline cardiac physiology is being studied during a diagnostic catheterization. Therefore, any derangements to that physiology secondary to anesthetic technique are undesired.
        - These derangements may occur secondary to:
            - supplemental oxygen application
            - hypotension relative to their baseline
            - hypercarbia as a normal response to sedation or analgesics
            - tachycardia from inadequate sedation or inadequate analgesia

                - positive pressure ventilation
                - hypovolemia from fasting or hypervolemia from over-resuscitation
                    - interventional cardiologists must repeatedly flush their sheaths with heparinized saline which often yields large increases in intravascular volume along with hemodilution
                    - This fluid burden is especially noteworthy in infants
                - unwanted changes in contractility/ afterload
            - The ideal patient for a diagnostic catheterization is motionless and unresponsive to stimulus while breathing spontaneously on room air with normal acid-base status. This set of parameters cannot always be achieved in pediatric patients.
            - The anesthetic goal is to do as little as possible to maintain a patient who remains motionless, eucapnic, and has baseline oxygenation with IV sedation. If this is not achievable, then a general anesthetic is needed.
            - Muscle relaxation (and intubation) may be needed to facilitate accurate intervention, either because of patient movement or the need for apneas.
        - Anesthetic and Physiologic Implications of the Surgical Procedure
            - After local anesthetic administration in the vascular access site by the cardiologist, cardiac catheterization is a largely non-stimulating procedure.
            - If interventions are undertaken by the proceduralist, profound derangements to physiology can occur.
- Induction
    - When general anesthesia is required, induction should be tailored to the patient's known underlying cardiac function and lesions.
- Positioning
    - For diagnostic catheterization, a patient remains supine throughout the procedure.
    - Proceduralists may require that a patient’s arms be placed above their head to remove them from the fluoroscopic windows.
    - Careful attention should be paid to patient positioning and lines prior to moving the X-ray cameras into position.
- Maintenance
    - Sedation
        - Many techniques for sedation are feasible to prevent movement and recall and vary by institution.
            - Intravenous midazolam, remimazolam, dexmedetomidine, propofol, or ketamine boluses or infusions
            - Fentanyl IV bolus
        - Regardless of the sedative used, the plane of anesthesia should be titrated to maintain spontaneous unsupported ventilation and normocarbia.
    - General Anesthesia
        - A balanced anesthetic that allows a patient to best maintain their baseline cardiac function and physiology
        - In patients with cardiac lesions that are affected significantly by afterload reduction, a baseline vasopressor infusion such as phenylephrine or vasopressin may be utilized to counteract any volatile anesthetic effect. The use of a consistent "background" vasopressor will also help to avoid excessive intravascular volume administration. Changes in vasoactive infusions should be discussed with the proceduralist.

        - If positive pressure ventilation and/or oxygen supplementation is unavoidable, the proceduralist must be informed, as positive pressure ventilation changes the approach to waveform analysis.
- Hemodynamic/Physiologic Goals and Surgical Considerations
    - As discussed in the general section, matching of the patient's baseline physiology is desired to get accurate diagnostic information.
- Emergence/Disposition and Post-op Care
    - When femoral access is utilized, the patient is often required to remain supine without any flexion at the hip or knee for many hours after the procedure is complete to prevent hematoma formation at the site of access, ie. Flat time.
    - Excessive coughing or bucking at emergence can compromise vascular hemostasis and lead to hematoma formation.
    - Jugular access does not require strict supine positioning, but the site is often monitored in PACU and extended recovery for several hours.
    - For femoral access, various closure devices can be utilized in select patients that reduce the "lay-flat" time.
    - In difficult patients, midazolam boluses or dexmedetomidine infusions could be considered to help tolerate lay-flat time.
- Post-op Care
    - Patients with femoral access are often asked to restrict exercise and heavy lifting for a significant period. Access sites are monitored in PACU and on the floor for up to 6 hours with high frequency depending on the size of the sheaths utilized.
    - Postoperative pain is not expected unless a procedure is many hours, which may lead to back, neck, shoulder, and hip pain from the rigid radiolucent table.
    - In diagnostic catheterizations without intervention, a patient would be expected to discharge from the hospital after recovery in the PACU.

Case-Specific Complications/Pitfalls

- Catheterization complication rate
    - For all pediatric cardiac catheterizations (which includes interventional catheterizations) the complication rate is 7.3%[3]
        - 32.4% of complications were vascular injuries
    - The cardiac arrest rate is 0.7- 1.6%[2]
    - Specific to pediatric and adult CHD patients, a direct comparison has been made between diagnostic and interventional catheterizations: diagnostic catheterizations had a 10% complication rate whereas interventional procedures had an 11.1% complication rate[4]

References

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