Pediatric Cardiac Anesthesia 5: Non-Cardiac Surgery
SBE Prophylaxis
Cardiac Emergency Algorithms
Adult CHD

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With co-authorship attribution to
Dean Andropoulos, MD

Intensive Review of Pediatric Anesthesia
2015
Disclosures

• No financial conflicts
• Devices illustrated in talk are in use at my center; many other commercial devices are available -- photos are not an endorsement
• Acknowledgements:
  – Dean B Andropoulos, MD MHCM (TCH/BCM)
  – SPA website for critical events checklists (downloadable as an “app”)

Intensive Review of Pediatric Anesthesia
2015
Learning Objectives

• Discuss risks and care of the patient with CHD undergoing non cardiac surgery or anesthetics (NCS)
• Review the essential interventions for cardiac emergencies in the OR
• Examine the most recent recommendations for SBE Prophylaxis
• Demographics & Evaluation of the adult CHD patient
ECA and NCS in Children with CHD

- **ExtraCardiac Anomalies** occur in 25% of CHD children
- Syndromes in 8% of patients

- Most common associated malformations:
  - Craniofacial (20%)
  - Genitourinary (15%)
  - Musculoskeletal (13%)
  - CNS (11%)

- Frequent need for non-cardiac operations, interventions and imaging studies-some where 100% of risk = anesthetic risk! (eg: MRI)
<table>
<thead>
<tr>
<th>SYNDROME</th>
<th>INCIDENCE</th>
<th>% CHDz?</th>
<th>lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trisomy 21</td>
<td>1:800</td>
<td>40%-50%</td>
<td>PDA, VSD, ASD, CCAVC, TOF</td>
</tr>
<tr>
<td>Trisomy 18</td>
<td>1:3500</td>
<td>&gt;50%</td>
<td>VSD &amp; polyvalvar dz</td>
</tr>
<tr>
<td>Trisomy 13</td>
<td>1:5000</td>
<td>&gt;85%</td>
<td>PDA, ASD, valve dz, dextrocardia</td>
</tr>
<tr>
<td>Turner’s (XO)</td>
<td>1:5000</td>
<td>&gt;40%</td>
<td>CoA, BAV, variable other</td>
</tr>
<tr>
<td>Williams</td>
<td>1:20,000</td>
<td>&gt;60%</td>
<td>Multilevel Ao, pulm stenoses &amp; CoA &amp; coronary arteriopathy</td>
</tr>
<tr>
<td>22q11 (VCF, DiGeorge, CATCH22)</td>
<td>1:3000</td>
<td>&gt;75%</td>
<td>Conotruncal anomalies, HLHS, wide variety of CV lesions (Cardiac anomalies, Abnormal facies, Thymic dysplasia, Cleft palate Hypocalcemia)</td>
</tr>
<tr>
<td>Noonan’s</td>
<td>1:1500</td>
<td>50%</td>
<td>Pulm stenosis; HCardiomyopathy</td>
</tr>
<tr>
<td>Marfan’s</td>
<td>1:10,000</td>
<td>develops</td>
<td>MVP, aortic root dilation, pa dilation</td>
</tr>
<tr>
<td>VACTERL</td>
<td>1:3000</td>
<td>75%</td>
<td>VSD, ASD, TOF, truncus, TGA</td>
</tr>
<tr>
<td>CHARGE</td>
<td>1:10,000</td>
<td>60%</td>
<td>Conotruncal, aortic arch anomalies</td>
</tr>
</tbody>
</table>
Anesthesia for the patient with congenital heart disease presenting for noncardiac surgery.
Gottlieb, Erin A.; Andropoulos, Dean B.
Current Opinion in Anaesthesiology.

42 References with descriptions of contents: including POCA registry data, outcomes in CHDz and laparoscopic surgery, MRI, cardiac cath, and reviews of care in pulm htn, single ventricle, DCM, etc
Highest Risk Lesions for Cardiac Arrest

• Pulmonary hypertension
  – Greatest with suprasystemic PA pressures

• Left-sided obstructive lesions; multilevel obstruction
  – Williams Syndrome

• Single ventricle lesions
  – Greatest with shunted infants before bidirectional cavopulmonary anastomosis

• Dilated cardiomyopathy
  – Ejection fraction <35%
Risk Factors for Procedural Cardiac Arrest

• Younger age (below 2) (75% POCA registry)
• Pulmonary hypertension w or w/o structural CV dz
• More severe disability at baseline (eg NYHA)
• Type, duration of procedure (? lit varies)
• Monitoring limitations, events such as breath-holds and balloon interventions? (MRI, cath data)
• Prolonged fasting?
Special Considerations-Anesthesia in the Cath Lab

- Remote Environment for Anesthesia
- Limited Access to patient
- Increased Interventional Procedures = higher mortality/morbidity than in past
- Not always good communication and pre-planning
- Desire for diagnostic “awake type” hemodynamics -(resp pattern, blood pressure, SVR and PVR, etc) yet immobility-? Anesth adaptive as plans change to interventions?
Special Considerations-Anesthesia in the Cath Lab

- Who covers the cases?-up to 40% diagnostic caths become interventional; hybrid labs are increasing
- 2014 Odegard et al (A &A 118:175-82) -1% arrest rate in cath lab covered by CV anesthesia; *highly associated with interventions and young age*
- **Anesthetic** – GA vs sedation – hemodynamic stability (Etomidate, dexmedetomidine vs volatile, other)
- Post procedural sedation in infants and toddlers to prevent post cath bleeding?
Special Considerations – MRI-1

- Remote monitoring + Limited monitoring (?)
- Need for breath holds = atelectasis = \( pvr \uparrow \) & \( \text{sats} \downarrow \)
- Inability to actively warm or humidify
- Foreign environment, Poor lighting, limited assistance

- Rangamani et al 143 infants CV MRI - sedation, bundling or GA - 8% ae’s (higher with GA)
- Stockton - 120 pts (48% 1 ventricle) - ae’s in 28%
- 3 arrests/263 cases \( (11\%) \) ( other ae’s= hypotension, hypothermia, hypoxia during and post-outpt admit rate of 20% )
Special Considerations – CV MRI-2

• Avoid prolonged npo; cardiologist involved- Induction outside the MRI + use of NIRS until a stable GA state established:

• Wet hme; vent-large TV and peep; bundled

• critical findings addressed (ie admit infant if discover a critically kinked bt shunt-shunt thrombosis risk)
Cardiac Emergencies in the Anesthetized Patient

please see, use and download free critical events algorithm checklists –link from SPA website or itunes store!

Free App for iphone and ipad:
(no Android version as yet)

Pediatric Critical Events Checklist
By The Children's Hospital of Philadelphia
Open iTunes to get app.
Bradycardia: Unstable

Bradycardia ± heart block, hypotensive with pulses

- Age < 30 days: HR < 100
- Age > 30 days < 1yr: HR < 80
- Age > 1 yr: HR < 60

- Call for help and transcutaneous pacer.

- Hypoxia is common cause of bradycardia.
  - Ensure pt is not hypoxic. Give 100% oxygen.
  - Go to ‘Hypoxia’ card if hypoxia persists.

- Stop surgical stimulation. If laparoscopy, desufflate.

- Consider
  - Epinephrine 2-10 mcg/kg IV
  - Chest compression if ↓ pulses
  - Atropine (0.02mg/kg IV) if vagal etiology

- Assess for drug-induced causes
  - Beta-blocker overdose: Glucagon 0.05 mg/kg IV, then 0.07 mg/kg/h IV infusion
  - Calcium channel blocker overdose: Calcium chloride 10-20 mg/kg IV or calcium gluconate 50 mg/kg, then glucagon if calcium ineffective.

- If PEA develops, start chest compressions. Go to ‘Cardiac Arrest: Asystole, PEA’

Instructions for PACING
1. Place pacing ECG electrodes AND pacer pads on chest per package instructions.
2. Turn monitor/defibrillator ON, set to PACER mode.
3. Set PACER RATE (ppm) to desired rate/min. (Can be adjusted up or down based on clinical response once pacing is established).
4. Increase the milliamperes (mA) of PACER OUTPUT until electrical capture (pacer spikes aligned with QRS complex; threshold normally 65-100mA).
5. Set final mA to 10mA above this level.
6. Confirm pulse present.**
Cardiac Arrest: Asystole, PEA

- Call for help.
- Designate team leader, assign roles.
- Give 100% oxygen. Turn off all anesthetic gases. Place pt on backboard.
- Start chest compressions (100 chest compressions/min + 8 breaths/min)
  - Maintain good hand position.
  - Maximize ETCO₂ > 10 mm Hg with force/depth of compressions.
  - Allow full recoil between compressions.
  - Switch with another provider every 2 minutes, if possible.
  - Use sudden increase in ETCO₂ for ROSC – do not stop compressions for pulse check.
- Epinephrine 10 mcg/kg IV q 3-5 min
- Check pulse & rhythm (q 2 min during compressor switch).

- No Pulse and Not Shockable: Resume CPR and checklist.

<table>
<thead>
<tr>
<th>Read out H&amp;Ts</th>
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<tbody>
<tr>
<td>Hypovolemia</td>
</tr>
<tr>
<td>Hypoxemia</td>
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<tr>
<td>Hydrogen ion (acidosis)</td>
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<tr>
<td>Hyperkalemia</td>
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<tr>
<td>Hypoglycemia</td>
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<tr>
<td>Hypothermia</td>
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<tr>
<td>Tension Pneumothorax</td>
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<tr>
<td>Tamponade (Cardiac)</td>
</tr>
<tr>
<td>Thrombosis</td>
</tr>
<tr>
<td>Toxin (anesthetic, β-blocker)</td>
</tr>
<tr>
<td>Trauma (bleeding outside surgical area)</td>
</tr>
</tbody>
</table>

- Call for ECMO (if available) if no ROSC after 6 min of CPR.
Cardiac Arrest: VF/VT

- Call for help and defibrillator.
- Designate team leader/assign roles.

- Give 100% oxygen. Turn off all anesthetic gases. Place pt on backboard.

- Start chest compressions (100 chest compressions/min + 8 breaths/min).
  - Maintain good hand position
  - Maximize ETCO₂ > 10 mm Hg with force/depth of compressions
  - Allow full recoil between compressions—lift hands off chest

- Shock 2-4 joules/kg
- Resume chest compressions x 2 min.
- Epinephrine 10 mcg/kg IV
- Check pulse & rhythm (q2 min during compressor switch)

If shockable rhythm continues:
- Shock 4 joules/kg.
- Resume chest compressions x 2 min.
- Epinephrine 10 mcg/kg IV
- Check pulse & rhythm (q2 min during compressor switch).

- Shock 4-10 joules/kg, continue chest compressions, and epinephrine 10 mcg/kg every 3-5 min.
- Amiodarone 5 mg/kg bolus; may repeat x 2
- Call for ECMO (if available) after 6 min of CPR
Cardiac Arrest: Prone CPR

- Call for help.

Children/Adolescents

No midline incision:
Compress with heel of hand on spine and second hand on top

Midline incision:
Compress with heel of each hand under scapula

Infants

Compress with encircling technique:
- Thumbs midline if no incision
- Thumbs lateral if incision


Myocardial Ischemia

Recognition
- ST depression >0.5 mm in any lead
- ST elevation >1 mm (2mm in precordial lead)
- Flattened or inverted T waves
- Arrhythmia: VF, VT, ventricular ectopy, heart block

Treat potential causes
- Severe hypoxemia
- Systemic arterial hypo- or hypertension
- Marked tachycardia
- Severe anemia
- Coronary air embolus
- Cardiogenic shock
- Local anesthetic toxicity

Diagnostic studies
- 12-lead ECG:
  - II, III, aVF for inferior (RCA)
  - V5 for lateral ischemia (LCx)
  - V2, V3 anterior ischemia (LAD)
- Compare to previous ECGs
- Ped Cardiology consult; echocardiography

Treatment
- Improve O₂ Supply
  - 100% oxygen
  - Correct anemia
  - Correct hypotension
- Decrease O₂ Demand
  - Reduce heart rate
  - Correct hypertension
  - Restore sinus rhythm
- Drug therapy
  - Nitroglycerin 0.5-5 mcg/kg/min
  - Consider heparin infusion
    - 10 units/kg bolus, then 10 units/kg/hr
Tachycardia

**Diagnosis:**
- ST: narrow complex, p waves present before every QRS
- SVT: narrow complex, no p waves or p waves not associated with QRS
- VT: wide complex, polymorphic or monomorphic

**Treatment:**
If no pulse present, start CPR, go to ‘Cardiac Arrest, VF/VT’ Card

If pulse present:
**Narrow Complex**
- Vagal maneuvers: Ice to face; Valsalva; carotid massage
- Adenosine 0.1-0.3 mg/kg iv push
  (Max 1st dose 6mg/max 2nd dose 12mg)

**Wide Complex**
- Synchronized cardioversion at 0.5 -1.0 joules/kg (see table)
- Amiodarone 5 mg/kg IV bolus over 20-60 minutes, or
- Procainamide 15 mg/kg IV bolus over 30-60 minutes, or
- Lidocaine 1 mg/kg IV bolus

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**Read out H&Ts**

<table>
<thead>
<tr>
<th>Hypovolemia</th>
<th>Tension</th>
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<tbody>
<tr>
<td>Hypoxemia</td>
<td>Pneumothax</td>
</tr>
<tr>
<td>Hydrogen ion</td>
<td>Tamponade</td>
</tr>
<tr>
<td>(acidosis)</td>
<td>Thrombosis</td>
</tr>
<tr>
<td>Hyperkalemia</td>
<td>Toxin</td>
</tr>
<tr>
<td>Hypoglycemia</td>
<td>Trauma</td>
</tr>
<tr>
<td>Hypothermia</td>
<td></td>
</tr>
</tbody>
</table>

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**VT, Wide-complex irregular rhythm**
- Biphasic 2 J/kg, then 4 J/kg for additional shocks

**SVT, tachyarrhythmias with pulse**
- Synchronized cardioversion
  - 0.5-1 J/kg, then 2 J/kg for additional shocks
Anesthetic Management Principles
Anesthetic Management Principles in CHD

• Understand hemodynamic consequences of the lesion and stage of repair
• Construct a set of hemodynamic goals
• Plan anesthetic agents and techniques, ventilatory management, and inotropic/vasoactive drugs based on these goals
• No agent or technique is proscribed, but avoid agents or doses counter to goals, and use agents that promote these goals
# CARDIAC GRID FOR CHD

<table>
<thead>
<tr>
<th>Category</th>
<th>Example</th>
<th>HR</th>
<th>SVR</th>
<th>PVR</th>
<th>PBF</th>
<th>SaO2</th>
<th>FiO2</th>
<th>Contractility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanotic</td>
<td>TOF</td>
<td>↓</td>
<td>↑</td>
<td>⇨</td>
<td>⇨</td>
<td>&gt;80%</td>
<td>1.0</td>
<td>↓</td>
</tr>
<tr>
<td>Mixing</td>
<td>d-TGA</td>
<td>↑</td>
<td>⇨</td>
<td>⇨</td>
<td>⇨</td>
<td>&lt;85%</td>
<td>0.21</td>
<td>⇨</td>
</tr>
<tr>
<td>Acyanotic</td>
<td>VSD</td>
<td>⇨</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>100%</td>
<td>0.21</td>
<td>⇨</td>
</tr>
<tr>
<td>Obstructive</td>
<td>AS</td>
<td>↓</td>
<td>⇨</td>
<td>⇨</td>
<td>⇨</td>
<td>100%</td>
<td></td>
<td>↓</td>
</tr>
<tr>
<td>Single Ventricle</td>
<td>Fontan</td>
<td>↑</td>
<td>⇨</td>
<td>⇨</td>
<td>⇨</td>
<td>&gt;90%</td>
<td>1.0</td>
<td>↑</td>
</tr>
<tr>
<td>Eisenmenger</td>
<td></td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
<td>&gt;80%</td>
<td>1.0</td>
<td>↑</td>
</tr>
</tbody>
</table>
Cardiovascular Effects of Volatiles vs. Fentanyl Midazolam

Echo in 54 2-ventricle patients with CHD
Anesthesiology 2001;94:223
Cardiovascular Effects of Volatile Agents & Fentanyl/Midazolam

Anesthesiology 2001;94:223

H=halothane
S=sevoforane
I=isoforane
F/M=fentanyl/midazolam
Speed of Induction in CHD

• **R to L** shunt: slower inhaled induction
  – No uptake in blood bypassing lungs
  – Affects the least soluble agents the most
    • Anesth Analg 1999;88:759

• **R to L** shunt: faster IV induction
  – Direct passage to arterial blood
    • Anesthesiology 1987;67:739

• **L to R** shunt: no difference inhaled induction or IV induction
# IV Anesthetics and Cardiovascular Effects

<table>
<thead>
<tr>
<th>Agent</th>
<th>Myocardial Contractility</th>
<th>Heart Rate</th>
<th>Arterial Blood Pressure</th>
<th>Cardiac Output</th>
<th>Pulmonary Vascular Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fentanyl</td>
<td>---</td>
<td>Í Í</td>
<td>---</td>
<td>Í</td>
<td>Í Í</td>
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<tr>
<td>Midazolam</td>
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<tr>
<td>Ketamine</td>
<td>--- or Í</td>
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<td>Ë</td>
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<tr>
<td>Propofol*</td>
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<td>Í Í</td>
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</tr>
<tr>
<td>Etomidate¶</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Dexmedetomidine</td>
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</tr>
</tbody>
</table>

*Avoid propofol in preload dependent patients: L side obstruction, dilated cardiomyopathy, decreased LV function
¶ Etomidate preferred in these patients (see A&A 101: 645-50 Sarker et al

Anesthesia for CHD, 2nd Ed., Chapter 6, pp. 77-92.
<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose</th>
<th>Receptors</th>
<th>Inotropy</th>
<th>HR</th>
<th>SVR</th>
<th>PVR</th>
<th>Renal Vascular resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephrine</td>
<td>0.02–0.2 μg/kg/min</td>
<td>$\beta_1, \beta_2 &gt; \alpha_1$</td>
<td>↑</td>
<td>↑</td>
<td>↔</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>Lower Dose</td>
<td>$\alpha_1 &gt; \beta_1, \beta_2$</td>
<td>↑</td>
<td>↑</td>
<td>↔</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>Higher Dose</td>
<td></td>
<td></td>
<td>↑</td>
<td>↑</td>
<td>↔</td>
<td>↓</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>0.02–0.2 μg/kg/min</td>
<td>$\alpha_1 &gt; \beta_1, \beta_2$</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Dopamine</td>
<td>2–5 μg/kg/min</td>
<td>$DA_1, DA_2$</td>
<td>↔</td>
<td>↔</td>
<td>↔</td>
<td>↔</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>5–10 μg/kg/min</td>
<td>$\beta_1, \beta_2 &gt; \alpha_1$</td>
<td>↑</td>
<td>↑</td>
<td>↔</td>
<td>↓</td>
<td>↔</td>
</tr>
<tr>
<td></td>
<td>&gt; 10 μg/kg/min</td>
<td>$\alpha_1 &gt; \beta_1, \beta_2$</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>2–20 μg/kg/min</td>
<td>$\beta_1 &gt; \beta_2, \alpha_1$</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↔</td>
</tr>
<tr>
<td>Isoproterenol</td>
<td>0.01–0.2 μg/kg/min</td>
<td>$\beta_1, \beta_2$</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Milrinone</td>
<td>Loading 25–100 μg/kg Infusion 0.25–0.75 μg/kg/min</td>
<td>Phosphodiesterase III inhibitor/↑ cAMP</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Calcium chloride</td>
<td>5–10 mg/kg IV bolus; 10 mg/kg/h infusion</td>
<td>Contractile proteins</td>
<td>↑</td>
<td>↔, ↓</td>
<td>↑</td>
<td>↔, ↑</td>
<td>↔, ↔</td>
</tr>
<tr>
<td>Nesiritide</td>
<td>1 μg/kg load; 0.1–0.2 μg/kg/min</td>
<td>B-Natriuretic peptide</td>
<td>↔</td>
<td>↔</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Levosimendan</td>
<td>6–12 μg/kg load; 0.05–0.1 μg/kg/min</td>
<td>Troponin C, increasing Ca²⁺ sensitivity; ATP-sensitive K⁺ channels for vasodilation</td>
<td>↑</td>
<td>↔</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Drug</td>
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<tr>
<td>Vasopressin</td>
<td>0.01–0.05 U/kg/h</td>
<td>$V_1$, $V_2$</td>
<td>↔</td>
<td>↔,</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>0.02–0.3 μg/kg/min</td>
<td>$\alpha_1$ (Agonist)</td>
<td>↔</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>0.2–10 μg/kg/min</td>
<td>Vascular myocyte/Guanylyl Cyclase, cGMP↑</td>
<td>↔</td>
<td>↔,</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Nitroprusside</td>
<td>0.2–5 μg/kg/min</td>
<td>Vascular myocyte/Guanylyl Cyclase, cGMP↑</td>
<td>↔</td>
<td>↔,</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Inhaled nitric oxide</td>
<td>10–40 ppm</td>
<td>Vascular myocyte/cGMP↑</td>
<td>↔</td>
<td>↔,</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Prostaglandin $E_1$</td>
<td>0.01–0.2 μg/kg/min</td>
<td>Vascular myocyte/cAMP↑</td>
<td>↔</td>
<td>↔,</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Fenoldopam</td>
<td>0.025–0.3 μg/kg/min initial dose, titrate to maximum dose 1.6 μg/kg/min</td>
<td>DA-1, $\alpha_2$</td>
<td>↔</td>
<td>↔,</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Nicardipine</td>
<td>0.1–0.3 mg/kg/h; maximum 15 mg/h</td>
<td>Calcium channel antagonist</td>
<td>↔</td>
<td>↑</td>
<td>↓</td>
<td></td>
<td>↓</td>
</tr>
<tr>
<td>Drug</td>
<td>Dose</td>
<td>Indications</td>
<td>Comments</td>
<td></td>
<td></td>
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<tr>
<td>--------------</td>
<td>-------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
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<tr>
<td>Adenosine</td>
<td>100 μg/kg rapid bolus, double if ineffective, max: 300 μg/kg</td>
<td>Supraventricular tachycardia</td>
<td>May cause sinus pauses, bradycardia, and A-V block</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amiodarone</td>
<td>Load: 5mg/kg over 30-60 minutes; may repeat twice Infusion: 15-20mg/kg/24hr</td>
<td>Atrial tachycardia, atrial flutter, atrial fibrillation JET; VT and VF</td>
<td>May cause sinus bradycardia, A-V block, or hypotension; drug interactions with procainamide and β-blockers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atropine</td>
<td>10-20 μg/kg</td>
<td>Sinus bradycardia A-V block</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epinephrine</td>
<td>1-5 μg/kg</td>
<td>Sinus bradycardia A-V block</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esmolol</td>
<td>Load: 250-500 μg/kg over 1-2 minutes Infusion: 50-500 μg/kg/min</td>
<td>Sinus tachycardia; atrial and ventricular tachyarrhythmias</td>
<td>May cause negative inotropy, bradycardia, sinus pauses, and A-V block</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoproterenol</td>
<td>0.01-0.03 μg/kg/min</td>
<td>Sinus bradycardia in denervated heart; complete A-V block</td>
<td>β₂ effects may decrease diastolic BP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lidocaine</td>
<td>Load: 1-2 mg/kg over 1 minute; may repeat Infusion: 20-50 μg/kg/min</td>
<td>Premature ventricular contractions VT, VF</td>
<td>Toxicity from hepatic/renal failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium sulfate</td>
<td>Load: 25-50mg/kg over 30 minutes</td>
<td>VT (torsade de pointes) Prevention of JET</td>
<td>May cause muscle weakness and sedation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procainamide</td>
<td>Load: 10-15mg/kg over 30-45min Infusion: 20-40 μg/kg/min</td>
<td>Atrial tachycardia JET, VT</td>
<td>Monitor procainamide, N-acetylprocainamide levels; may cause hypotension; synergistic adverse effects with amiodarone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Andropoulos and Gottlieb; Congenital Heart Disease, Anesthesia and Uncommon Diseases, 6th Ed., Fleisher L., (ed.) 2012, p. 81
Infective Endocarditis Prophylaxis: Cardiac Indications

• Prosthetic cardiac valve or conduit
• Previous infective endocarditis
• Congenital heart disease:
  – Unrepaired or palliated cyanotic CHD
  – Completely repaired CHD with patch during 1st 6 months
  – Repaired CHD with residual defects at or near patch or device – no time limit
• Cardiac transplant recipients with valvulopathy

Circulation 2007; 116:1736
Infective Endocarditis: Procedural Indications

- Dental procedure with disruption of gums or mucosa
- Airway procedures that break the mucosa: tonsillectomy, bronchoscopy with biopsy (not a flex bronch alone absent active infection)
- Procedures involving infected:
  - Skin, soft tissue, musculoskeletal tissue
  - Gastrointestinal, genitourinary track
- NOT recommended for colonoscopy, GI endoscopy, sterile surgical procedures

Circulation 2007; 116:1736
# IE Regimens for Dental Procedures

## Table 3-7: Endocarditis Prophylaxis: Dental Regimens for CHD Surgical Patients

<table>
<thead>
<tr>
<th>Situation</th>
<th>Agent</th>
<th>Regimen*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral</td>
<td>Amoxicillin</td>
<td>Adults: 2 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 50 mg/kg</td>
</tr>
<tr>
<td>Unable to take oral medication</td>
<td>Ampicillin or Cefazolin or Ceftriaxone</td>
<td>Adults: 2 g IM or IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 50 mg/kg IM or IV</td>
</tr>
<tr>
<td>Allergic to penicillins or ampicillin (oral)</td>
<td>Cephalexin†† or Clindamycin or Azithromycin or Clarithromycin</td>
<td>Adults: 2 g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 50 mg/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adults: 600 mg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 20 mg/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adults: 500 mg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 15 mg/kg</td>
</tr>
<tr>
<td>Allergic to penicillins or ampicillin and unable to take oral medication</td>
<td>Cefazolin or Ceftriaxone† or Clindamycin</td>
<td>Adults: 1 g IM or IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 50 mg/kg IM or IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adults: 600 mg IM or IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Children: 20 mg/kg IM or IV</td>
</tr>
</tbody>
</table>

*Circulation 2007; 116:1736*
Adult Congenital Heart Disease
Adult Congenital Population Currently Exceeds Pediatric Population and will Increase over next Decade; Need for Hospital Services will Escalate

Percent of Pediatric to Adult Patients With Congenital Heart Disease

Age Range of Patients With Congenital Heart Disease at Hospital Admission

Reference:

Society for Pediatric Anesthesia
education • research • patient safety

Intensive Review of Pediatric Anesthesia
2015
Conclusion:

Adult CHDz diagnoses mirror current pediatric survival groups except expect more single venticle, other common complex lesions in newer data.
Adult Congenital Heart Disease

- Complete permanent correction rare (PDA, ASD)
- Most lesions s/p “complete repair” require long term followup: late sequelae are common:

  - Late bilateral pulmonary stenoses (TOF age 32, also with severe PI not shown)
  - 6.7 cm aneurysm above coarctation repair
Long Term Sequelae of Adult CHD

- Coagulopathy of polycythemia
  - Hct >55%
  - Lower plasma coagulation proteins
  - Platelet dysfunction

- Thrombosis:
  - Sluggish blood flow in Fontan connections
  - Atrial fibrillation

- Pulmonary hypertension
  - Unrepaired/residual VSD, ASD, PDA

- Heart failure

- Dysrhythmias
  - At least 50% of moderate to complex CHD

- Stroke

- Renal/hepatic dysfunction

- Coronary disease >40: 9% incidence, same as general population
<table>
<thead>
<tr>
<th>Low severity</th>
<th>Moderate severity</th>
<th>Complex-high risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD (closed)</td>
<td>A-V canal (good repair)</td>
<td>Cyanotic congenital Fontans; any single ventricle</td>
</tr>
<tr>
<td>PDA (occluded)</td>
<td>Coarctation aorta</td>
<td>Transposition of Great Arteries</td>
</tr>
<tr>
<td>VSD (full repair)</td>
<td>Ebstein’s (functional)</td>
<td>Double outlet or inlet ventricles</td>
</tr>
<tr>
<td>Isolated mild Ao valve dz, pulm dz or mitral dz</td>
<td>PDA not closed</td>
<td>Conduits</td>
</tr>
<tr>
<td>Coarctation with minimal residual Ao stenosis</td>
<td>Pulmonary stenosis or regurg (mod to severe)</td>
<td>s/p Ross Procedure</td>
</tr>
<tr>
<td></td>
<td>Tetralogy of Fallot</td>
<td>Eisenmenger syndrome</td>
</tr>
<tr>
<td></td>
<td>VSD with:</td>
<td>Severe Ebstein’s</td>
</tr>
<tr>
<td></td>
<td>absent valve</td>
<td>Truncus arteriosus</td>
</tr>
<tr>
<td></td>
<td>Ao regurg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>subAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mitral disease</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RVOT obstruction</td>
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<td></td>
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</tbody>
</table>
EXERCISE CAPACITY FOR 335 ADULTS with CCHDZ AND 40 CHF ADULTS VS Age Matched CONTROL GROUPS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean ± SD (ml/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic coarctation</td>
<td>28.7 ± 10.4</td>
</tr>
<tr>
<td>Tetralogy of Fallot</td>
<td>25.5 ± 9.1</td>
</tr>
<tr>
<td>VSD</td>
<td>23.4 ± 8.9</td>
</tr>
<tr>
<td>Mustard-operation</td>
<td>23.3 ± 7.4</td>
</tr>
<tr>
<td>Valvular disease</td>
<td>22.7 ± 7.6</td>
</tr>
<tr>
<td>Ebsteins anomaly</td>
<td>20.8 ± 4.2</td>
</tr>
<tr>
<td>Pulmonary atresia</td>
<td>20.1 ± 6.5</td>
</tr>
<tr>
<td>Fontan-operation</td>
<td>19.8 ± 5.8</td>
</tr>
<tr>
<td>ASD (late closure)</td>
<td>19.2 ± 6.2</td>
</tr>
<tr>
<td>ccTGA</td>
<td>18.6 ± 6.9</td>
</tr>
<tr>
<td>Complex Anatomy</td>
<td>14.6 ± 4.7</td>
</tr>
<tr>
<td>Eisenmenger</td>
<td>11.5 ± 3.6</td>
</tr>
</tbody>
</table>

(controls 45 +/- 8.6)

ANOVA P<0.0001


Intensive Review of Pediatric Anesthesia 2015
Reference Sources

- Society for Pediatric Anesthesia, Critical Events Checklists; www.pedsanesthesia.org