

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



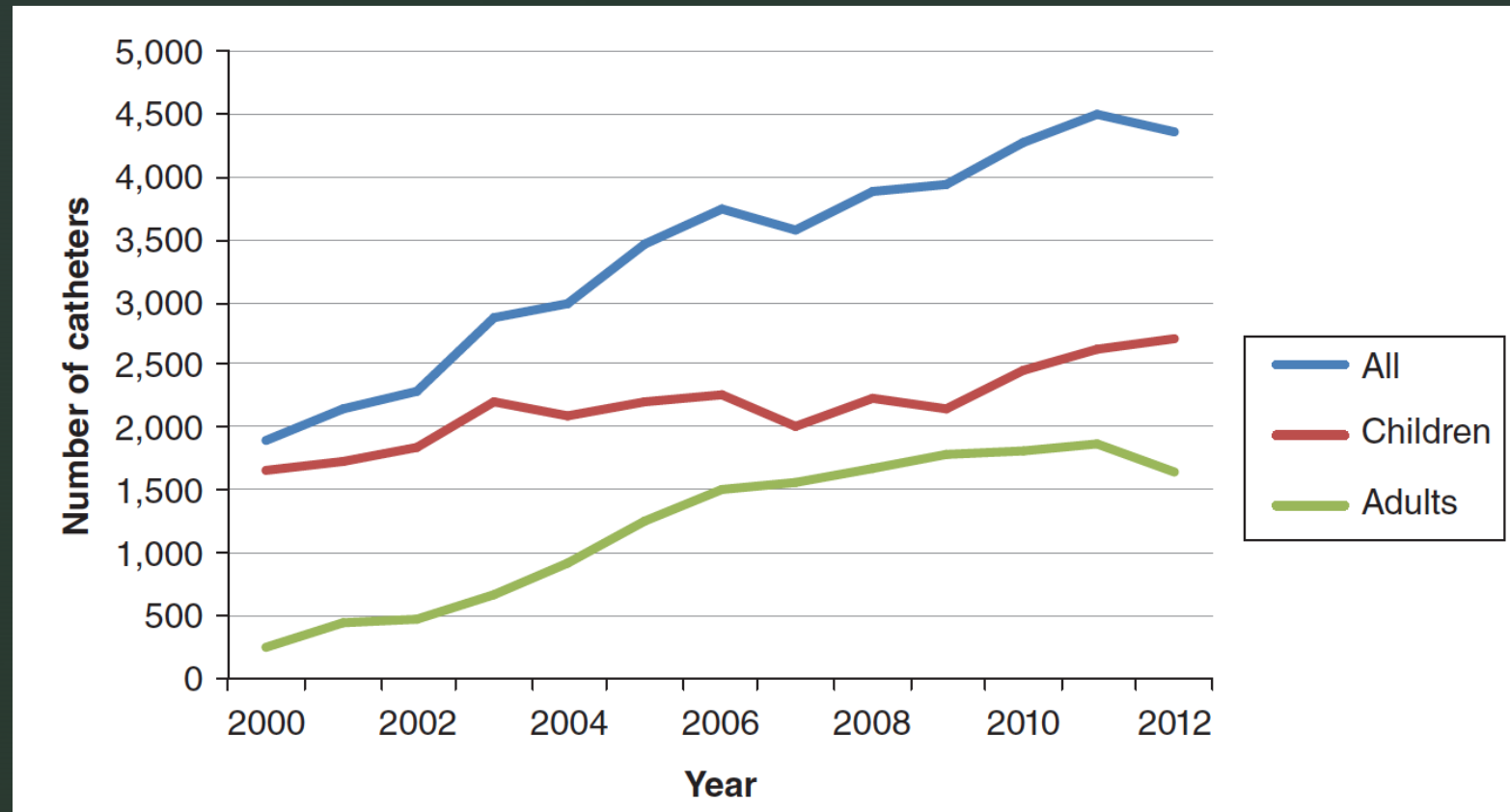
ACHD as part of a Systemic Disease

- 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



EFFECTS OF ANAESTHESIA AND VENTILATION

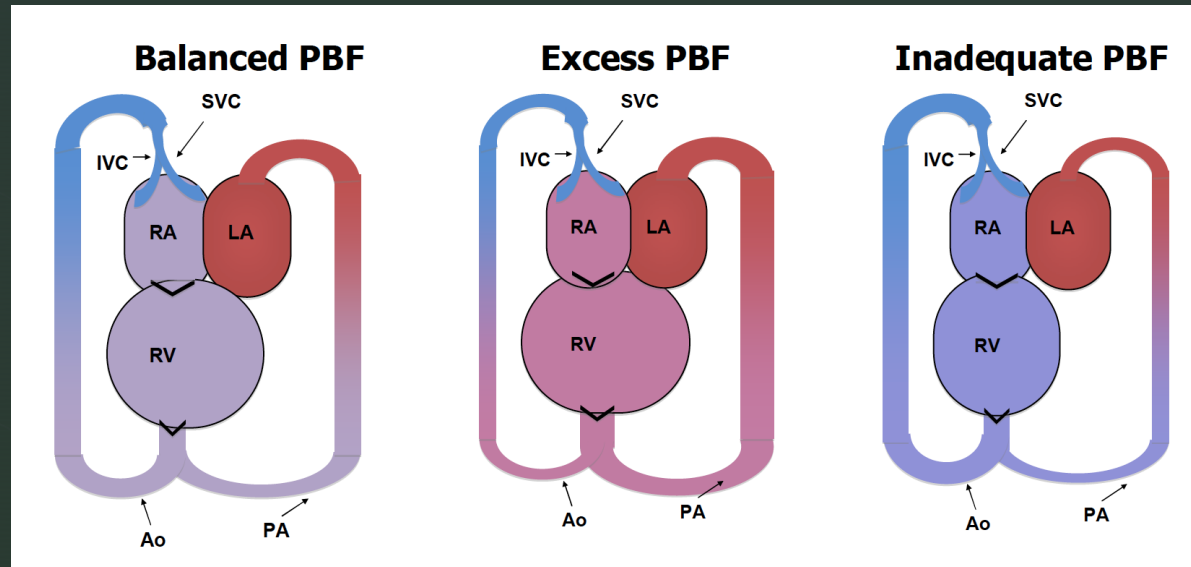
Anaesthesia & Ventilation

- 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

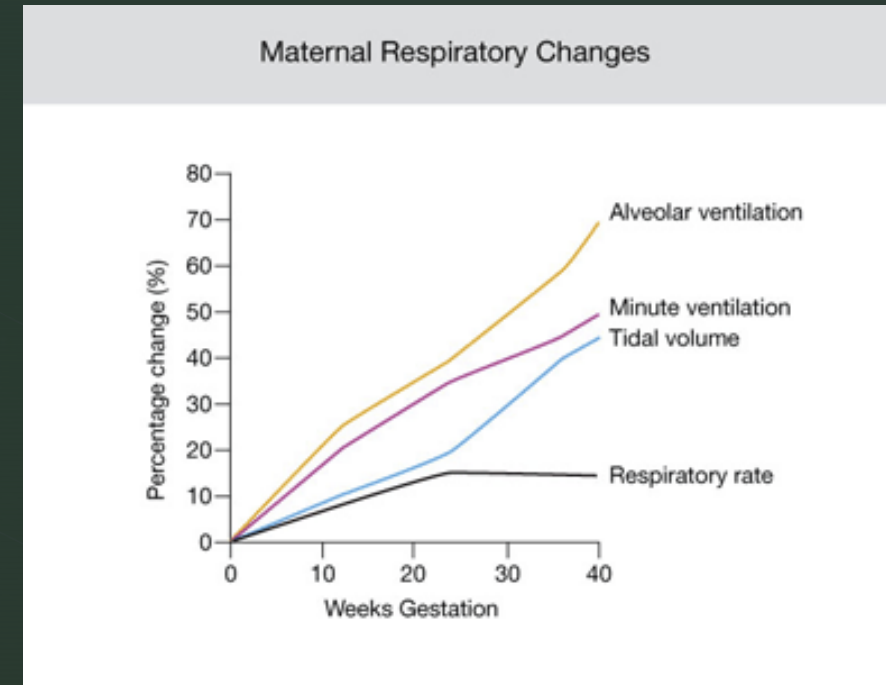
Predictors of cardiovascular events	Point
Prior cardiac event (heart failure, transient ischemic attack, and infarction prior to pregnancy) or arrhythmias	1
NYHA functional class at baseline >II or cyanosis	1
Left heart obstruction (mitral valve area <2.0 cm ² , aortic valve area <1.5 cm ² , and LV outflow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

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

ARISCAT	PERISCOPE
Low systemic saturation <96%	SpO2 <95%
RTI within 1 month	One/more respiratory symptoms
Increasing age	Chronic liver disease
Anaemia <100g/L	Heart failure
Thoracic/upper abdominal surgery	Thoracic/upper abdominal surgery
Surgery >2 hours	Surgery >2 hours
Emergency surgery	Emergency surgery

Surgery specific tools available – eg EuroLUNG 1&2 + ESOS for Thoracic surgery



Published Risk Factors

Patient factors	Procedure factors	Laboratory testing
<p>Non-modifiable</p> <p>Age^{4-7 10 13 14 18 20 24 25 27 33 36}</p> <p>Male sex^{12 19 33}</p> <p>ASA ≥II^{5 11-14 16 19 27 33}</p> <p>Functional dependence (frailty)^{10-13 25 27 34 36}</p> <p>Acute respiratory infection (within 1 month)^{4 6}</p> <p>Impaired cognition⁷</p> <p>Impaired sensorium²⁵</p> <p>Cerebrovascular accident²⁵</p> <p>Malignancy^{7 15}</p> <p>Weight loss >10% (within 6 months)^{15 25}</p> <p>Long-term steroid use²⁵</p> <p>Prolonged hospitalization¹⁵</p> <p>Modifiable</p> <p>Smoking^{57 12 13 15 25 32 33 61}</p> <p>COPD^{10 12 13 15-19 24 25 27 32 33 36}</p> <p>Asthma^{20 32}</p> <p>CHF^{15 16 18 27 29 33}</p> <p>OSA⁶²</p> <p>BMI <18.5 or > 40 kg m⁻² ¹⁵</p> <p>BMI >27 kg m⁻² ⁷</p> <p>Hypertension¹⁵</p> <p>Chronic liver disease²⁹</p> <p>Renal failure¹⁹</p> <p>Ascites¹²</p> <p>Diabetes mellitus^{15 17}</p> <p>Alcohol^{17 25}</p> <p>GORD¹⁷</p> <p>Preoperative sepsis^{13-15 33}</p> <p>Preoperative shock¹²</p>	<p>Non-modifiable</p> <p>Type of surgery:^{4-7 10-13 15-18 23 25 27 29}</p> <ul style="list-style-type: none"> • upper abdominal • AAA • Thoracic • Neurosurgery • head and neck • vascular <p>Emergency (vs elective)^{4-6 10 11 16 18 19 23 25 29 33 36}</p> <p>Duration of procedure^{6 12 14 20 22 27 29 32}</p> <p>Re-operation^{18 23 36}</p> <p>Multiple GA during admission¹⁹</p> <p>Modifiable</p> <p>Mechanical ventilation strategy^{3 19 63-71}</p> <p>GA (vs regional)^{4 25 27 72}</p> <p>Long-acting NMBDs and TOF ratio <0.7 in PACU⁷³</p> <p>Residual neuromuscular block</p> <p>Intermediate-acting NMBDs with surgical time <2 h (not antagonized)²¹</p> <p>Neostigmine^{21 74}</p> <p>Sugammadex with supraglottic airway^{75 76}</p> <p>Failure to use peripheral nerve stimulator^{21 74}</p> <p>Open abdominal surgery (vs laparoscopic)^{5 26 77-79}</p> <p>Perioperative nasogastric tube^{18 20 22 23 25 80}</p> <p>Intraoperative blood transfusion^{19 25 36}</p>	<p>Urea >7.5 mmol litre⁻¹ ^{10 25}</p> <p>Increased creatinine³³</p> <p>Abnormal liver function tests¹⁵</p> <p>Low preoperative oxygen saturation^{4 6 29}</p> <p>'Positive cough test'²⁰</p> <p>Abnormal preoperative CXR^{9 27}</p> <p>Preoperative anaemia (<100 g litre⁻¹)^{4 6}</p> <p>Low albumin^{5 10 27}</p> <p>Predicted maximal oxygen uptake³²</p> <p>FEV₁:FVC <0.7 and FEV₁ <80% of predicted⁵</p>



Table 3 Published risk factors for developing a postoperative pulmonary complication, categorized by patient and procedure factors (as defined by Smetana and colleagues),²⁷ further divided into non-modifiable and modifiable factors. AAA, abdominal aortic aneurysm; COPD, chronic obstructive pulmonary disease; CXR, chest X-ray; FEV₁, forced expiratory volume in 1 second; GA, general anaesthesia; GORD, gastro-oesophageal reflux disease; NMBDs, neuromuscular blocking drugs; PACU, postanaesthesia care unit; 'Positive cough test', patient takes a deep breath and coughs after the initial cough; TOF, train of four

Patient factors	Procedure factors
Non-modifiable	Non-modifiable
Age ^{4-7 10 13 14 18 20 24 25 27 33 36}	Type of surgery: ^{4-7 10-13 15-18 23 25 27 29}
Male sex ^{12 19 33}	• upper abdominal
ASA ≥ II ^{5 11-14 16 19 27 33}	• AAA
Impaired cognition ⁷	• Thoracic
Acute respiratory infection (within 1 month) ^{4 6}	• Neurosurgery
Impaired sensorium ²⁵	• head and neck
Cerebrovascular accident ²⁵	• vascular
Emergency (vs elective) ^{4-6 10 11 16 18 19 23 25 29 33 36}	Emergency (vs elective) ^{4-6 10 11 16 18 19 23 25 29 33 36}
Duration of procedure ^{6 12 14 20 22 27 29 32}	Duration of procedure ^{6 12 14 20 22 27 29 32}
Weight loss >10% (within 6 months) ^{15 25}	Re-operation ^{18 23 36}
Long-term steroid use ¹³	Multiple GA during admission ¹⁹
Prolonged hospitalization ¹⁵	Modifiable
Smoking ^{5 7 12 13 15 25 32 33 61}	Mechanical ventilation strategy ^{3 19 63-71}
COPD	GA (vs regional) ^{4 25 27 72}
Asthma ^{20 32}	Long-acting NMBDs and TOF ratio <0.7 in PACU ⁷³
CHF	Residual neuromuscular block
OSA ⁶⁴	Intermediate-acting NMBDs with surgical time <2 h (not antagonized) ²¹
BMI <18.5 or >40 kg m ⁻² ¹⁵	Neostigmine ^{21 74}
BMI >27 kg m ⁻² ⁷	Sugammadex with supraglottic airway ^{75 76}
Hypertension ¹⁵	Failure to use peripheral nerve stimulator ^{21 74}
Chronic liver disease ²⁹	Open abdominal surgery (vs laparoscopic) ^{5 26 77-79}
Renal failure ¹⁹	Perioperative nasogastric tube ^{18 20 22 23 25 80}
Ascites ¹²	Intraoperative blood transfusion ^{19 25 36}
Diabetes mellitus ^{15 17}	
Alcohol ^{17 25}	
GORD ¹⁷	
Preoperative sepsis ^{13-15 33}	
Preoperative shock ¹²	

- 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):

	0 points	1 point
Do you snore loudly? (Louder than talking or loud enough to be heard through closed doors)	No	Yes
Do you often feel tired, fatigued, or sleepy during the daytime?	No	Yes
Has anyone observed you stop breathing during sleep?	No	Yes
Do you have (or are you being treated for) high blood pressure?	No	Yes
BMI	≤35 kg/m ²	>35 kg/m ²
Age	≤50 years	>50 years
Neck circumference	≤40 cm	>40 cm
Gender	Female	Male

- 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

