Cardiac arrest in children

Dr J Lauweryns
Overview

• 1. Causes and outcome of cardiac arrest (CA)
• 2. Prevention
• 3. Basic life support
• 4. Advanced life support
• 5. Resuscitation of the newborn
• 6. Specific situations
1. Causes and outcome

• Pediatric perioperative cardiac arrest (POCA) studies

• Multicenter study, 373 CA patients, operation theatre and PACU

• Causes of CA, outcome (10 points severity of injury scale after 24h, outcome at the last clinical evaluation)

• Anesthesia related
# Age

<table>
<thead>
<tr>
<th></th>
<th>Patients with HD (n = 127)</th>
<th>Without HD (n = 245)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–6 mo</td>
<td>59 (47%)</td>
<td>94 (39%)</td>
<td>0.071</td>
</tr>
<tr>
<td>7 mo to 12 mo</td>
<td>8 (6%)</td>
<td>24 (10%)</td>
<td></td>
</tr>
<tr>
<td>&gt;1–2 y</td>
<td>22 (17%)</td>
<td>35 (14%)</td>
<td></td>
</tr>
<tr>
<td>&gt;2–5 y</td>
<td>13 (10%)</td>
<td>31 (13%)</td>
<td></td>
</tr>
<tr>
<td>6–10 y</td>
<td>6 (5%)</td>
<td>28 (11%)</td>
<td></td>
</tr>
<tr>
<td>11–18 y</td>
<td>18 (14%)</td>
<td>32 (13%)</td>
<td></td>
</tr>
<tr>
<td>Emergency</td>
<td>18 (14%)</td>
<td>59 (24%)</td>
<td></td>
</tr>
<tr>
<td>ASA physical status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I–II</td>
<td>10 (8%)</td>
<td>92 (38%)</td>
<td></td>
</tr>
<tr>
<td>III–IV</td>
<td>117 (92%)</td>
<td>153 (62%)</td>
<td></td>
</tr>
</tbody>
</table>

*P values by Fisher exact test.
HD = heart disease.

Location

• General operating room: 54%

Gastrointestinal> ear, nose, throat > placement of CVC
Urology, orthopedics, ophtalmology, plastics, dental and thoracic procedures
less frequent

• Cardiac OR: 26%

• Cardiac catheterization lab: 17%

• Other imaging suites 3%
Phase of anesthesia during arrest

- Surgical maintenance (cardiovascular): 48%
- Presurgical: 36%
- Postsurgical (respiratory): 16%
Etiology of arrest


Figure 1. Causes of anesthesia-related cardiac arrest associated with heart disease (n = 127) versus nonheart disease (n = 245). *P = 0.03, **P = 0.01.
Etiology of arrest

• Cardiovascular:
  Hypovolemia from blood loss: spinal fusion, craniotomy/craniectomie
  Hyperkalemia: secondary to perfusion of stored blood
  CV Surgery

• Respiratory: laryngospasm, airway surgery

• Medication–related:
  halothane, hyperkalemia after sux, neostigmine (even with appropriate doses of glycopyrrolate)

• Equipment: CVC
## Etiology of arrest

**Table 3.** Anesthesia-Related Factors in Cardiac Arrests from Hypovolemia Due to Blood Loss 1998-2004 ($n = 23$)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underestimation of blood loss</td>
<td>11 (48%)</td>
</tr>
<tr>
<td>Inadequate peripheral venous access</td>
<td>5 (22%)</td>
</tr>
<tr>
<td>Central venous catheter not present or not transduced</td>
<td>5 (22%)</td>
</tr>
<tr>
<td>Arterial catheter not present or malfunctioning</td>
<td>4 (17%)</td>
</tr>
<tr>
<td>Underestimation of pre-existing hypovolemia or anemia</td>
<td>3 (13%)</td>
</tr>
<tr>
<td>Not enough help available to treat blood loss</td>
<td>3 (13%)</td>
</tr>
<tr>
<td>Delay in getting blood from blood bank</td>
<td>3 (13%)</td>
</tr>
<tr>
<td>Hypocalcemia not appreciated, or undertreated</td>
<td>3 (13%)</td>
</tr>
<tr>
<td>Development of coagulopathy</td>
<td>2 (9%)</td>
</tr>
</tbody>
</table>

Percentages in parentheses may sum to >100% due to multiple factors in some cases.

Etiology of arrest


<table>
<thead>
<tr>
<th>Cause of arrest</th>
<th>n (% of 127)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
<td>63 (50%)</td>
</tr>
<tr>
<td>Myocardial ischemia</td>
<td>5 (4%)</td>
</tr>
<tr>
<td>Hyperkalemia</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>&quot;Tet&quot; spell</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Hypovolemic preexisting</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Sudden arrhythmia</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Hypovolemic/blood loss</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Other miscellaneous CV cause*</td>
<td>11 (9%)</td>
</tr>
<tr>
<td>Presumed CV: unclear etiology</td>
<td>33 (26%)</td>
</tr>
<tr>
<td>Medication</td>
<td>26 (20%)</td>
</tr>
<tr>
<td>Inhaled anesthetic CV depression</td>
<td>8 (6%)</td>
</tr>
<tr>
<td>Halothane</td>
<td>6 (5%)</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Intravenous drug CV depression</td>
<td></td>
</tr>
<tr>
<td>Propofol</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Narcotics</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Wrong dose</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Medication combinations</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Other*</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>21 (17%)</td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>6 (5%)</td>
</tr>
<tr>
<td>Inadequate oxygenation</td>
<td>6 (5%)</td>
</tr>
<tr>
<td>Difficult intubation</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>Other miscellaneous respiratory cause*</td>
<td>5 (4%)</td>
</tr>
<tr>
<td>Equipment</td>
<td>11 (9%)</td>
</tr>
<tr>
<td>Central line complications</td>
<td>9 (7%)</td>
</tr>
<tr>
<td>Breathing circuit obstruction</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Endotracheal tube obstruction</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Multiple events</td>
<td>3 (2%)</td>
</tr>
<tr>
<td>Unknown cause</td>
<td>4 (3%)</td>
</tr>
</tbody>
</table>

CV = cardiovascular.
* One case each: air embolism, hypovolemia from surgical retraction, left ventricular outflow obstruction, pacemaker failure, right-to-left shunt, severe valvular dysfunction, vagal response, acidosis, pulmonary hypertensive crisis, myocardial dysfunction, and severe coronary artery disease.
* One case each: epinephrine-induced ventricular fibrillation, prostacyclin effect, and intravascular injection of local anesthetic.
* One case each: esophageal intubation, premature extubation, pneumothorax, endobronchial intubation, presumed respiratory, and cause unclear.
Resuscitation

- Resuscitation details: 68 patients
- Non-survivors vs survivors:
  - longer total duration (53 vs 6 minutes)
  - larger number of drugs
  - more rounds of drugs
- No difference:
  - delay until start of resuscitation
  - use of defibrillation
- Epinephrine: intervention most often associated with return of circulation
- Occasionally CPB and ECMO
- Longest resuscitation with intact survivor: 35min reanimation, start ECMO
Outcome

• Mortality higher in ASA III-IV

• Mortality rates after CA:
  - Cardiac OR 45%
  - General OR 26%
  - Catheterization laboratory 33%

• Highest mortality rate in children with heart disease:
  aortic stenosis > cardiomyopathy > single ventricle > other unrepaired > palliated > completely repaired

• CNS injuries: 5-6%: E, parietal and occipital infarcts, global cerebral ischemia, intraventricular hemorrhage, left-sided paresis,…
1. Causes and outcome

- Perioperative cardiac arrest at the mayo clinic 1988-2005
- Single centre study, 80 patients
- Incidence, causes, outcome of CA in children<18Y
- All cardiac and noncardiac surgery
Results

• Incidence: declining: 8.6/10000 (overall)
  Highest in neonates and infants

• Only 18.8% of CA perioperative = anesthesia related

• Majority of cardiac arrests (67.5%) = cardiac surgery (includes: failure to wean from bypass) (case-mix)

• Pattern of causality ~ POCA: respiratory, medication, equipment

• Mortality ~ anesthesia related (lower), type of surgery (cardiac), age
2. Prevention of arrest

- Recognition of high risk situations!!!

- High risk cases: use of invasive monitors and large bore peripheral IV catheters

- Autologous transfusions, intraoperative blood salvage, antifibrinolytics, control arterial blood pressure

- No transfusion via hand-held syringes in small catheters(<22G), fresh red blood cells, saline washing of irradiated blood, monitor serum K+

- Early administration of sux IM before onset of bradycardia

- US guidance of CVC puncture
ERC (European resuscitation council) guidelines for resuscitation 2010
3. Basic life support

- 1. Recognition of cardiorespiratory failure

  responsiveness

  airway

  circulation:
  -> pulse palpation: decision to start CPR in less than 10 s

  infants (<1Y): brachial, femoral pulse

  children: carotid, femoral pulse

  <60/
3. Basic life support

Paediatric basic life support

UNRESPONSIVE?

Shout for help

Open airway

NOT BREATHING NORMALLY?

5 rescue breaths

NO SIGNS OF LIFE?

15 chest compressions

2 rescue breaths
15 compressions

Call cardiac arrest team or Paediatric ALS team
3. Basic life support

Fig. 6.2. Mouth-to-mouth ventilation – child.

Fig. 6.3. Mouth-to-mouth and nose ventilation – infant.
3. Basic life support

Fig. 6.4. Chest compression – infant.

Fig. 6.5. Chest compression with one hand – child.
3. Basic life support

• CPR: ‘push hard and push fast’

• Infants: 2 fingers (1 person), thumb encircling (2 persons) technique
  Children: 1 hand
  Adolescent: 2 hands

• Adequate depth: 1/3 of the anterior-posterior chest diameter

• Complete release

• 100-120/’
4. Advanced life support

• 1. Recognition of cardiorespiratory failure

• Respiratory failure:

  Respiratory rate outside the normal range

  Increased work of breathing -> inadequate/decreased work of breathing +
  additional noises: stridor, wheeze, grunting, loss of breath sounds

  Decreased Vt, shallow breathing

  Hypoxaemia
4. Advanced life support

- www.normalbreathing.com
4. Advanced life support

• 1. Recognition of cardiorespiratory failure

• Circulation

Increased heart rate -> bradycardia

Hypotension: decreased systemic blood pressure: late sign of hypovolemia!

Weak or absent peripheral pulses

Prolonged capillary refill, decreased skin temperature, pale or mottled skin

Systemic: decreased urinary output, metabolic acidosis, level of consciousness may be decreased: poor cerebral perfusion
4. Advanced life support

**Normal Resting Heart Rates**

- **Newborns (0 – 3 months old):** 100 – 150 beats per minute
- **Infants (3 – 6 months old):** 90 – 120 beats per minute
- **Infants (6 – 12 months old):** 80 – 120 beats per minute
- **Children 1 – 10 years:** 70 – 130 beats per minute
- **Children over 10 and adults (including seniors):** 60 – 100 beats per minute
- **Well-trained athletes:** 40 – 60 beats per minute

4. Advanced life support

- 2. management of cardiorespiratory failure
- Respiration

Bag mask, (LMA), ETT: oral route, cuffed

Sudden deterioration in an intubated child: ‘DOPES’
Displacement of the tracheal tube
Obstruction
Pneumothorax
Equipment failure(source of gas, ventilator,…)
Stomach distension
4. Advanced life support

<table>
<thead>
<tr>
<th></th>
<th>Uncuffed</th>
<th>Cuffed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonates</td>
<td>Gestational age in weeks/10</td>
<td>Not used</td>
</tr>
<tr>
<td><em>premature</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neonates</td>
<td>3.5</td>
<td>Not usually used</td>
</tr>
<tr>
<td><em>Full term</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infants</td>
<td>3.5–4.0</td>
<td>3.0–3.5</td>
</tr>
<tr>
<td>Child 1–2 years</td>
<td>4.0–4.5</td>
<td>3.5–4.0</td>
</tr>
<tr>
<td>Child &gt;2 years</td>
<td>Age/4 + 4</td>
<td>Age/4 + 3.5</td>
</tr>
</tbody>
</table>

4. Advanced life support

- **Oxygen**
  - neonates: room air
  - older child: 100% FiO2, ROSC: titrate FiO2 to SaO2 94-98%

- **Ventilation**
  - avoid hyperventilation! increased intrathoracic pressure, decreased coronary and cerebral perfusion (adults), 10-12", moderate rise thorax

- **Monitoring**
  - capnography: absence does not guarantee tube displacement, efficiency of compressions (strive to >15mmHg)/early indicator of ROSC (pulse oximetry)
4. Advanced life support

• 2. management of cardiorespiratory failure

• Circulation

• Establish cardiac monitoring (pulse oximetry, ECG, NIBP)

• Defibrillation

• Cardiorespiratory arrest in children: usually of respiratory origin, if fibrillation: speed of defibrillation ~ survival
4. Advanced life support

- AED 1-8Y: can recognize pediatric shockable rhythms, dose attenuator 50-75J, >8Y adult
  Manual defibrillation: preference for biphasic shocks, 4J/kg
  Internal defibrillation: 0,6-0,7J/kg (+0,5J/kg)
- Paddle size: largest possible without the paddles touching each other
  4,5 cm infants, children<10kg
  8-12cm >10kg (>1y)
- Apply firmly
- Position: below right clavicle, in the left axilla
  alternative: upper back (below left scapula) and the other on the front
4. Advanced life support
4. Advanced life support

- Intravascular access: IV, IO or CVC (use if in place)
  
intravenous: if unsuccessful after 1 min -> IO
CVC: no advantages during resuscitation

tracheal tube access: inferior to IV/IO, highly variable absorption
4. Advanced life support

- **IO route**

- **Rationale:** medullary cavity: network of venous sinusoids-> drained by a single central venous canal->via emissary vessels directly into large central venous circulation (popliteal vein)

- **Onset medication IO=IV**

- **Infants and children:** anteromedial surface of the tibia, 1-2cm below the tibial tuberosity(cortex thinnest), needle inserted 90°to the skin

- **Other sites:** sternum, distal femur, lateral or medial malleoli, iliac crest, distal radius
Figure 1. Location on the tibia for the insertion routes for a pediatric or adult intraosseous infusion needle.

4. Advanced life support

- Correct placement: aspiration of bone marrow, free flow of crystalloid by gravity (slow! or not spontaneous) without extravasation, US

- Flush each medication with 10cc saline
4. Advanced life support

Tracheal route

- (Adrenaline 100µg/kg)
- Lidocaïne 2-3mg/kg
- Atropine 30µg/kg

Dilate the drug in 5ml saline, follow administration with 5 ventilations, do not give non-lipid soluble medications (e.g. glucose, bicarbonate, calcium)
4. Advanced life support

- Fluid bolus when circulatory failure and no signs of fluid overload, even with normal blood pressure

- 20ml/kg

- Isotonic crystalloids recommended as initial resuscitation fluid, avoid dextrose unless hypoglycemia

- No sufficient data to recommend delayed fluid resuscitation in the hypotensive child with blunt trauma, unsufficient data to recommend the use of hypertonic saline for circulatory failure associated with head injuries or hypovolemia
4. Advanced life support

- Drugs as required

- Adenosine: brief AV block/impairs accessory bundle re-entry at the level of the AV node, indication: SVT, short half life (10s) for asthma, second-third degree AV block, long QT, cardiac transplants

- Adrenaline (epinephrine): algorithm, intratracheal no longer recommended, use of higher doses via IV/IO route not routinely recommended: no improvement survival/neurological outcome, after ROSC low dose continuously IV sometimes useful

- Amiodarone: non-competitive inhibitor of adrenergic receptors: depresses conducton in myocardial tissue and therefore slows AV conduction, prolongs QT-interval and refractory period
4. Advanced life support

- **Atropine:** bradycardia caused by increased vagal tone or cholinergic drug toxicity $\leftrightarrow$ bradycardia with poor perfusion, unresponsive to ventilation and oxygenation: use adrenaline as first line treatment!

- **Calcium:** on specific indications: hypocalcemia, calcium channel blocker overdose, hypermagnesaemia, hyperkalaemia $\rightarrow$ routine use does not improve the outcome from cardiopulmonary arrest

- **Glucose:** if hypoglycemia

- **Magnesium:** not routinely, hypomagnesemia, torsades de pointes

- **Sodium bicarbonate:** prolonged cardiopulmonary arrest or severe metabolic acidosis, hyperkalemia, tricyclic antidepressant drug overdose
4. Advanced life support

- Lidocaine: less effective for VF/pulseless VT in adults -> not a first line treatment for children

- Vasopressin-Terlipressin: evidence lacking, improves hemodynamics (survival??) in children with refractory, vasodilatory septic shock, cardiac arrest refractory to several adrenaline doses
## 4. Advanced life support

<table>
<thead>
<tr>
<th>Product</th>
<th>Dose</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenaline</td>
<td>10µg/kg IV</td>
<td>Every 3-5 min, max 1mg</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>5mg/kg IV</td>
<td>After 5th shock</td>
</tr>
<tr>
<td>Atropine</td>
<td>0,01-0,02mg/kg IV</td>
<td></td>
</tr>
<tr>
<td>Calciumchloride</td>
<td>25mg/kg IV</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>50mg/kg IV</td>
<td></td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>1mmol/kg IV or 1ml/kg IV from solution 8,4%</td>
<td></td>
</tr>
<tr>
<td>Adenosine</td>
<td>0,1mg/kg IV</td>
<td>Repeat: 0,2mg/kg IV</td>
</tr>
</tbody>
</table>
Paediatric Advanced Life Support

Unresponsive?
Not breathing or only occasional gasps

CPR (5 initial breaths then 15:2)
Attach defibrillator/monitor
Minimise interruptions

Call Resuscitation Team
(1 min CPR first, if alone)

Assess rhythm

Shockable
(VF/Pulseless VT)

1 Shock 4 J/Kg

Immediately resume:
CPR for 2 min
Minimise interruptions

Non-shockable
(PEA/Axystole)

Return of spontaneous circulation

Immediately resume:
CPR for 2 min
Minimise interruptions

During CPR
- Ensure high-quality CPR (rate, depth, recoil)
- Plan actions before interrupting CPR
- Give epinephrine
- Vascular access (intravenous, intracerebral)
- Give adrenaline every 3-5 min
- Consider advanced airway and capnography
- Continuous chest compression when advanced airway in place
- Correct reversible causes

Reversible causes
- Hypoxia
- Hypovolaemia
- Hypokalaemia/metabolic
- Hypothermia
- Tension pneumothorax
- Toxins
- Tamponade - cardiac
- Thrombocytopenia
4. Advanced life support
4. Advanced life support

• Post-arrest management

• Hypothermia? No RC trials (extrapolation adults, neonates)
  After ROSC, if the patient remains comatose:
  do not treat mild hypothermia \( \geq 32^{\circ}C \)
  may benefit from active cooling to 32-34\(^{\circ}C\)
  treat fever aggressively
  rewarm slowly!!! 0.25-0.5\(^{\circ}C/h\)

• Avoid hypo en hyperglycemia (no specific protocols)

• Titrate vasoactive drugs (adrenaline, dobutamine, dopamine, noradrenaline) to improve hemodynamic status
4. Advanced life support

• When to stop? Consider after 20 min

• Parental presence:
  better coping, no real guidelines
  member of the team should explain the process
  if impeding the process of resuscitation -> leave
  the leader of the resuscitation team makes the final decision to stop
  resuscitation efforts
5. Resuscitation of the newborn

• Seldom required

• If needed: usually assisted lung aeration
  Small minority: chest compressions

• At risk: intrapartum evidence of significant fetal compromise, <35 weeks, vaginal delivery by the breech, multiple pregnancies

• Be prepared! Minimum set up of equipment: device for safe assisted lung aeration, warm dry towels and blankets, sterile instrument for cutting the umbilical cord, clean gloves, suction catheter, tongue depressor (or laryngoscope)
5. Resuscitation of the newborn

- Drying and wrapping, <28w: no drying, plastic wrapping

- Recognition of cardiorespiratory failure

- **Apgar**: not made for recognition of cardiorespiratory failure, helpful

  **Breathing**: rate, depth, symmetry of breathing together, abnormal breathing: grunting, gasping

  **Heart rate**: apex of the heart (with stethoscope), cord pulsation: not reliable under 100/”, pulse oximeter (pre-ductal)

  **Colour**: poor predictor: healthy baby: blue at birth, turn pink within 30s at the onset of effective breathing, peripheral cyanosis= common->if a baby is blue: check oxygenation with pulse-oximeter

  **Tone**: very floppy-> likely unconscious-> likely need for ventilatory support
## 5. Resuscitation of the newborn

<table>
<thead>
<tr>
<th>Classification according to initial assessment</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate &gt;100/’ Vigorous breathing or crying Good tone</td>
<td>No intervention, wrapping+ give to mother ‘skin to skin contact’</td>
</tr>
<tr>
<td>Breathing inadequately or apnoeic Normal or reduced tone Heart rate &lt;100/’</td>
<td>Dry and wrap, may improve with mask inflation, if the heart rate does not increase: chest compressions</td>
</tr>
<tr>
<td>Breathing inadequately or apnoeic Flopy Low or undetectable heart rate Often pale suggesting poor perfusion</td>
<td>Dry and wrap, immediate airway control, lung inflation and ventilation, may need chest compressions and drugs</td>
</tr>
</tbody>
</table>
5. Resuscitation of the newborn

Airway: neutral position or towel under the shoulders, consider jaw thrust in floppy babies

Suction: only if the airway is obstructed or in the presence of thick meconium in the non-vigourous baby
5. Resuscitation of the newborn

5 initial breaths, maintain the initial inflation pressure 2-3s, 20->40cm H2O, until rise in heart rate, ventilate 30/’, 1sec/inflation, 4-8ml/kg, pressure 20-20cm H2O, CPAP (LMA? >2kg, back up plan)
5. Resuscitation of the newborn

<table>
<thead>
<tr>
<th>Labor</th>
<th>At 10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>SaO2 60%</td>
<td>SaO2 &gt;90%</td>
</tr>
<tr>
<td>25th percentile SaO2 40%</td>
<td>SaO2 80%</td>
</tr>
</tbody>
</table>

- Term babies: room air
- If, despite effective ventilation, there is no increase in heart rate or oxygenation (oximetry!): use a higher concentration of oxygen
- <32w blended oxygen and air guided by pulse oxymetry to SaO2 90%
5. Resuscitation of the newborn

• When to intubate?

- when suctioning to remove meconium or other tracheal blockage is required
- if bag-mask ventilation is ineffective or prolonged
- when chest compressions are performed
- special circumstances (e.g.; congenital diaphragmatic hernia, birth weight below 1000g)
Table 7.1. Oral tracheal tube lengths by gestation.

<table>
<thead>
<tr>
<th>Gestation (weeks)</th>
<th>Tracheal tube at lips (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23–24</td>
<td>5.5</td>
</tr>
<tr>
<td>25–26</td>
<td>6.0</td>
</tr>
<tr>
<td>27–29</td>
<td>6.5</td>
</tr>
<tr>
<td>30–32</td>
<td>7.0</td>
</tr>
<tr>
<td>33–34</td>
<td>7.5</td>
</tr>
<tr>
<td>35–37</td>
<td>8.0</td>
</tr>
<tr>
<td>38–40</td>
<td>8.5</td>
</tr>
<tr>
<td>41–43</td>
<td>9.0</td>
</tr>
</tbody>
</table>
5. Resuscitation of the newborn

Chest compressions if heart rate <60/” despite adequate ventilation

Two thumbs encircling technique (lower third sternum)

3/1 compression /ventilation ratio=> 90/30
5. Resuscitation of the newborn

Drugs: heart rate remains <60/’ despite adequate ventilation and chest compressions->IV adrenaline 10-30 µg/kg, bicarbonate 1-2 mmol/kg(prolonged resuscitation) ; IV fluids: blood, isotonic crystalloids 10ml/kg(pale, poor perfusion, weak pulse), glucose
Newborn Life Support

1. **Dry the baby**
   - Remove any wet towels and cover
   - Start the clock or note the time

2. **Assess (tone), breathing and heart rate**

3. **If gasping or not breathing**
   - Open the airway
   - Give 5 inflation breaths
   - Consider SpO2 monitoring

4. **Re-assess**
   - If no increase in heart rate
   - Look for chest movement

5. **If chest not moving**
   - Recheck head position
   - Consider two-person airway control or other airway manoeuvres
   - **Repeat Inflation breaths**
   - Consider SpO2 monitoring
   - Look for a response

6. **If no increase in heart rate**
   - Look for chest movement

7. **When the chest is moving**
   - If the heart rate is not detectable or slow (< 60)
   - Start chest compressions
   - 3 compressions to each breath

8. **Reassess heart rate every 30 seconds**
   - If the heart rate is not detectable or slow (< 60)
   - Consider venous access and drugs

*www.pediatrics.org/cgi/doi/10.1542/peds.2019-1570*
6. Specific situations

- Children with congenital cardiac problems
- Local anesthetic toxicity
- Malignant hyperthermia
- Anaphylactic reaction
- Bronchospasm
6. Specific situations

- Congenital cardiac disease
- Single ventricle post stage 1 repair: classic resuscitation protocols
- Single ventricle post Fontan: may benefit from negative pressure ventilation
  Consider ECMO
- Pulmonary hypertension: high FIO2, normo-hyperventilation
  Consider NO, epoprostenol
  Consider right ventricular support device
- Aortic stenosis: difficult!
**AAGBI Safety Guideline**

**Management of Severe Local Anaesthetic Toxicity**

<table>
<thead>
<tr>
<th>1 Recognition</th>
<th>2 Immediate Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signs of severe toxicity:</td>
<td></td>
</tr>
<tr>
<td>- Sudden alteration in mental status, severe agitation or loss of consciousness, with or without tonic-clonic convulsions</td>
<td></td>
</tr>
<tr>
<td>- Cardiovascular collapse: sinus bradycardia, conduction blocks, asystole and ventricular tachyarrhythmias may all occur</td>
<td></td>
</tr>
<tr>
<td>- Local anaesthetic (LA) toxicity may occur some time after an initial injection</td>
<td></td>
</tr>
<tr>
<td>Stop injecting the LA</td>
<td></td>
</tr>
<tr>
<td>- Call for help</td>
<td></td>
</tr>
<tr>
<td>- Maintain the airway and, if necessary, secure it with a tracheal tube</td>
<td></td>
</tr>
<tr>
<td>- Give 100% oxygen and ensure adequate lung ventilation (intubation and ventilation may help by increasing plasma pH in the presence of metabolic acids)</td>
<td></td>
</tr>
<tr>
<td>- Confirm or establish intravenous access</td>
<td></td>
</tr>
<tr>
<td>- Control seizures: give a benzodiazepine, thiopental or propofol in small incremental doses</td>
<td></td>
</tr>
<tr>
<td>- Assess cardiovascular status throughout</td>
<td></td>
</tr>
<tr>
<td>- Consider drawing blood for analysis, but do not delay definitive treatment to do this</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3 Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IN CIRCULATORY ARREST</strong></td>
</tr>
<tr>
<td>- Start cardiopulmonary resuscitation (CPR) using standard protocols</td>
</tr>
<tr>
<td>- Manage arrhythmias using the same protocols, recognising that arrhythmias may be very refractory to treatment</td>
</tr>
<tr>
<td>- Consider the use of cardiopulmonary bypass if available</td>
</tr>
<tr>
<td><strong>GIVE INTRAVENOUS LIPOID EMULSION</strong> (following the regimen overleaf)</td>
</tr>
<tr>
<td>- Continue CPR throughout treatment with lipid emulsion</td>
</tr>
<tr>
<td>- Recovery from LA-induced cardiac arrest may take &gt;1 h</td>
</tr>
<tr>
<td>- Propofol is not a suitable substitute for lipid emulsion</td>
</tr>
<tr>
<td>- Lidocaine should not be used as an anti-arrhythmic therapy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4 Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Arrange safe transfer to a clinical area with appropriate equipment and suitable staff until sustained recovery is achieved</td>
</tr>
<tr>
<td>- Exclude paracetamol by regular clinical review, including daily amnule and biphasic assays for two days</td>
</tr>
<tr>
<td>- Report cases as follows</td>
</tr>
<tr>
<td>- In the United Kingdom to the National Patient Safety Agency (via <a href="http://www.npsa.nhs.uk">www.npsa.nhs.uk</a>)</td>
</tr>
<tr>
<td>- In the Republic of Ireland to the Irish Medicines Board (via <a href="http://www.imb.ie">www.imb.ie</a>)</td>
</tr>
<tr>
<td>- If lipid has been given, please also report its use to the International registry at <a href="http://www.lipidregistry.org">www.lipidregistry.org</a></td>
</tr>
<tr>
<td>- Details may also be posted at <a href="http://www.lipidregistry.org">www.lipidregistry.org</a></td>
</tr>
</tbody>
</table>

---

This guideline is not a standard of medical care. The ultimate judgment with regard to a particular clinical procedure or treatment plan must be made by the clinician in the light of the clinical data presented and the diagnostic and treatment options available.

© The Association of Anaesthetists of Great Britain & Ireland 2015
**IMMEDIATELY**
- Give an initial intravenous bolus injection of 20% lipid emulsion 1.5 ml·kg⁻¹ over 1 min
- AND Start an intravenous infusion of 20% lipid emulsion at 15 ml·kg⁻¹·h⁻¹

**AFTER 5 MIN**
- Give a maximum of two repeat boluses (same dose) if:
  - cardiovascular stability has not been restored
  - an adequate circulation deteriorates
- Leave 5 min between boluses
- A maximum of three boluses can be given (including the initial bolus)
- AND Continue infusion at the same rate, but:
  - Double the rate to 30 ml·kg⁻¹·h⁻¹ at any time after 5 min, if:
  - cardiovascular stability has not been restored
  - an adequate circulation deteriorates
- Continue infusion until stable and adequate circulation restored or maximum dose of lipid emulsion given

**Do not exceed a maximum cumulative dose of 12 ml·kg⁻¹**

An approximate dose regimen for a 70-kg patient would be as follows:

**IMMEDIATELY**
- Give an initial intravenous bolus injection of 20% lipid emulsion 100 ml over 1 min
- AND Start an intravenous infusion of 20% lipid emulsion at 1000 ml·h⁻¹

**AFTER 5 MIN**
- Give a maximum of two repeat boluses of 100 ml
- AND Continue infusion at the same rate, but double rate to 2000 ml·h⁻¹ if indicated at any time

**Do not exceed a maximum cumulative dose of 840 ml**

This JADIS Safety Guideline was produced by a Working Party that comprised:
- Grant Conley, William Griffiths (Chair), Martin Clayson, Tim Backland, Jonathan Trueman, Tim Short and Gary Maberg.

This Safety Guideline is endorsed by the Australian and New Zealand College of Anaesthetists (ANZCA).
Box 1 EMHG Guidelines: Recognizing an MH crisis

Early recognition of an impending MH crisis and its immediate treatment is essential for the patient’s survival. As the clinical signs associated with MH are not unique, anaesthetists must be able to recognize a pattern of signs in order to make a rapid diagnosis. Any patient may develop MH during or shortly after an anaesthetic where trigger agents are used—this can occur even in patients who have had uneventful general anaesthesia previously.

**Trigger agents are**
- all volatile (inhalation) anaesthetic agents;
- succinylcholine.

**Clinical signs**

**Early signs**

**Metabolic**
- Inappropriately elevated CO₂ production (raised end-tidal CO₂ on capnography, tachypnoea if breathing spontaneously).
- Increased O₂ consumption.
- Mixed metabolic and respiratory acidosis.
- Profuse sweating.
- Mottling of skin.

**Cardiovascular**
- Inappropriate tachycardia.
- Cardiac arrhythmias (especially ectopic ventricular beats and ventricular bigeminis).
- Unstable arterial pressure.

**Muscle**
- Masseter spasm if succinylcholine has been used.
- Generalized muscle rigidity.

**Later signs**
- Hyperkalaemia.
- Rapid increase in core body temperature.
- Grossly elevated blood creatine phosphokinase levels.
- Grossly elevated blood myoglobin levels.
- Dark-coloured urine due to myoglobinuria.
- Severe cardiac arrhythmias and cardiac arrest.
- Disseminated intravascular coagulation.

**Differential diagnosis**
- Insufficient anaesthesia, analgesia, or both.
- Infection or septicemia.
- Insufficient ventilation or fresh gas flow.
- Anaesthetic machine malfunction.
- Anaphylactic reaction.
- Phaeochromocytoma.
- Thyroid crisis.
- Cerebral ischaemia.
- Neuromuscular disorders.
- Elevated end-tidal CO₂ due to laparoscopic surgery.
- Ecstasy or other dangerous recreational drugs.
- Malignant neuroleptic syndrome.
Box 2 EAHIS Guidelines: Managing an MH Crisis

Start treatment as soon as an MH crisis is suspected.
The clinical presentation of MH varies and treatment should be modified accordingly.

Treatment

Immediately
- Stop all trigger agents.
- Hyperventilate (use a minute volume 2–3 times normal) with 100% O₂ at high flow.
- Declare an emergency and call for help.
- Change to non-trigger anaesthesia (TIVA).
- Inform the surgeon and ask for termination/postponement of surgery.
- Disconnect the vaporizer—do not waste time changing the anaesthetic machine.

Dantrolene
- Give dantrolene 2 mg kg⁻¹ i.v. (ampoules of 20 mg are mixed with 60 ml sterile water).
- Obtain dantrolene from other sources, for example, pharmacy/nearby hospitals—at least 36–50 ampoules may be needed for an adult patient.
- Dantrolene infusions should be repeated until the cardiac and respiratory systems stabilize.
- The maximum dose (10 mg kg⁻¹) may need to be exceeded.

Monitoring
- Continue routine anaesthetic monitoring (SaO₂, ECG, NIBP, ECG).
- Measure core temperature.
- Establish good i.v. lines with wide-bore cannulas.
- Consider inserting an arterial and central venous line, and a urinary catheter.
- Obtain samples for measurement of K⁺, Ca²⁺, arterial blood gases, myoglobin, and glucose.
- Check renal and hepatic function and coagulation.
- Check for signs of compartment syndrome.
- Monitor the patient for a minimum of 24 h (ICU, HDU, or in a recovery unit).

Symptomatic treatment

Treat hyperthermia
- 2000–3000 ml of chilled (4°C) 0.9% saline at i.v.
- Surface cooling wet, cold sheets, fans, and ice packs placed in the axilla and groin.
- Other cooling devices if available.
- Stop cooling once temperature <38.5°C

Treat hypotension
- Dextrose 50%, 50 ml with 50 IU insulin (adult dose).
- Aminophylline 0.1 mmol kg⁻¹ i.v. (e.g. 7 mmol=10 ml for a 70 kg adult).
- Dialysis may be required.

Treat acidosis
- Hyperventilate to normocapnoea.
- Give sodium bicarbonate i.v. if pH < 7.2.

Treat arrhythmias
- Amiodarone 300 mg for an adult (3 mg kg⁻¹ i.v.).
- β-blockers (e.g. propranolol/metoprolol/hexamethonium)—if tachycardia persists.

Maintain urinary output >2 ml kg⁻¹ h⁻¹
- Furosemide 0.5–1 mg kg⁻¹.
- Mannitol 1 g kg⁻¹.
- Fluids: crystalloids (e.g. lactated Ringer’s solution or 0.9% saline) i.v.

Consult your local Malignant Hyperthermia Investigation Unit about the case

Patients suspected of being MH-susceptible should undergo diagnostic testing using in vitro contracture testing (IVCT) at a designated MH-laboratory (www.eahis.org).
Management of a Patient with Suspected Anaphylaxis During Anaesthesia

SAFETY DRILL

(Revised 2009)

Immediate management

- Use the ABC approach (Airway, Breathing, and Circulation). Team work enables several tasks to be accomplished simultaneously.
- Remove all potential causative agents and maintain anaesthesia, if necessary, with an inhalational agent.
- CALL FOR HELP and note the time.
- Maintain the airway and administer oxygen 100%. Intubate the trachea if necessary and ventilate the lungs with oxygen.
- Elevate the patient’s legs if there is hypotension.
- If appropriate, start cardiopulmonary resuscitation immediately according to Advanced Life Support Guidelines.
- Give adrenaline i.v.
  - Adult dose: 50 μg (0.5 ml of 1:10 000 solution).
  - Child dose: 1.0 μg.kg⁻¹ (0.1 ml.kg⁻¹ 1:100 000 solution).
- Several doses may be required if there is severe hypotension or bronchoospasm. If several doses of adrenaline are required, consider starting an intravenous infusion of adrenaline.
- Give saline 0.9% or lactated Ringer’s solution at a high rate via an intravenous cannula of an appropriate gauge (large volumes may be required).
  - Adult: 500 – 1 000 ml
  - Child: 20 ml.kg⁻¹
- Plan transfer of the patient to an appropriate Critical Care area.

CONTINUED OVERLEAF

© The Association of Anaesthetists of Great Britain & Ireland 2009
Secondary management

- Give chlorphenamine i.v.
    - Adult: 10 mg
    - Child 6 - 12 years: 5 mg
    - Child 6 months - 6 years: 2.5 mg
    - Child <6 months: 250 µg/kg

- Give hydrocortisone i.v.
    - Adult: 200 mg
    - Child 6 - 12 years: 100 mg
    - Child 6 months - 6 years: 50 mg
    - Child <6 months: 25 mg

- If the blood pressure does not recover despite an adrenaline infusion, consider the administration of an alternative i.v. vasopressor according to the training and experience of the anaesthetist, e.g. metaraminol.

- Treat persistent bronchospasm with an i.v. infusion of salbutamol. If a suitable breathing system connector is available, a metered-dose inhaler may be appropriate. Consider giving i.v. aminophylline or magnesium sulphate.

Investigation

- Take blood samples (5 - 10 ml clotted blood) for mast cell tryptase:
  - Initial sample as soon as feasible after resuscitation has started – do not delay resuscitation to take the sample.
  - Second sample at 1 - 2 h after the start of symptoms.
  - Third sample either at 24 h or in convalescence (for example in a follow-up allergy clinic). This is a measure of baseline tryptase levels as some individuals have a higher baseline level.
- Ensure that the samples are labelled with the time and date.
- Liaise with the hospital laboratory about analysis of samples.

Later investigations to identify the causative agent

The anaesthetist who gave the anaesthetic or the supervising consultant anaesthetist is responsible for ensuring that the reaction is investigated. The patient should be referred to a specialist Allergy or Immunology Centre (see www.aagbi.org for details). The patient, surgeon and general practitioner should be informed. Reactions should be notified to the AAGBI National Anaesthetic Anaphylaxis Database (see www.aagbi.org).

This guideline is not to be construed as a standard of medical care. Standards of medical care are determined on the basis of all clinical data available for an individual case and are subject to change as knowledge advances. The ultimate judgement with regard to a particular clinical procedure or treatment plan must be made by the clinician in light of the clinical data presented and the diagnostic and treatment options available.

© The Association of Anaesthetists of Great Britain & Ireland 2009

**Diagnosis of laryngospasm**

Identification and removal of the stimulus (secretion, blood, nociceptive stimulus)

- Chin lift and jaw thrust
- Oropharyngeal airway
- CPAP + FiO2 100%

**Complete Laryngospasm**

Call for help

Positive pressure ventilation with face mask

- No improvement

  - **IV access**
    - IV suxamethonium 0.5 to 2 mg.kg⁻¹ after IV atropine 0.02 mg.kg⁻¹ or IV propofol 1 mg.kg⁻¹
  
  - **No IV access**
    - IM (1.5-4 mg.kg⁻¹) or intraosseous (0.5-1 mg.kg⁻¹) suxamethonium

- **No improvement**
  - Cardiopulmonary resuscitation

**Partial laryngospasm**

Deepen anesthesia with small doses of propofol or inhaled agent

- Reassess air entry with CPAP

  - Improvement
  
  - Surgery or PACU

**Assess air entry Bag movement?**
Referenties

5. Tobias J.D., Kinder Ross A., Intraosseous infusions: a review for the anesthesiologist with a focus on pediatric use, Anest Analg 2010; 110:391-401