Center for Congenital Heart Disease

Anesthetic approach in pulmonary hypertension

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Anesthesia-Related Cardiac Arrest in Children with Heart Disease: Data from the Pediatric Perioperative Cardiac Arrest (POCA) Registry

- 80 North American institutions providing pediatric anesthesia (voluntary enrollment in registry)
- Time period: 1994 (start registration) to 2005
- Risk associated with anesthesia:
  - Anesthesia-related cardiac arrest: approx. 1.4 per 10,000 anesthetics
  - 26% mortality rate after arrest
  - Children < 1 year
  - ASA status >3
  - Cardiac disease
- Most frequent in general operating room and during the surgical phase of the anesthetic

<table>
<thead>
<tr>
<th>Table 1 Changing trends in anaesthesia-related complications [5]</th>
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<td>Respiratory</td>
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Postoperative Mortality in Children After 101,885 Anesthetics at a Tertiary Pediatric Hospital

van der Griend et al. Anesth Analg 2011;112:1440-7

- Registry: 2003 – 2008
- 45% day-cases (operating room, medical imaging, radiotherapy)
- All consultants were pediatric anesthesiologists or supervised trainees
- No anesthetic-related death in children without significant comorbidities
- Incidence of anesthesia-related death: 1 per 10,000 anesthetics (0.01%)
  - Highest risk: age < 30 days
  - More frequent after cardiac surgery compared to non-cardiac surgery
  - **Pulmonary hypertension** involved in 50% of cases
- No standard or consensus to define what is anesthesia-related death
- Incidence of mortality from any cause after anesthesia severely dependent on case-load
Perioperative Complications in Children with Pulmonary Hypertension Undergoing Noncardiac Surgery or Cardiac Catheterization

- Prevalence cardiac arrest: 117 per 10,000 anesthetics (1.17%)
- Overall mortality rate: 0.78%
- Prevalence of cardiac arrest (2.1%) and mortality (1.4%) higher in children undergoing *cardiac catheterisation*
Perioperative Complications in Children with Pulmonary Hypertension Undergoing Noncardiac Surgery or Cardiac Catheterization


- Minor complications (5%):
  - Bradycardia
  - Hypotension
  - Desaturation (SpO₂ <90%)
  - Incidence not significantly associated with:
    - type of procedure
    - type of anesthetic
    - etiology of PH or severity of baseline PAP

- Major complications (4.5%):
  - Cardiac arrest
  - Pulmonary hypertensive crisis
    - Most important risk factor: suprasystemic PH
TRUST ME, I'M AN ANESTHESIOLOGIST
Perioperative or procedural management

- Cardiac lesions in congenital heart disease
- Post-surgical anatomic variation
- Total correction
- Staged intervention
- Palliative intervention

- Hypoxemia (cyanosis)
- Arrhythmias
- Ventriculair dysfunction (heart failure)
- Pulmonary hypertension

- Minor / major surgery
- Cardiac catheterisation
- Radiology examination (e.g. MRI)
Two clinical categories in PHT for planning anesthesiologic management

1. **Child with newly diagnosed PH**
   - At risk for life-threatening pulmonary hypertensive crisis
   - Greater prevalence in children with idiopathic PAH


2. **Older child with ongoing or chronic PH**
   - Comorbidities
   - Increased PVR with RV hypertrophy
   - Greater risk for ischemia, arrhythmias and ventricular failure
Cardiovascular risk mechanism and management

Main goals

1. Maintain pulmonary blood flow
2. Prevent excess workload for the right ventricle
3. Maintain cardiac output
## Pulmonary hypertensive crisis

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Pulmonary vascular resistance in infants after cardiac surgery: Role of carbon dioxide and hydrogen ion

Considerable disagreement on the effects of CO$_2$ on the pulmonary vasculature in studies in both animal and man

PaCO$_2$↑ increases PVR after cardiopulmonary bypass

Effect independent of the manner in which PaCO$_2$ is raised

Increasing the arterial pH by NaHCO$_3$ or other buffer solution during hypercapnia decreases the pulmonary vascular resistance

These changes were observed without alteration in PaCO$_2$

Conclusion:
Metabolic alkalosis may have a role in the treatment of increased pulmonary vascular resistance in infants after cardiopulmonary bypass for cardiac surgery.

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Choice of anesthetic drugs

- Volatile anesthetics
- Opioids
- Propofol
- Ketamine
- Thiopental
- Nitrous oxide
- Etomidate?
Volatile anesthetics

- Propofol
- Ketamine
- Anesthetic drugs
- Opioids

- Vascular smooth muscle largely regulated by ATP-sensitive potassium channels (pathway for prostacyclin and inhaled NO)
- Isoflurane inhibits activity of these channels; sevoflurane does not
- Isoflurane potentiates vasodilator response to β1-adrenoreceptor activation without effect on baseline pulmonary tone
- Both volatile anesthetics attenuate hypoxic pulmonary vasoconstriction (V-P mismatch)
- Dose-dependent myocardial depression
- Sevoflurane drug of choice
Anesthetic drugs

- Propofol
  - Suitable for total intravenous anesthesia technique
  - Not thoroughly studied for effects on pulmonary vasculature
  - Decreases PVR (bolus and infusion)
  - Negative effect on SVR
  - Mild myocardial depression
  - Reduces effects of noxious stimuli
  - In presence of R-L atrial shunt and fixed elevated PVR:
    - rapid transit time to systemic circulation
    - rapid decrease of SVR
    - arterial desaturation
  - Use with care

- Ketamine
- Opioids
- Volatile anesthetics

[Source: Williams GD. Anesth Analg 1999;89:1411-16]
Anesthetic drugs

- Ketamine
- Propofol
- Opioids
- Volatile anesthetics

- Has been controversial for a long time (but not anymore)

- Maintains PVR and SVR if:
  - anesthetized with sevoflurane
  - no hypercarbia
  - supplemental oxygen

- Not advised in spontaneously breathing children for cardiac catheterization (unless hypercarbia and ventilatory depression are avoided)

Williams GD. Anest Analg 2007;105:1578-84
Hickey PR. Anesthesiology 1985;62:287-93
Morray JP. Anest Analg 1984;63:895-99
Anesthetic drugs

- Opioids
- Ketamine
- Propofol
- Volatile anesthetics

- Minimal pulmonary and systemic hemodynamic effects
- Attenuate vascular response to noxious stimuli
- Important component of total intravenous anesthesia technique
New developments

- **Cardiac surgery and congenital heart disease** (50% of PH)
  - inhaled iloprost (pathway cAMP) vs. inhaled NO (pathway cGMP)
    - patients with L-R shunt and PH after weaning from CPB
    - >90% at least one major or minor PHC on both groups
  - combination therapy?

  Loukanov T. Clin Res Cardiol 2011;100:595-602
  Gorenflo M. Cardiology 2010;116:10-7

- **Anesthesia and Intensive Care**
  - Dexmedetomidine (alpha2-agonist)
    - blunting of the sympathetic stress response
    - reduction of endogenous catecholamine release
    - decrease in intraoperative anesthetic requirements
    - limitation of postoperative opioid requirements

  Tobias JD. Pediatr Cardiol 2011;32:1075-87
An “ordinary” case
# Preoperative considerations in patients with PAH

1. Is the planned surgery elective and might the morbidity and mortality risks be avoided by choosing a nonsurgical management strategy?

2. Is the type of PH well characterized or is further testing required to confirm WHO group or subgroup diagnosis?

3. Has the patient been recently evaluated with history, examination, BNP/blood testing, echocardiogram or MRI, and possibly right heart catheterization to assess right ventricular function?

4. If right ventricular function is not optimized (eg, volume overload/edema/ascites, TAPSE <2 cm, elevated BNP, cardiac index <2), can the surgery be safely delayed while additional treatment options are initiated? Is there time to initiate a pulmonary rehabilitation program?

5. Has the medical center for the proposed surgery been matched with regard to availability of essential PH medications, anesthesia, and surgical expertise to manage potential intra- and perioperative challenges in patients with PH?

6. Is there an intra-, peri-, and postoperative plan and lines of responsibility communicated to involve all members of the patient’s PH multidisciplinary care team?

7. Is there a health care proxy clearly identified and has there been substantial conversation regarding goals of care and complications that might result in changes in DNR status?

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*from Studer S. Advances in Pulmonary Hypertension 2013;12:13-7*
Perioperative or procedural management

- Cardiac lesions in congenital heart disease
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- Total correction
- Staged intervention
- Palliative intervention

- Hypoxemia (cyanosis)
- Arrhythmias
- Ventricular dysfunction (heart failure)
- Pulmonary hypertension

- Minor / major surgery
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Anesthesia in children with pulmonary hypertension

General anesthesiologist, Pediatric anesthesiologist or Pediatric cardiac anesthesiologist?