Respiratory Function in Adult Congenital Heart Disease

When is Anaesthesia & Ventilation a Worry?

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OUTLINE

▪ Quantifying Risk
▪ Co-morbidities and why ACHD is special
▪ Who is operating and where
▪ Effects on Anaesthesia on Ventilation
▪ Special Populations
▪ Recognising Respiratory Risk
▪ Planning for your Patient
QUANTIFYING RISK
Quantifying Risk

- What defines risk in ACHD?
- How do we recognise risk?
Risk of Adverse Event in ACHD

- **High Risk:**
  - Cyanotic, severe pulmonary hypertension, univentricular, severe systemic ventricular dysfunction, severe outflow obstruction, ventricular arrhythmia, complex disease requiring anticoagulation

- **Moderate Risk**
  - Prosthetic valve or conduit, intra-cardiac shunt, moderate systemic ventricular dysfunction and moderate outflow obstruction
Focused on cardiac events…

- IMPACT – Improving Pediatric and Adult Congenital Treatment
- NCCD – National Cardiovascular Data Registry (US) of ACC
- MAGIC – Mid-Atlantic Group of Interventional Cardiology
- C3PO – Congenital Cardiac Catheterisation Project on Outcomes
- CCISC – Congenital Cardiovascular Interventional Study Consortium
- JCCHS – Joint Council on Congenital Heart Disease
IMPACT REGISTRY

- Paediatric and Adult CHD Registry; nearly 20,000 patients
- Events occurring in 10% of diagnostic and 11.1% of interventional procedures
- Highest event rate in single ventricles, AS and Dilated Cardiomyopathy
- Variables identified:
  - young patient age, renal insufficiency, single ventricle physiology, procedure-type, low systemic saturation, low mixed venous saturation, elevated systemic ventricular end-diastolic pressure and elevated main PA mean pressure
Closed Claims Analysis and Arrest Registries

- Closed Claims Project Sub-Analysis of Congenital Heart Disease
  - Major Anaesthesia contribution to mortality in around 55%
  - Greater than nature of CHD (45%) and preoperative optimization (40%)

- ACHD vs non-ACHD
  - Maxwell et al. analyzed 1191 cases with CHD in non-cardiac surgery and observed significantly higher rates of death, perioperative cardiac arrest, myocardial infarction, stroke, respiratory complications, renal failure, sepsis, venous thromboembolism, perioperative transfusion
  - Nationwide Inpatient Sample database: mortality >4% compared with 1.75%

- Perioperative Cardiac Arrest (POCA) Registry
  - CHD dominates the registry with more than one third
Adults are not just big kids!

- Profile of Adults versus Kids with adverse events in C3PO
  - More: non cardiac comorbid conditions, elevated ventricular EDP, low cardiac index
  - Less: emergencies, single ventricles, genetic syndromes, adverse events, blood transfusion

- Adverse Events in Adults
  - 2% of total cases had an issue with sedation/anesthesia/airway

- Same lesion, different clinical picture
  - Kid with Tetralogy: Severe RVOT obstruction, RVH & cyanosis; specialised centre
  - Adult with Tetralogy: Severe PR and dysfunctional RV; non-tertiary care more common
CO-MORBIDITIES & ISSUES WITH ANAESTHESIA & VENTILATION
Airway abnormalities

- Upper airway abnormalities
- Genetic abnormalities and facial dysmorphism: macroglossia, retrognathia
- Tracheomalacia
Respiratory Insufficiency

- Chest wall: scoliosis and restrictive lungs post thoracotomy and chronic limited chest expansion with recurrent laryngeal nerve injury

- Chronic Heart Failure:
  - Loss of parenchymal function with water retention
  - Susceptibility to infection especially when malnourished
  - Development of pulmonary hypertension

- Univentricular issues:
  - Slow pulmonary flow with development of collaterals
  - Restrictive physiology
  - Tendency to thromboembolism

The respiratory system in chronic heart disease
ACHD as part of a Systemic Disease

- CNS: Seizure disorders
- RESP: Restrictive and Obstructive Disease in adulthood
- Haem: Polycythaemia and thromboembolism especially with cyanotic lesions
- Renal Dysfunction
- Increased risk of endocarditis
- Musculoskeletal abnormalities
- Higher risk of metabolic syndrome and cancer
WHO IS OPERATING?
WHEN, WHERE, HOW?
When and where does Anaesthesia get involved?
Anaesthesia outside of the Operating Room

- Compared to open surgery:
  - Less pain, fluid shifts and inflammatory response
  - Same opportunity for life threatening events

- Need to establish:
  - Is suppression of consciousness required?
  - If consciousness is to be suppressed, then to what level?
  - Who will administer this and monitor its effectiveness?
Borrow from the children…

- Preoperative planning especially for high risk procedures
- Small expert teams at specialised centres
- Anaesthesia vs MAC
  - Be prepared to manage the airway
  - Airway obstruction and hypoventilation can have profound effects
  - Must be able to rapidly identify and respond to changes
  - Airway or ventilation failure is over represented in cardiac arrest & leads to death more frequently

SCAI/CCAS/SPA Expert Consensus Statement for Anesthesia and Sedation Practice: Recommendations for Patients Undergoing Diagnostic and Therapeutic Procedure
Anesthesia & Analgesia 2016; 123
EFFECTS OF ANAESTHESIA AND VENTILATION
Anaesthesia & Ventilation

- IPPV versus Spontaneous Ventilation
  - Less relevant in era of pressure support ventilation
  - Effects of alterations of intrathoracic pressure on haemodynamics most apparent in right heart failure, hypovolaemia and univentricular physiology

- Non instrumented spontaneous ventilation requires close observation:
  - Airway obstruction, hypoventilation and respiratory acidosis all elevate PVR

- Should monitor ETCO2 regardless of technique
SPECIAL POPULATIONS
Univentricular +/- palliation +/- shunts

- Peripheral saturations are related to more than diffusion:
  - Effects of shunt and absolute flow
- Shunting
  - affects ETCO2 measurement; Aa pCO2 gradient increases as shunting worsens
  - direct measurement of arterial CO2 will be more accurate than end-tidal CO2 monitoring in patients who are at risk of elevated PVR because of hypercarbia
# Cardiac Disease & Pregnancy

## Table 2. Cardiac Disease in Pregnancy Risk score

<table>
<thead>
<tr>
<th>Predictors of cardiovascular events</th>
<th>Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior cardiac event (heart failure, transient ischemic attack, and infarction prior to pregnancy) or arrhythmias</td>
<td>1</td>
</tr>
<tr>
<td>NYHA functional class at baseline &gt;II or cyanosis</td>
<td>1</td>
</tr>
<tr>
<td>Left heart obstruction (mitral valve area &lt;2.0 cm(^2), aortic valve area &lt;1.5 cm(^2), and LV outflow tract gradient &gt;30 mmHg)</td>
<td>1</td>
</tr>
<tr>
<td>Reduced systolic ventricular function (ejection fraction &lt;40%)</td>
<td>1</td>
</tr>
</tbody>
</table>

Zero point confers a 5% risk of cardiac complications during pregnancy, 1 point a 27% risk, and 2 or more points a 75% risk. NYHA, New York Heart
Changes in Pregnancy

- Lung Volumes
  - Loss of FRC; higher MV requirement
- Decreased chest wall compliance
  - Tendency to atelectasis
- Altered response to O2/CO2
- Increased VO2
  - Faster desaturation
RECOGNISING RESPIRATORY RISK IN ADULTS
Post operative Pulmonary Complications

- Common, costly and increase mortality
- More common than cardiac complications in elective surgery
- Hypoxaemia in PACU
  - Airway obstruction
  - Continued sedation
  - Residual neuromuscular blockade
  - Impaired ventilatory response to CO2
Preoperative Risk Stratification

<table>
<thead>
<tr>
<th>ARISCAT</th>
<th>PERISCOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low systemic saturation &lt;96%</td>
<td>SpO2 &lt;95%</td>
</tr>
<tr>
<td>RTI within 1 month</td>
<td>One/more respiratory symptoms</td>
</tr>
<tr>
<td>Increasing age</td>
<td>Chronic liver disease</td>
</tr>
<tr>
<td>Anaemia &lt;100g/L</td>
<td>Heart failure</td>
</tr>
<tr>
<td>Thoracic/upper abdominal surgery</td>
<td>Thoracic/upper abdominal surgery</td>
</tr>
<tr>
<td>Surgery &gt;2 hours</td>
<td>Surgery &gt;2 hours</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>Emergency surgery</td>
</tr>
</tbody>
</table>

Surgery specific tools available – eg EuroLUNG 1&2 + ESOS for Thoracic surgery
## Published Risk Factors

<table>
<thead>
<tr>
<th>Patient factors</th>
<th>Procedure factors</th>
<th>Laboratory testing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-modifiable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age 2-4 10 13 14 18 20 24 25 27 33 36</td>
<td>Type of surgery 2-3 10 13 15 18 25 27 29</td>
<td>Urea &gt;7.5 mmol litre (^{-1}) 3 10 25</td>
</tr>
<tr>
<td>Male sex 2-3 13 19 25</td>
<td>Upper abdominal</td>
<td>Increased creatinine 29</td>
</tr>
<tr>
<td>ASA 2-5 13-14 15 17 19</td>
<td>AAA</td>
<td>Abnormal liver function tests 15</td>
</tr>
<tr>
<td>Functional dependence (frailty) 15-13 25 27 34 36</td>
<td>Thoracic</td>
<td>Low preoperative oxygen saturation 6 29</td>
</tr>
<tr>
<td>Acute respiratory infection (within 1 month) 16 18 20</td>
<td>Neurosurgery</td>
<td>'Positive cough test' 50</td>
</tr>
<tr>
<td>Impaired cognition 17</td>
<td>Head and neck</td>
<td>Abnormal preoperative CXR 7 27</td>
</tr>
<tr>
<td>Impaired sensorium 25</td>
<td>Vascular</td>
<td>Preoperative anemia (Hb &lt;100 g litre (^{-1})) 9 4</td>
</tr>
<tr>
<td>Cerebrovascular accident 23</td>
<td>Emergency (as elective) 5-6 10 15 16 18 19 25 27 29</td>
<td>Low albumin 10 27</td>
</tr>
<tr>
<td>Malignancy 7 15</td>
<td>Duration of procedure 5 12 14 20 20 27 29 30</td>
<td>Predicted maximal oxygen uptake 37</td>
</tr>
<tr>
<td>Weight loss &gt;10% (within 6 months) 15 25</td>
<td>Re-operation 18 23 36</td>
<td>FEV(_1)/FVC &lt;0.7 and FEV(_1) &lt;80% of predicted 1</td>
</tr>
<tr>
<td>Prolonged hospitalization 15</td>
<td>Multiple GA during admission 19</td>
<td></td>
</tr>
<tr>
<td><strong>Modifiable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking 18 13 15 25 33 35 61</td>
<td>Mechanical ventilation strategy 7 19 20 23 27 31</td>
<td></td>
</tr>
<tr>
<td>COPD 16 13 15 19 24 29 25 37 33 36</td>
<td>GA (general anaesthesia) 15 22 27 30</td>
<td></td>
</tr>
<tr>
<td>Asthma 20 13 16 18 27 39 33</td>
<td>Long-acting NMBDs and TOF ratio &lt;0.7 in PACU 17</td>
<td></td>
</tr>
<tr>
<td>CHF 16 13 18 27 39 33</td>
<td>Residual neuromuscular block</td>
<td></td>
</tr>
<tr>
<td>OSA 42</td>
<td>Intermediate-acting NMBDs with surgical</td>
<td></td>
</tr>
<tr>
<td>BMI &lt;18.5 or &gt;40 kg m (^{-2}) 3 15</td>
<td>time &lt;2 h (not antagonized) 29</td>
<td></td>
</tr>
<tr>
<td>BMI &gt;27 kg m (^{-2}) 7</td>
<td>Neostigmine 1 7 4</td>
<td></td>
</tr>
<tr>
<td>Hypertension 11</td>
<td>Succinylcholine with supraglottic airway 7 24</td>
<td></td>
</tr>
<tr>
<td>Chronic liver disease 79</td>
<td>Failure to use peripheral nerve stimulator 21</td>
<td></td>
</tr>
<tr>
<td>Renal failure 43</td>
<td>Open abdominal surgery (vs laparoscopic) 20 77 79</td>
<td></td>
</tr>
<tr>
<td>A cirrhosis 42</td>
<td>Perioperative nasogastric tube 28 74 77 80</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus 33 17</td>
<td>Intraoperative blood transfusion 25 36</td>
<td></td>
</tr>
<tr>
<td>Alcohol 17 25</td>
<td>GORD 30</td>
<td></td>
</tr>
<tr>
<td>Preoperative sepsis 13-15 10</td>
<td>Preoperative shock 12</td>
<td></td>
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### Table 3 Published risk factors for developing a postoperative pulmonary complication, category, and laboratory testing (as defined by Linzma and colleagues): further divided into non-modifiable and modifiable factors.

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<td>ASA ≤ 25</td>
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</tr>
<tr>
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<td>Thoracic</td>
</tr>
<tr>
<td>Gynecovascular accident</td>
<td>Neurosurgery</td>
</tr>
<tr>
<td>Hemodynamically</td>
<td>Head and neck</td>
</tr>
<tr>
<td>Weight loss - 10% (within 6 months)</td>
<td>Vascular</td>
</tr>
<tr>
<td>Long-term steroid use</td>
<td>Emergency (as elective)</td>
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<td>Open abdominal surgery (laparoscopic)</td>
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<td>Anxiety</td>
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<td>Preoperative shock</td>
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### Risk Factors

- **Acute Respiratory Infection**
- **Malnutrition**
- **Smoking**
- **Asthma**
- **OSA**
Perioperative Asthma Management

- Preoperative assessment
  - Warning signs: previous perioperative exacerbation; marked reversibility or depressed FEV1/PEFR, recent RTI or symptomatology
  - Control reflux

- Intraoperative
  - Avoid triggers: airway instrumentation, agents
  - Plan to manage bronchospasm

- Post operative
  - Spirometry, deep breathing exercises, early mobilisation
Obstructive Sleep Apnoea

- Directly related to respiratory complications
  - Follow on effects on LOS, morbidity and mortality
- Preoperative Screening
  - STOP-BANG
  - sMVP
STOP-BANG

**FORMULA**
Addition of the selected points (for the first four, ask the patient):

<table>
<thead>
<tr>
<th></th>
<th>0 points</th>
<th>1 point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you snore loudly? (Louder than talking or loud enough to be heard through closed doors)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Do you often feel tired, fatigued, or sleepy during the daytime?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Has anyone observed you stop breathing during sleep?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Do you have (or are you being treated for) high blood pressure?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>BMI</td>
<td>≤35 kg/m²</td>
<td>&gt;35 kg/m²</td>
</tr>
<tr>
<td>Age</td>
<td>≤50 years</td>
<td>&gt;50 years</td>
</tr>
<tr>
<td>Neck circumference</td>
<td>≤40 cm</td>
<td>&gt;40 cm</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>Male</td>
</tr>
</tbody>
</table>

- **S** – Snore
- **T** – Tired
- **O** – Observed
- **P** – pressure (hypertension)
- **B** – BMI >35
- **A** – Age >50
- **N** – Neck circumference >40
- **G** – Gender = male
PLANNING FOR YOUR PATIENT
Preoperative Assessment

- Signs of cyanosis or worsening heart failure
- Baseline saturations
- Recent respiratory issues
- Continuation of pulmonary vasoactives
- Judicious use of anxiolysis
Intraoperative Strategies

▪ Ventilatory Strategies
  ▪ Spontaneous negative pressure with pressure support if possible
  ▪ Protective ventilation especially in obese: low TV+PEEP; I<E
  ▪ High flow nasal oxygen

▪ Management of neuromuscular blockade
  ▪ Monitoring essential
  ▪ Reversible agent or non-organ dependent clearance

▪ Management of pneumoperitoneum – insufflate <8-12cmH₂O

▪ Agent specific effects: N2O; volatiles; complex opioids
Post operative Management

- Emergence and extubation management
- Extubation criteria
- Post operative pain and anxiety management
- Post operative ventilation in ICU