Disaster in the cath lab!
Preparedness and resource utilization for a routine intervention turned into an OR emergency.

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Goals:

- Discuss the utilization of manpower for this type of case. Who is the appropriate anesthesiologist for this procedure?
- Discuss the incidence of complications during interventional catheterization procedures in congenital heart disease. Is there a difference between daytime and after-hours cases?
- Discuss the management of an iatrogenic aortopulmonary fistula causing massive pulmonary edema during pulmonary balloon angioplasty after arterial switch operation.
- Highlight principles which can be applied to other scenarios.

Case:

Our patient is an 8yr old male with double outlet right ventricle (DORV), interrupted aortic arch (IAA), and D-malposed great arteries (D-MGA). Status post: Arterial Switch Operation and Interrupted Aortic Arch Repair and VSD closure at 7 days of age. Balloon angioplasty of branch pulmonary arteries & aorta and stent angioplasty of branch pulmonary arteries at 3 months, 15 months, and 3.25 yrs. Repair of hypoplastic transverse arch with placement of RV to PA homograft at 3.3 yrs. Bilateral branch pulmonary artery angioplasty and pulmonary artery stent placement at 4.3 yrs. Removal of a large homograft stent with pulmonary arterioplasty at 6 yrs.

The patient was doing well with improved exercise tolerance; a regular swimmer and participant in sports with no complaints or symptoms. There is no interval history of diaphoresis, cyanosis, breathing difficulty, syncope, or seizure.

Routine follow-up echocardiogram: mild to moderate TR with estimated RVSP ~65% systemic (unchanged), distal branch pulmonary artery stenosis, no significant homograft or proximal branch pulmonary stenosis, mild homograft insufficiency, fair ventricular function

EKG: low atrial rhythm, right bundle branch block

A cardiac catheterization was scheduled to evaluate the pulmonary arteries and stents with possible balloon dilatation of the stents if indicated.

Case Discussion:

1. Who would provide the anesthesia for this patient at your institution? (Interventional cardiologist with sedation nurse / pediatric cardiac / pediatric general / adult cardiac / adult general anesthesiologist?) How are cardiac catheterization cases categorized in your institution and what types of resources are available for each category?
2. What is the incidence of complications in the cardiac cath lab? What is the incidence of the need for extracorporeal circulation to manage cath lab disasters?
3. What are the hemodynamic goals for the induction of anesthesia in this patient?

Anesthesia is induced and two peripheral intravenous lines are placed without difficulty. The patient is intubated and the case starts. The case proceeds well. Balloon angioplasty of the right and left pulmonary arteries was done. A subsequent angiography of the descending aorta revealed a large left to right shunt between the aorta and pulmonary artery and an aortopulmonary fistula was thought to have been created.

4. What are the concerns at this point? What should one do and prepare to do?

The patient quickly becomes bradycardic and arrests. One minute of chest compressions were required, along with boluses of epinephrine, atropine and PRBCs before return of spontaneous circulation. Ice was placed on the head. Copious amounts of pink frothy secretions were seen in the endotracheal tube and circuit. The entire circuit filled with edema fluid with every expired breath.

5. Should the patient be placed on cardiopulmonary bypass (CPB) in the cath lab or in the OR? What can be done for neuroprotection intraoperatively?

The patient arrested in the cath lab (9:45am). Chest compressions were performed for one minute before spontaneous circulation returned. The patient was in the OR at 9:53am and was on CPB at 10:16am (31 min after the arrest). The patient was cooled to 20°C on CPB.

The aortopulmonary window was repaired and the RV-PA conduit was replaced. Anterior cerebral perfusion was conducted for 35 min (11:40am - 12:15pm) and cross-clamp time was 111 min (11:22am - 1:13pm). Total CPB time was 239 min (10:16am – 2:15pm). Cerebral NIRS monitors were used as well as somatic NIRS. Cerebral NIRS read in the 90s during bypass and in the 60s & 70s off bypass. The patient was rewarmed. CPB was discontinued at 2:15pm with epinephrine 0.2 mcg/kg/min and milrinone 0.5 mcg/kg/min for hemodynamic support. High frequency oscillatory ventilation (HFOV) was used in the OR to oxygenate the patient.

In the PICU, after 2 days, the patient was converted to conventional ventilation. A successful extubation was made on the 6th day (after two failed attempts on the 3rd (small pneumothorax) and 4th days). Junctional ectopic tachycardia (JET) developed in the PICU which resolved with amiodarone. On the 8th day, the patient was transferred to the pediatric floor and was discharged home on the 11th day, grossly neurologically intact.

6. Should therapeutic hypothermia be considered in the PICU?
7. Does a de-briefing session occur after every cardiac arrest in your institution?

Cardiac catheterization is being increasingly used for therapeutic purposes in the management of congenital heart disease. The incidence of periprocedural complications with interventions is greater than with diagnostic studies and the incidence of periprocedural cardiac arrest in the cath lab is higher than in general pediatric cases. So planning, preparation and appropriate allocation of resources is vital to ensure a good outcome.

Bergersen et al (3) divided cardiac catheterization adverse events into five categories (table below) and identified four factors correlated with a significantly increased risk of a level 3, 4, or 5 adverse event: (a) systemic ventricular EDP ≥ 18 mm Hg, (b) systemic arterial saturation < 95% (or < 78% if single ventricle [SV]), MVsat < 60% (or < 50% if SV), and pulmonary artery systolic pressure > 45 mm Hg (or mean > 17 if SV).

Definitions for Adverse Event Severity

Severity Level	Definition	Examples
1–None	No harm, no change in condition, may have required monitoring to assess for potential change in condition with no intervention indicated.	Balloon rupture Equipment problem
2–Minor	Transient change in condition, not life-threatening, condition returns to baseline, required monitoring, required minor intervention such as holding a medication, or obtaining laboratory test.	Groin hematoma Self-resolving arrhythmia
3–Moderate	Transient change in condition may be life-threatening if not treated, condition returns to baseline, required monitoring, required intervention such as reversal agent, additional medication, transfer to the intensive care unit for monitoring, or moderate transcatheter intervention to correct condition.	Unstable arrhythmia with preserved blood pressure requiring intervention Vascular damage not life-threatening but requiring intervention
4–Major	Change in condition, life-threatening if not treated, change in condition may be permanent, may have required an intensive care unit admission or emergent readmit to hospital, may have required invasive monitoring, required interventions such as electrical cardioversion or unanticipated intubation or required major invasive procedures or transcatheter interventions to correct condition.	Event requiring cardiopulmonary resuscitation Event leading to surgery or repeat catheterization Stroke
5–Catastrophic	Any death, and emergent surgery or heart lung bypass support (ECMO) to prevent death with failure to wean from bypass support.	Event resulting in death

The type of procedure performed also affects the likelihood of a complication in the cath lab (see table on next page from ref.3). Odegaard et al (2) recently published their data on cath lab periprocedural cardiac arrests. The incidence of cardiac arrests was 0.96/100 cases (Note that a case may have more than one procedure done during an encounter.). 90% of these cases were procedure-related. Overall mortality was 0.2% and this increased to 19% if cardiac arrest occurred. ECMO was required in 26% of the events with 56% (10/18) of ECMO cases surviving until hospital discharge. They also mention that greater involvement of the cardiac anesthesia service in all aspects of care from scheduling to anesthesia technique and anticipation of adverse events has resulted in a significant reduction of cardiac arrests in the recent era.

For congenital heart disease, cardiac catheterization has lagged behind surgery in monitoring quality and data collection. However, in the past decade several groups have collaborated to create databases and tools for comparison, quality measurement and control and improvement. Some examples are the Congenital Cardiac Catheterization and Outcome Project (C3PO), the MAGIC (Mid-Atlantic Group of Interventional Cardiology), the CCISC (Congenital Cardiovascular Interventional Study Consortium), and the IMPACT (Improving Pediatric Adult Congenital

Treatments) registry (started in 2011). Data from these groups provide an evidence base with which to plan for these procedures.

Procedure Type Risk Categories				
	Risk Category 1	**Risk Category 2**	**Risk Category 3**	**Risk Category 4**
Diagnostic case	Age ≥1 yr	Age ≥1 month <1 yr	Age <1 month	
Valvuloplasty		Pulmonary valve ≥1 month	Aortic valve ≥1 month Pulmonary valve <1 month Tricuspid valve	Mitral valve Aortic valve <1 month
Device or coil closure	Venous collateral LSVC	PDA ASD or PFO Fontan fenestration Systemic to pulmonary artery collaterals	Systemic surgical shunt Baffle leak Coronary fistula	VSD Perivalvular leak
Balloon angioplasty		RVOT Aorta dilation <8 atm	Pulmonary artery <4 vessels Pulmonary artery ≥4 vessels all <8 atm Aorta >8 atm or CB Systemic artery (not aorta) Systemic surgical shunt Systemic to pulmonary collaterals Systemic vein	Pulmonary artery ≥4 vessels Pulmonary vein
Stent placement		Systemic vein	RVOT Aorta Systemic artery (not aorta)	Ventricular septum Pulmonary artery Pulmonary vein Systemic surgical shunt Systemic pulmonary collateral
Stent redilation		RVOT Atrial septum Aorta Systemic artery (not aorta) Systemic vein	Pulmonary artery Pulmonary vein	Ventricular septum
Other	Myocardial biopsy	Snare foreign body Transseptal puncture	Atrial septostomy Recanalization of jailed vessel in stent Recanalization of occluded vessel	Atrial septum dilation and stent Any catheterization <4 days after surgery Atretic valve perforation

ASD = atrial septal defect; CB = cutting balloon; LSVC = left superior vena cava; PDA = patent ductus arteriosus; PFO = patent foramen ovale; RVOT = right ventricular outflow tract (RVOT includes right ventricle to pulmonary artery conduit or status post-RVOT surgery with no conduit); VSD = ventricular septal defect.

At our institution, cath lab cases are categorized into 3 levels. Level III requires the surgeon, perfusionist and OR team to be on standby and ready. Instrument packs are in place in the OR, but not open. Perfusion has a pump primed with crystalloid. For level II cath cases, the surgical team will be available within thirty minutes of being called. For level I cases, the surgical team is not informed. Surgeons are called from the cath lab when level II and III cases are started. The interventional cardiologist decides the level of the case. This case was a level II cath and the patient had one of the four risk factors for a level 3, 4, or 5 adverse event. The procedure was in risk category 3.

We have one unit of PRBCs available for all cath lab cases. This patient received two units of emergency release type-specific PRBCs to prime the pump.

Hemodynamic goals for induction include maintaining right ventricular contractility and preventing increases in pulmonary vascular resistance. Maintaining normovolemia is also important to support the right ventricle. These goals can be achieved in several ways and is patient and practitioner dependent.

When the aortopulmonary fistula was seen, the patient was stable for about a minute before becoming bradycardic and arresting. At this point the anesthesiologist needs to call for help and direct the team in the resuscitation of the patient while activating the OR team. The patient was transported to the OR for placement on CPB (cardiopulmonary bypass) and correction of the lesion. Distance between the cath lab and the OR and the patient's condition are key factors that influence this decision as transporting a patient on an ECMO circuit is time-consuming and can delay urgent surgical intervention. At this time, management of massive pulmonary edema was the overwhelming issue. The circuit was filled and subsequently emptied with every expiration. Small, and very rapid breaths were administered during transport (manual HFOV!). HFOV was utilized in the OR. This is a method of mechanical ventilation in which a distending pressure is applied to the airway to maintain a lung volume above functional residual capacity and small rapid oscillations are provided to prevent lung injury from the high pressures. Both oxygenation and ventilation are active processes. Oxygenation is achieved by the fractional inspired oxygen and mean airway pressure while ventilation is achieved with the frequency, amplitude, and time for inspiration. The mean airway pressure is set to 4 – 6 cm H_2O above the last mean airway pressure with the conventional ventilator. This is increased until the FiO_2 is reduced to the desired level. The amplitude is adjusted until one sees adequate movement of the chest and carbon dioxide removal. End tidal carbon dioxide monitors will not work with HFOV so a transcutaneous monitor is needed (9). We used a mean airway pressure of 26 cm H_2O, frequency of 4 Hz, amplitude of 70, and FiO_2 of 0.4.

Upon return of spontaneous circulation, the AHA recommends titrating oxygen down to maintain 95% saturation to decrease neurotoxicity secondary to oxygen derived free radicals. Other measures for neuroprotection include maintenance of adequate cerebral blood flow and prevention of hypoglycemia, hyperglycemia, hyperthermia & hypocarbia. The use of the NIRS or other monitor for cerebral perfusion might be helpful.

The AHA 2010 update mentions that therapeutic hypothermia "may be beneficial". If used, the PICU staff should be familiar with this procedure; especially the precautions needed during rewarming (6, 7).

JET is a well known postoperative arrhythmia in the world of pediatric congenital heart disease. Risk factors for JET include prolonged bypass times, cono-truncal defects, and high immediate post-op serum lactate levels > 20 mmol/l (4, 5). Treatment strategies include hypothermia, optimal sedation and pain control, optimizing the electrolytes, intravenous magnesium sulfate bolus of 30 mg/kg, minimizing exogenous catecholamines, if possible, and the use of amiodarone or other antiarrhythmics. Atrial or sequential pacing may be used to optimize hemodynamics in selected patients (8).

References:

(1) Lin C. H. et al: Incidence and Management of Life-Threatening Adverse Events During Cardiac Catheterization for Congenital Heart Disease: Pediatr Cardiol (2014) 35:140–148
(2) Odegaard et al: The Frequency of Cardiac Arrests in Patients with Congenital Heart Disease Undergoing Cardiac Catheterization: Anesthesia and Analgesia: January 2014, Volume 118, No. 1
(3) Bergersen et al: Catheterization for Congenital Heart Disease Adjustment for Risk Method (CHARM): JACC 2011, Vol(4) no.9
(4) Moak JP et al: Postoperative junctional ectopic tachycardia: Risk factors for occurrence in the modern surgical era. Pacing Clin Electrophysiol. 2013 Sep;36(9):1156-68.
(5) Makhoul M et al: Junctional ectopic tachycardia after congenital heart surgery in the current surgical era. Pediatr Cardiol. 2013 Feb;34(2):370-4
(6) Andropoulos et al: Neuroprotection in Pediatric Cardiac Surgery: What is On the Horizon? Prog Pediatr Cardiol. 2010 August 1; 29(2): 113–122
(7) Young et al: Effectiveness of Mild Therapeutic Hypothermia Following Cardiac Arrest in Adult Patients With Congenital Heart Disease, Am J Cardiol 2014;114:128e130
(8) Abdelaziz et al: Anticipation and management of junctional ectopic tachycardia in postoperative cardiac surgery: Single center experience with high incidence. Ann Pediatr Cardiol. 2014 Jan-Apr; 7(1): 19–24
(9) Tobias J.D, et al: Anaesthetic management and high frequency oscillatory ventilation. Paediatric Anaesthesia 2001, 11: 483-487