Resuscitation Science Update

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Disclosures

- I have received research funding from Covidien

Learning Objectives

- Discuss changes in the most recent updates in Pediatric Advanced Life Support (PALS) guidelines
- Discuss the scientific rationale behind the most recent updates
- Describe special adaptations of PALS to the perioperative setting

Perioperative Cardiac Arrest

- Time period encompassing care of patient by anesthesia team
  - Enter operating room
  - Events in recovery room
  - Events up to transfer of care to ICU
- Chest compressions (closed or open chest)
- Failure to wean from cardiopulmonary bypass

Flick RP, et al. *Anesthesiology* 2007

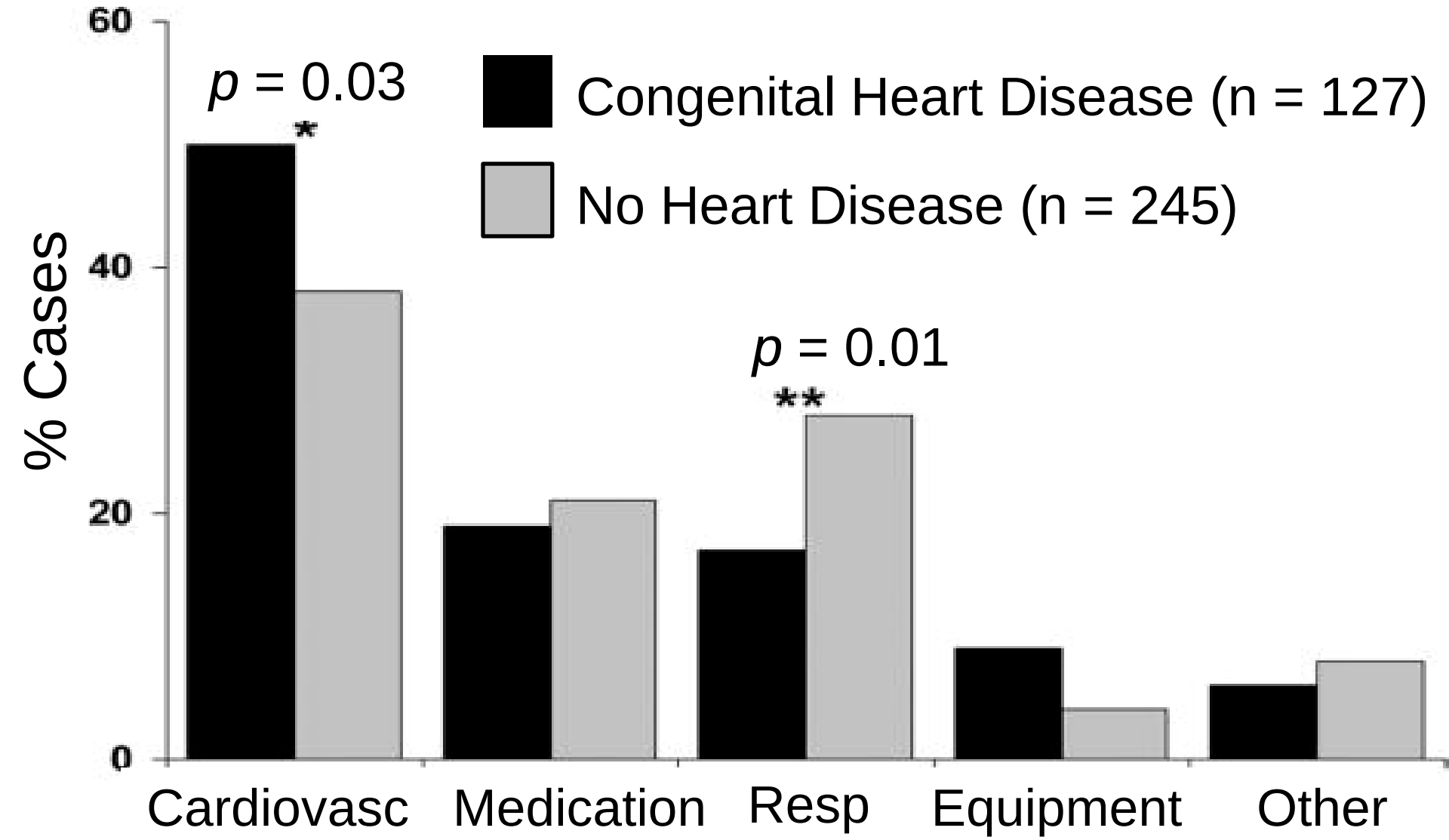
Risk of cardiac arrest is greatest in younger children and in children with congenital heart lesions

Age	Number of Cardiac Arrests per 10,000 Anesthetics			
	Non-cardiac Surgery (includes cardiac cath)		Cardiac Surgery	
	Estimate	95% C.I.	Estimate	95% C.I.
0 – 30 days	39	11 – 100	435	264 – 671
31 days – 1 year	23	14 – 36	197	111 – 323
1 – 3 years	8	4 – 13	118	57 – 215
4 – 9 years	4	2 – 8	35	10 – 90
10 – 18 years	3	2 – 6	57	21 – 124

Flick RP, et al. *Anesthesiology 2007*

Etiology of Cardiac Arrest (n = 373)

Pediatric Perioperative Cardiac Arrest (POCA) Registry



Ramamoorthy C, et al. *Anesth Analg* 2010

Etiology of Cardiac Arrest

Pediatric Perioperative Cardiac Arrest (POCA) Registry

- Cardiovascular
  - Hypovolemia
  - Myocardial ischemia
  - Hyperkalemia
  - Arrhythmia
- Medication
  - Cardiovascular depression from inhaled or intravenous anesthetic
  - Dose error

Ramamoorthy C, et al. *Anesth Analg* 2010

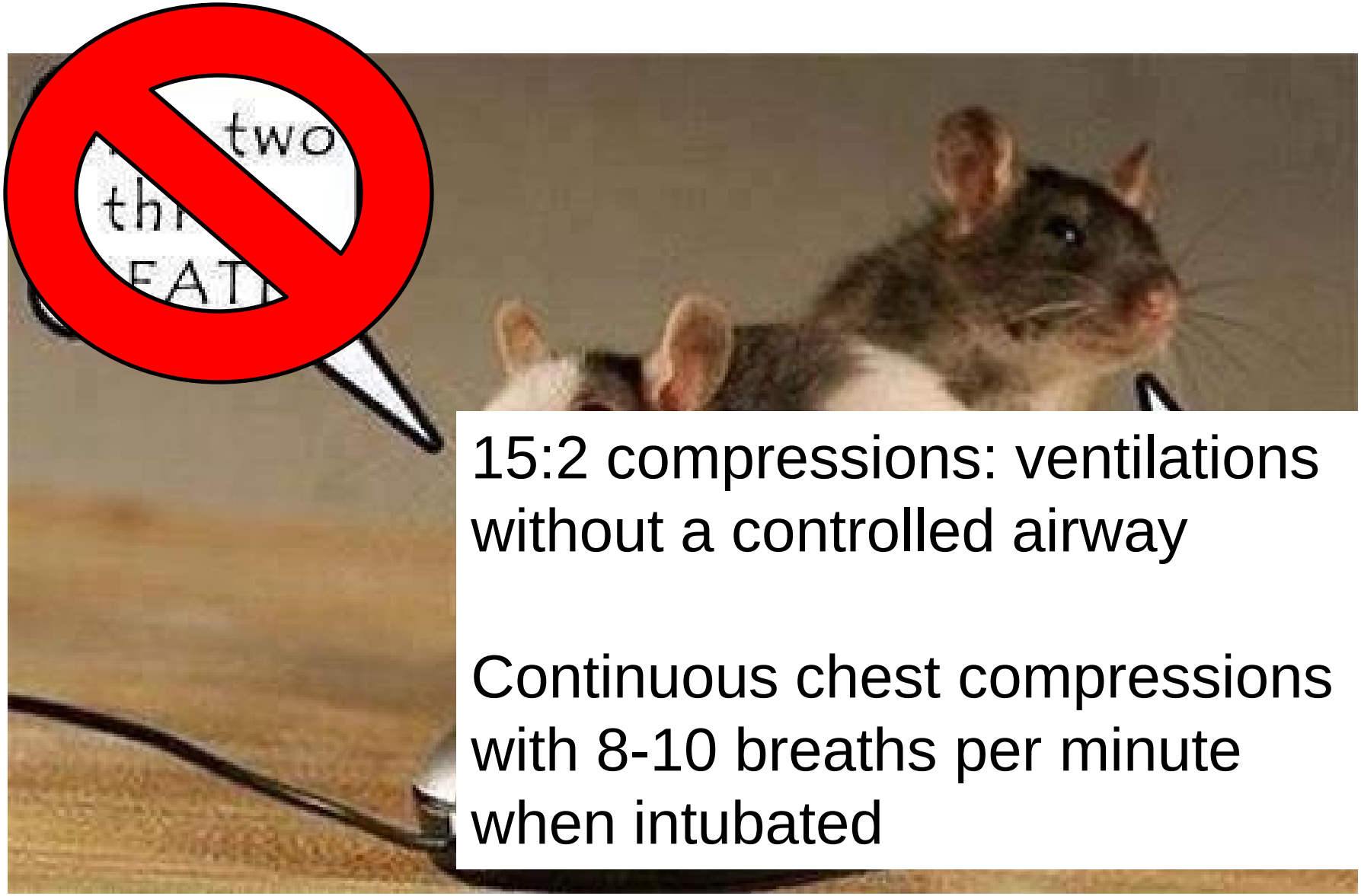
Etiology of Cardiac Arrest

Pediatric Perioperative Cardiac Arrest (POCA) Registry

- Respiratory
  - Laryngospasm
  - Inadequate oxygenation
  - Difficult intubation
  - Airway obstruction
- Equipment
  - Central line complication
  - Breathing circuit obstruction
  - Endotracheal tube obstruction

Ramamoorthy C, et al. *Anesth Analg* 2010

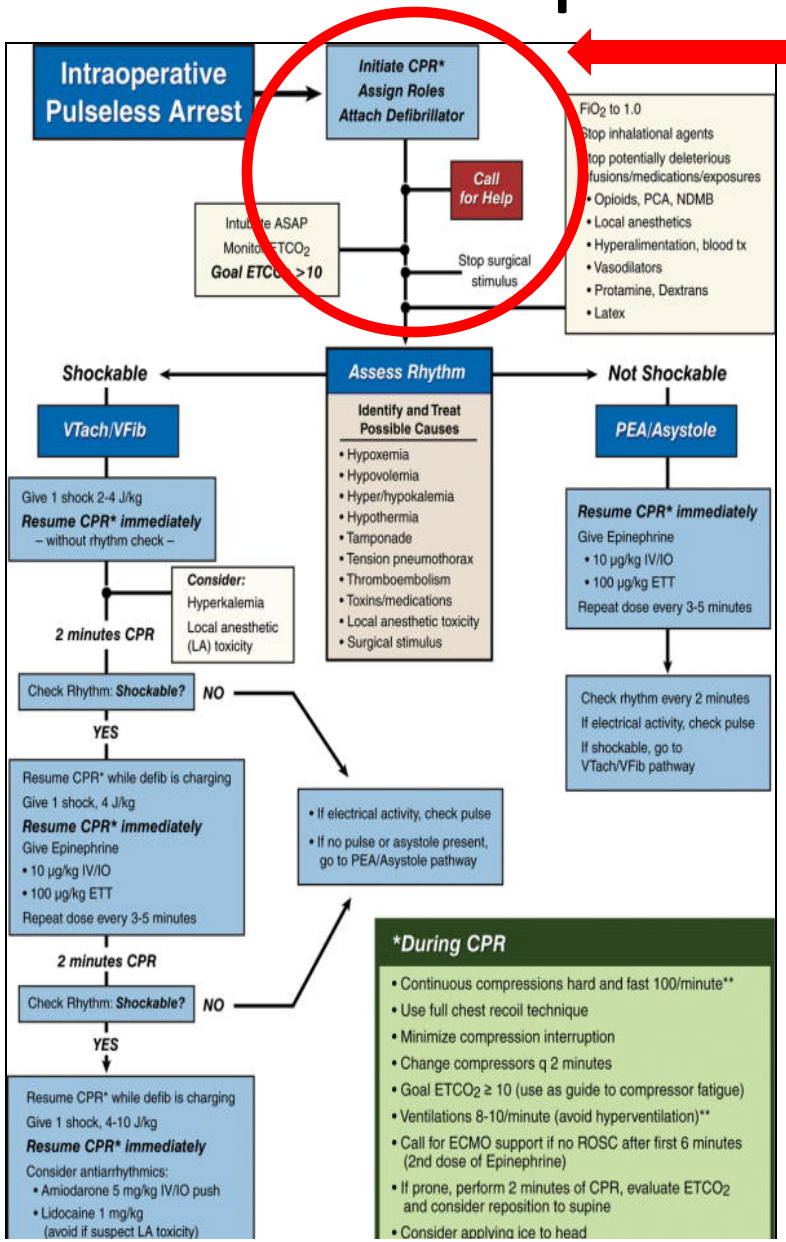
PALS Adaptations to the Operating Room



15:2 compressions: ventilations without a controlled airway

Continuous chest compressions with 8-10 breaths per minute when intubated

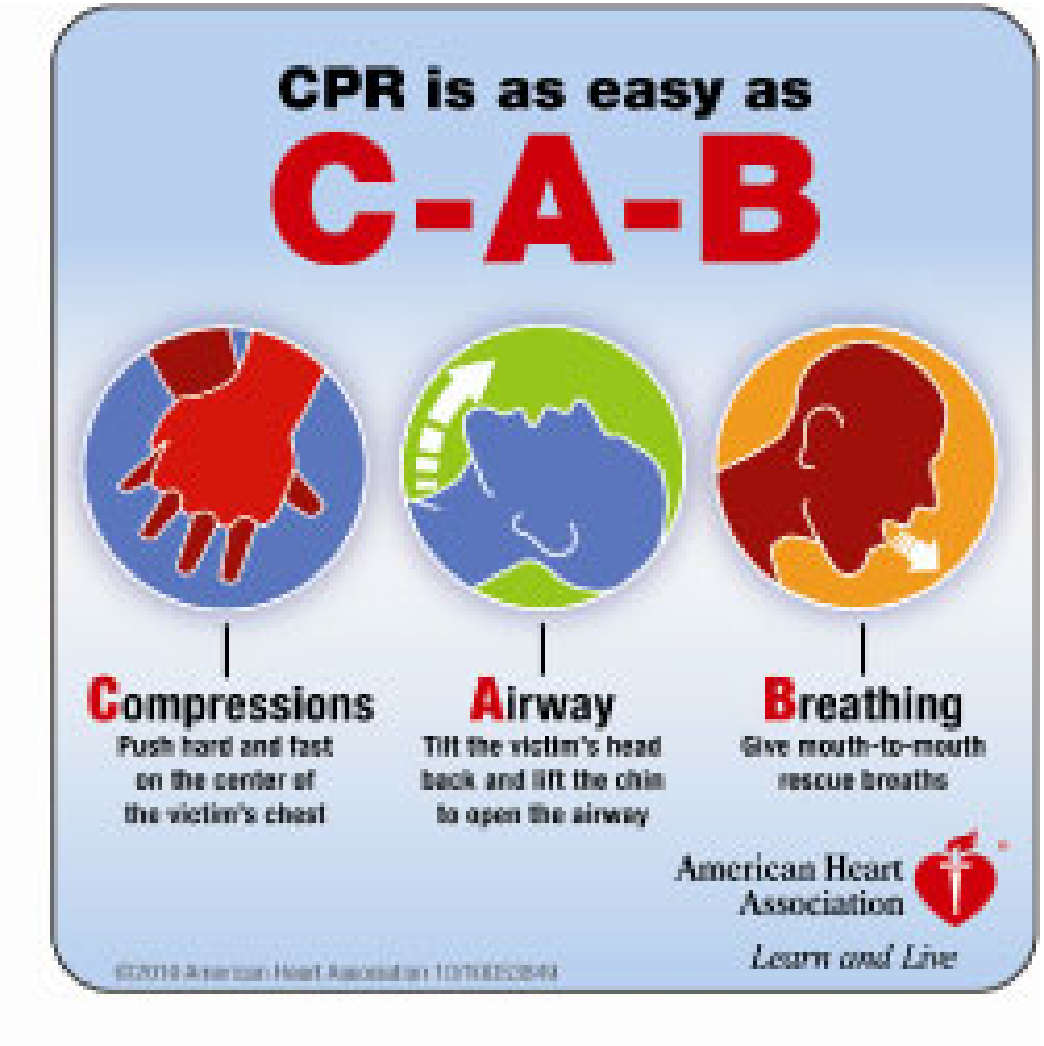
PALS Adaptations – Pulseless Arrest



- **Start chest compressions *as soon as possible***
- **Call for help**
- **Stop surgical stimulus**
- **Assign Roles**
  - Identify highly qualified personnel
  - Surgeons for IV access
  - Use specific names
- **Attach Defibrillator**

Shaffner DH, et al. *Anesth Analg* 2013

Minimize the “No Flow Time”

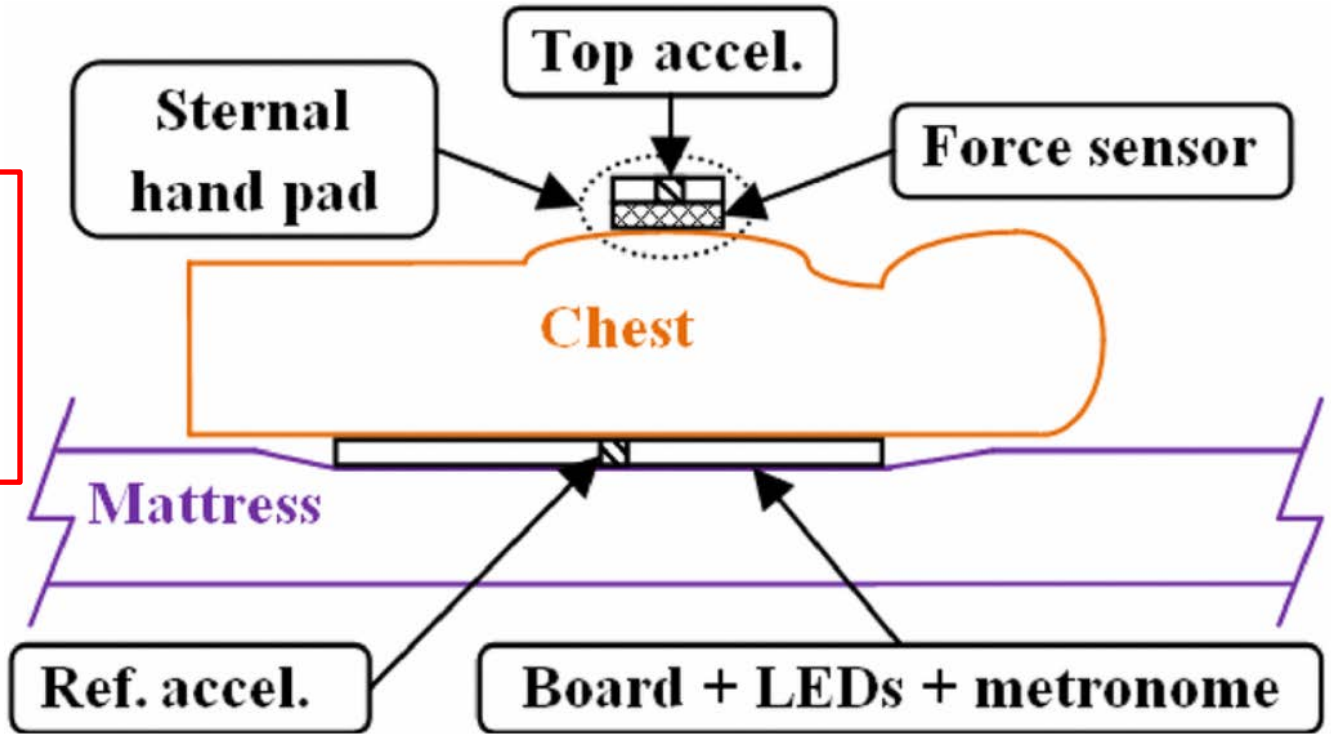


Optimize Chest Compressions

FAST
100/minute

HARD
(1/3 AP chest diameter)

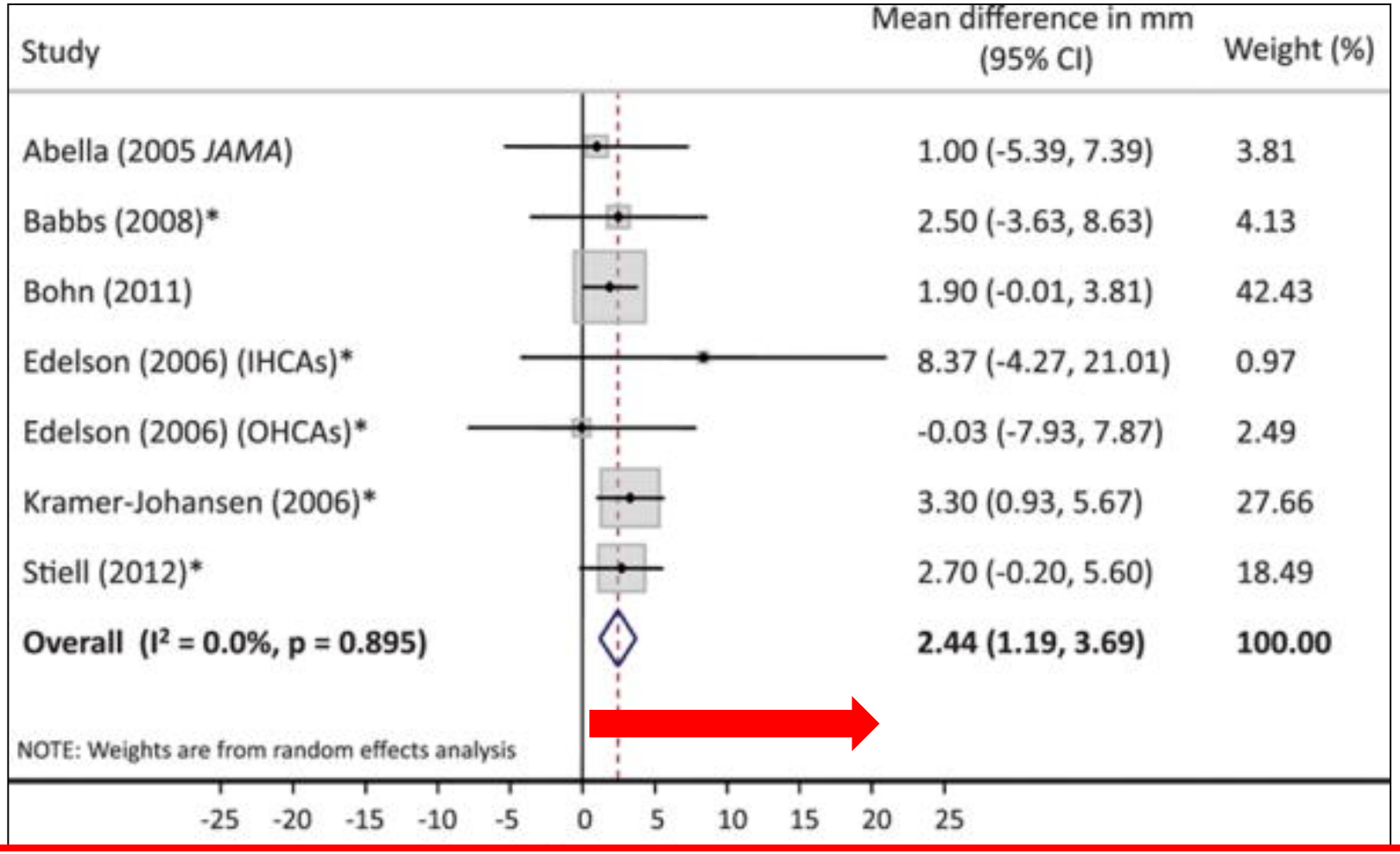
FULL RECOIL



MINIMIZE INTERRUPTIONS

Gohier F, et al. *Conf Proc IEEE Eng Med Biol Soc* 2013

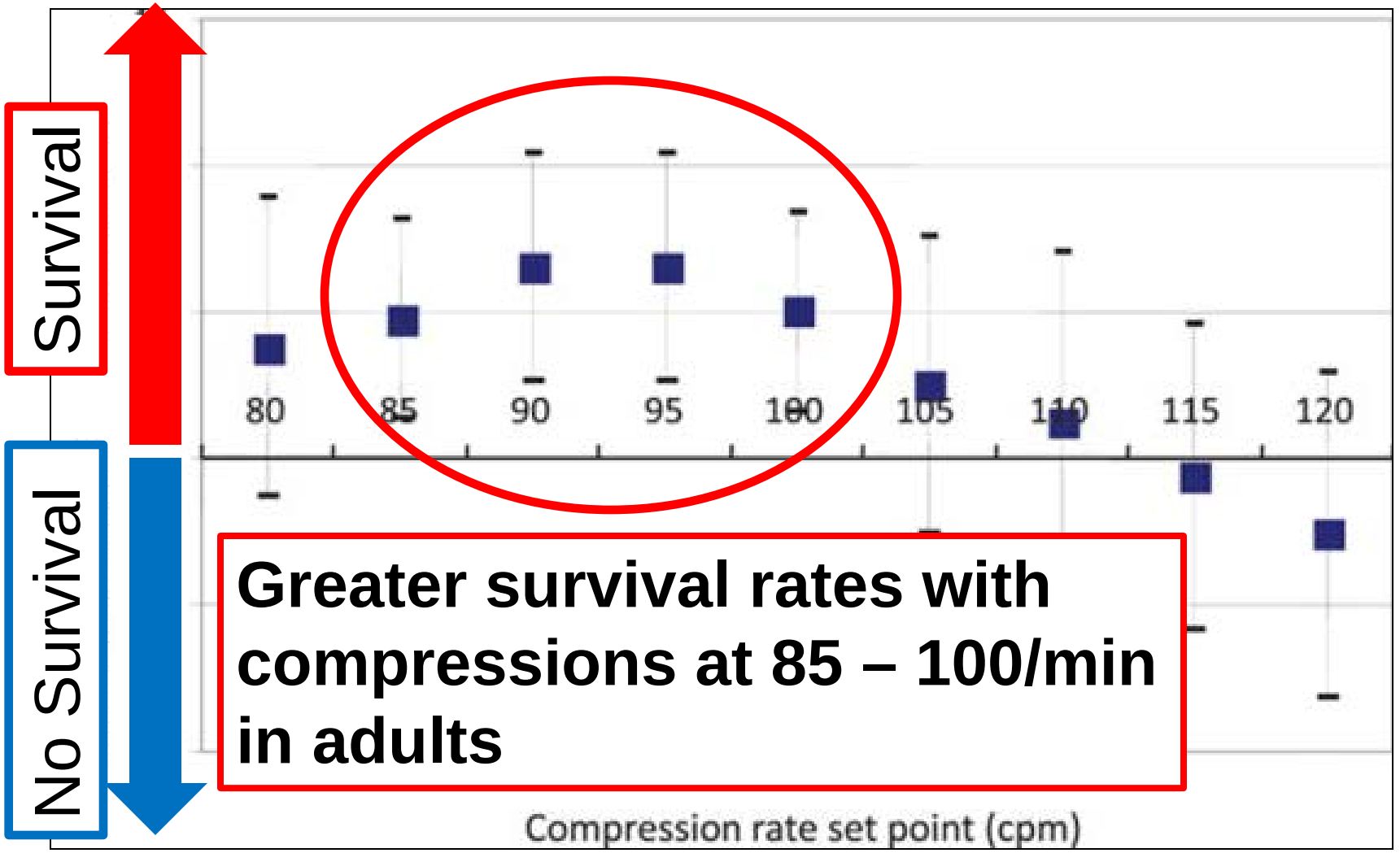
Meta-analysis of chest compression depth in adults (77 in-hospital and 1815 out-of-hospital arrests)



Greater survival rates with deeper compressions

Wallace SK, et al. *Circ Cardiovasc Qual Outcomes* 2013

Meta-analysis of chest compression rate in adults (176 in-hospital and 1465 out-of-hospital arrests)



Wallace SK, et al. *Circ Cardiovasc Qual Outcomes* 2013

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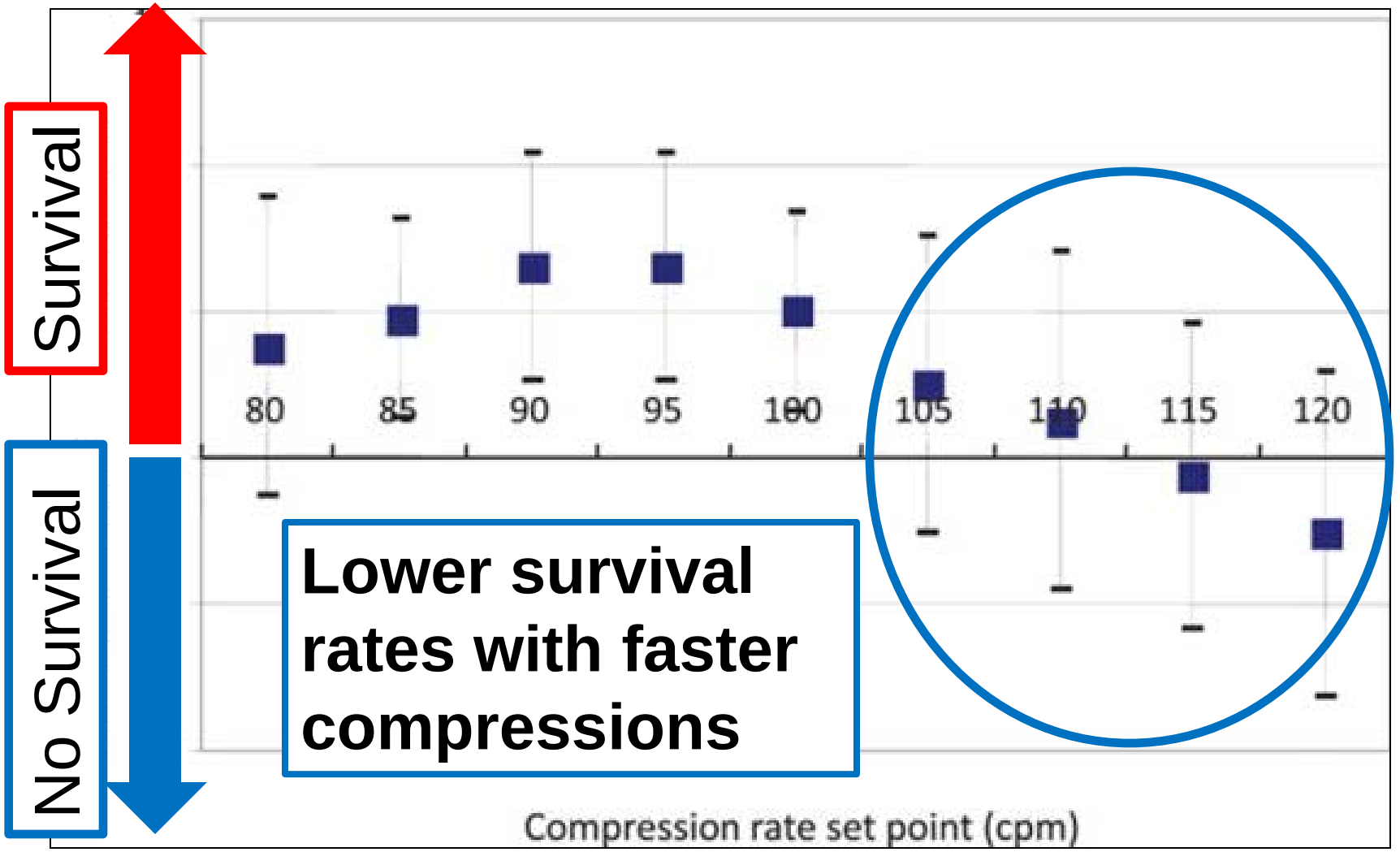
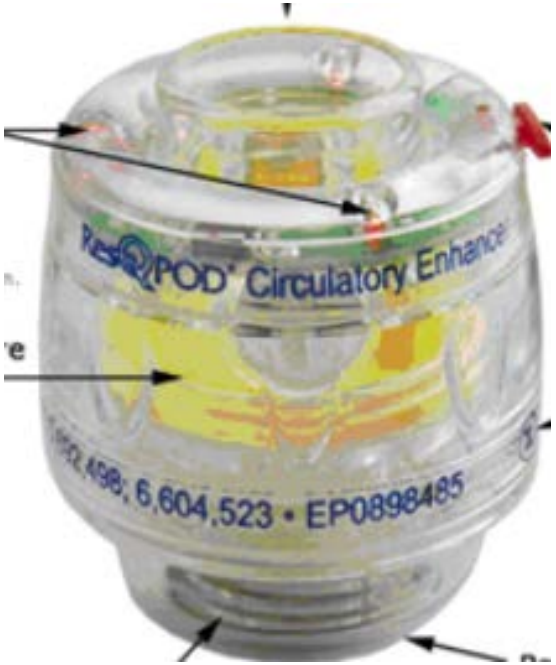


Wallace SK, et al. *Circ Cardiovasc Qual Outcomes* 2013

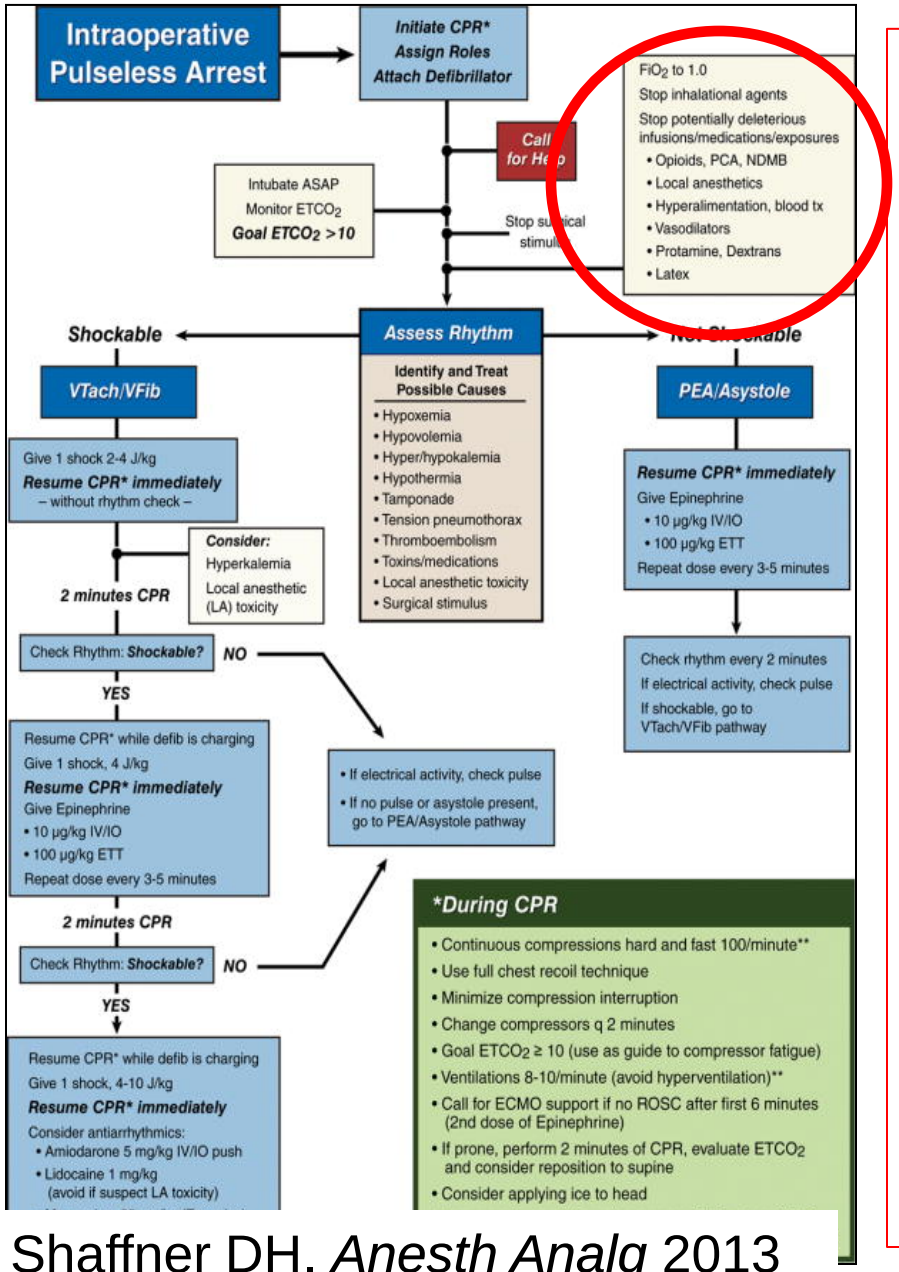
Impedance Threshold Device



1. Release chest compression
2. Device prevents air in-flow through endotracheal tube
3. Improved venous return during chest recoil

http://www.resuscitationcentral.com

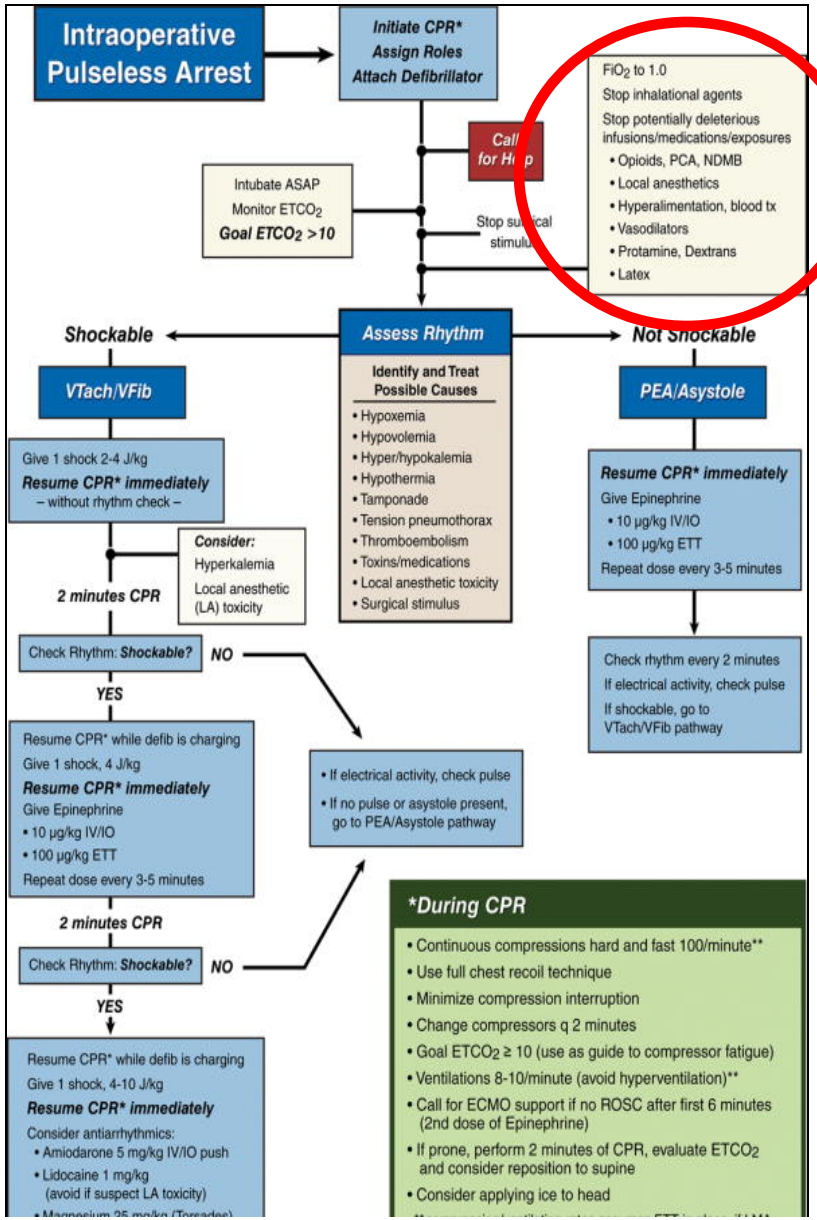
PALS Adaptations – Pulseless Arrest



- **Stop inhalational agents**
- **Stop potentially deleterious infusions**
  - Local anesthetics
  - Protamine
  - Vasodilators
  - Opiates, PCAs
  - Potassium-containing IV fluids, hyperalimentation
  - Blood products (potassium, calcium chelators)

Shaffner DH. *Anesth Analg* 2013

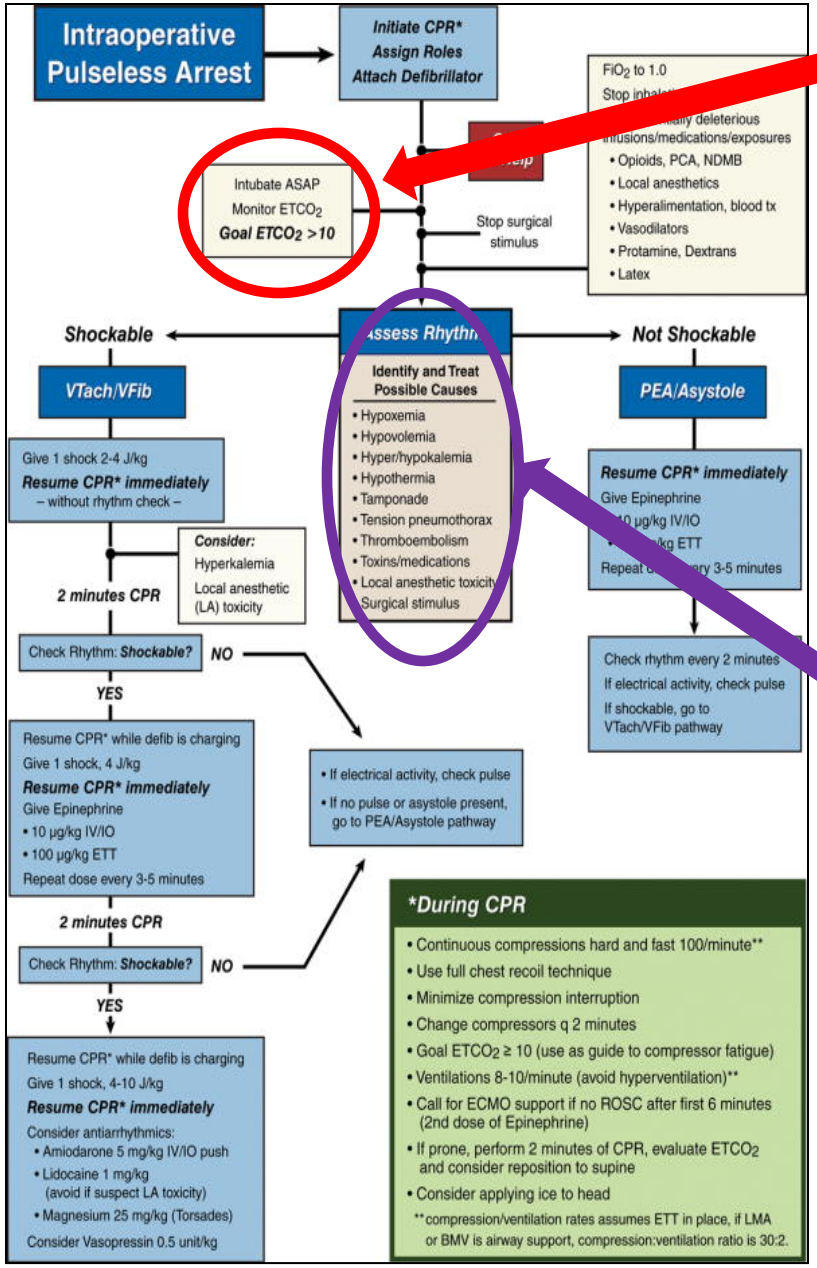
PALS Adaptations – Pulseless Arrest



Shaffner DH. *Anesth Analg* 2013

- **100% oxygen (unless airway fire)**
- **Remove/ stop infusion of potential allergens**
  - Antibiotics
  - Dextrans
  - Non-depolarizing paralytics
  - Protamine
  - Latex
- **Wide open IV fluids, Trendelenburg position if hypovolemic**

PALS Adaptations – Pulseless Arrest

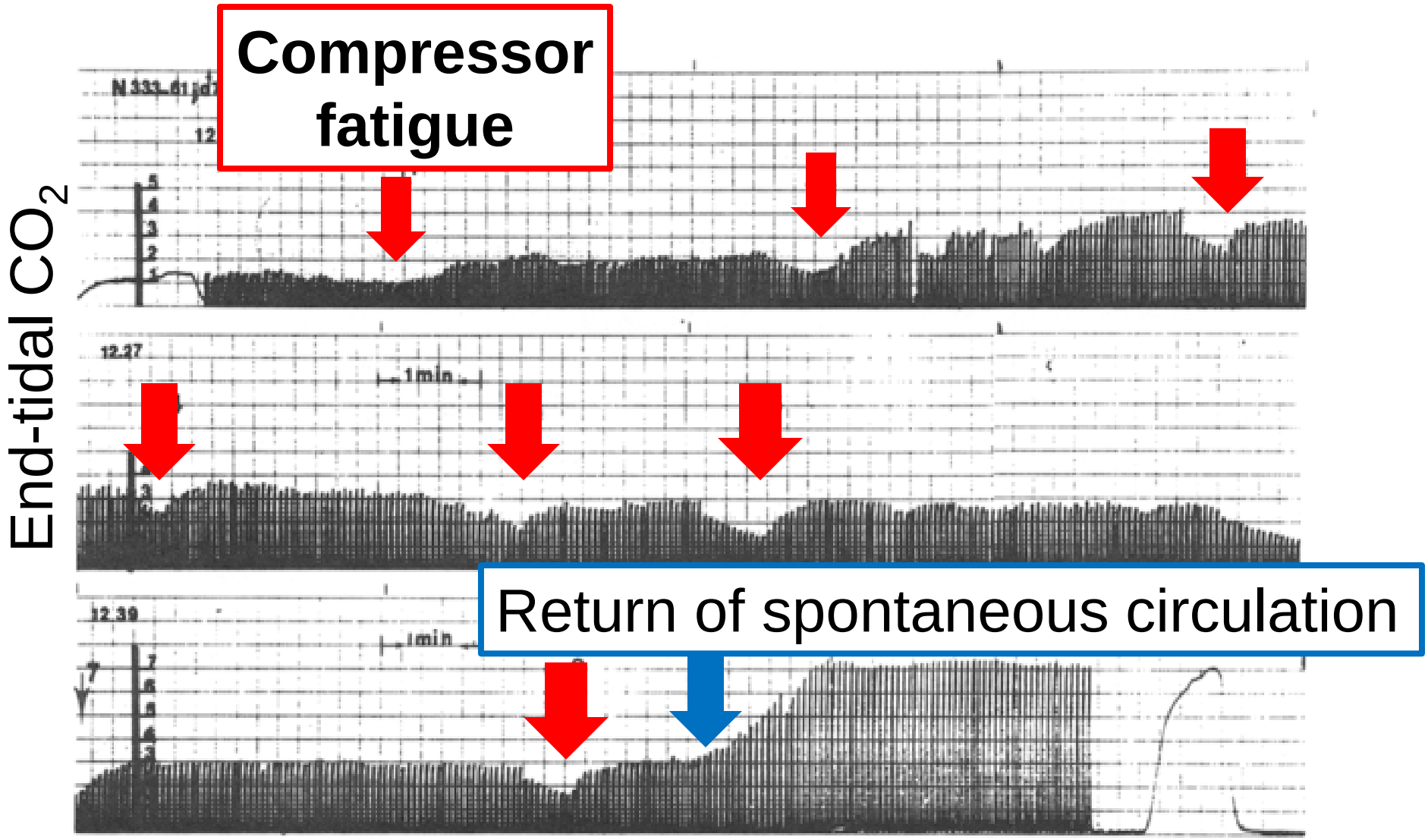


- **Intubate (8-10 breaths/min)**
- **Monitor $ETCO_2$**
- **Goal $ETCO_2$ > 10 mmHg**

- **Assess rhythm and identify possible causes:**
  - Local anesthetic toxicity
  - Surgical stimulus
  - Thromboembolism

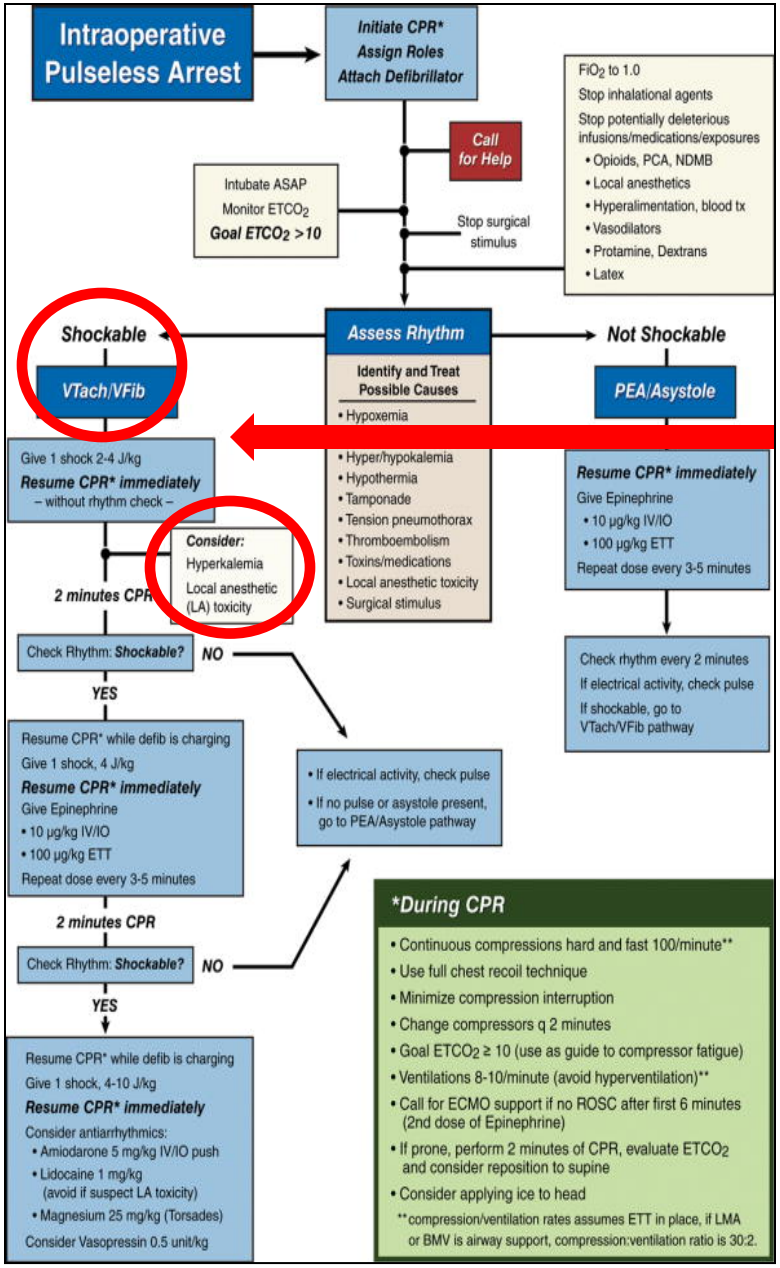
Shaffner DH, et al. *Anesth Analg* 2013

Assess Compressions with $ETCO_2$



Kalenda Z. *Resuscitation* 1978

PALS Adaptations – Pulseless Arrest



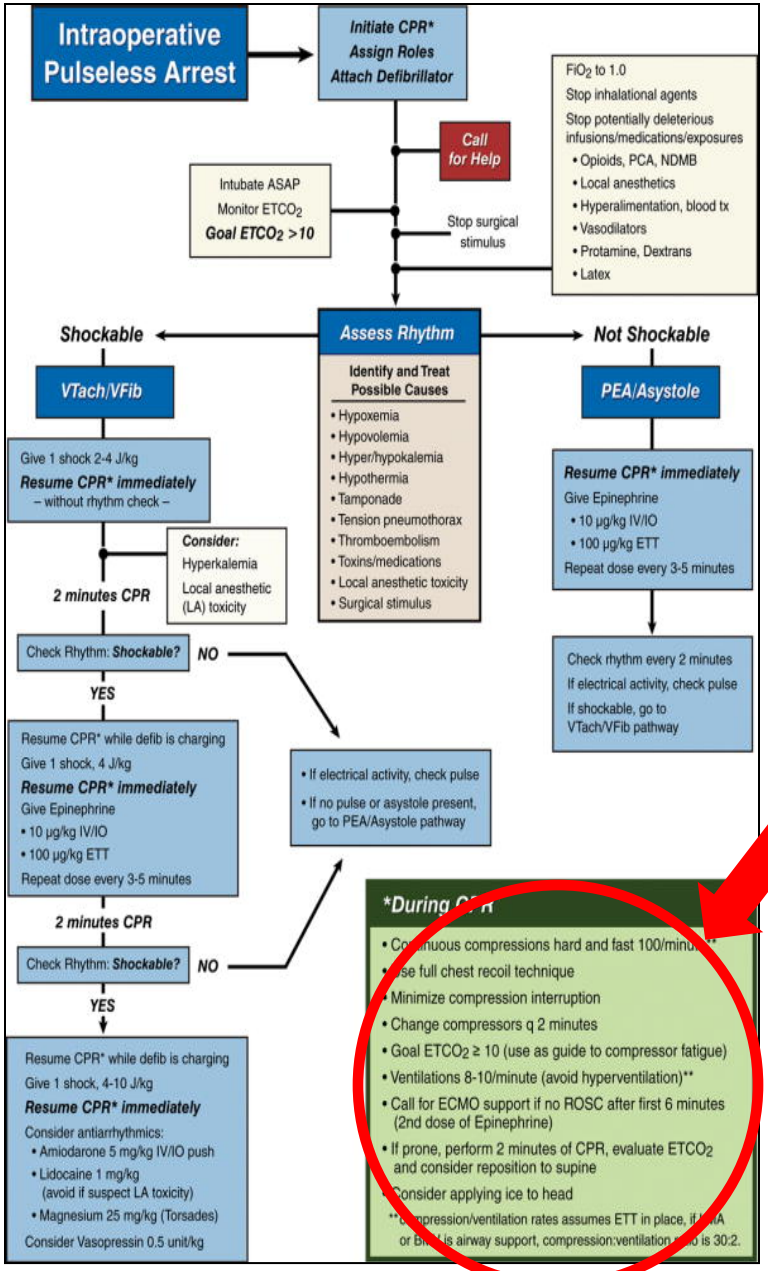
V-tach/ V-fib:

1. **One shock 2 - 4 J/kg**
2. **Resume CPR for 2 min (no rhythm check)**
3. **Check rhythm after 2 min of CPR**

Consider: hyperkalemia, local anesthetic toxicity

Shaffner DH, et al. *Anesth Analg* 2013

PALS Adaptations – Pulseless Arrest



- **Call for ECMO support early**
  - after second dose of epinephrine
- **Prone CPR for 2 minutes**
  - Assess $ETCO_2$
  - Turn supine if prone compressions are inadequate

Shaffner DH, et al. *Anesth Analg* 2013

Arrest During Inhalational Induction: Laryngospasm

- Stop nitrous oxide. Use 100% oxygen
- Deepen the inhaled anesthetic if patient has pulses
- Intubate if possible (if muscle tone is relaxed)
- IM or submental atropine (0.02 mg/kg) and/or succinylcholine 4 mg/kg (maximum 150 mg)

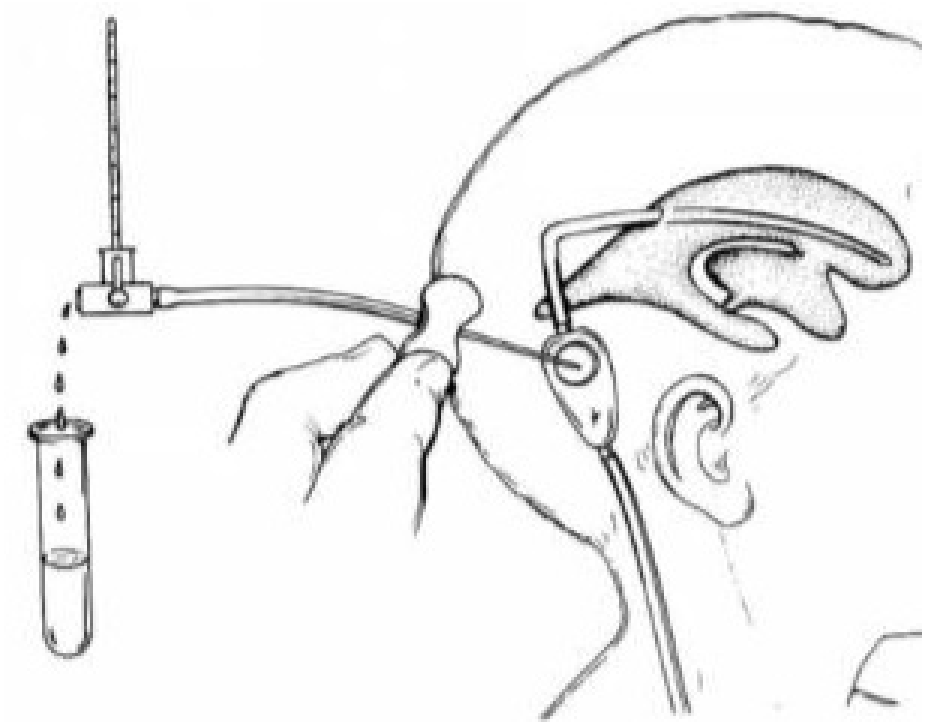
Arrest During Inhalational Induction: Laryngospasm

- Chest compressions

- Consider possible contributing etiologies:
  - Hypovolemia (bowel prep, fasting)
  - Opioids, clonidine
  - Acute alcohol ingestion
  - Age < 1 month

Arrest with Ventricular Shunt Malfunction

Cerebral Perfusion Pressure = MAP - ICP

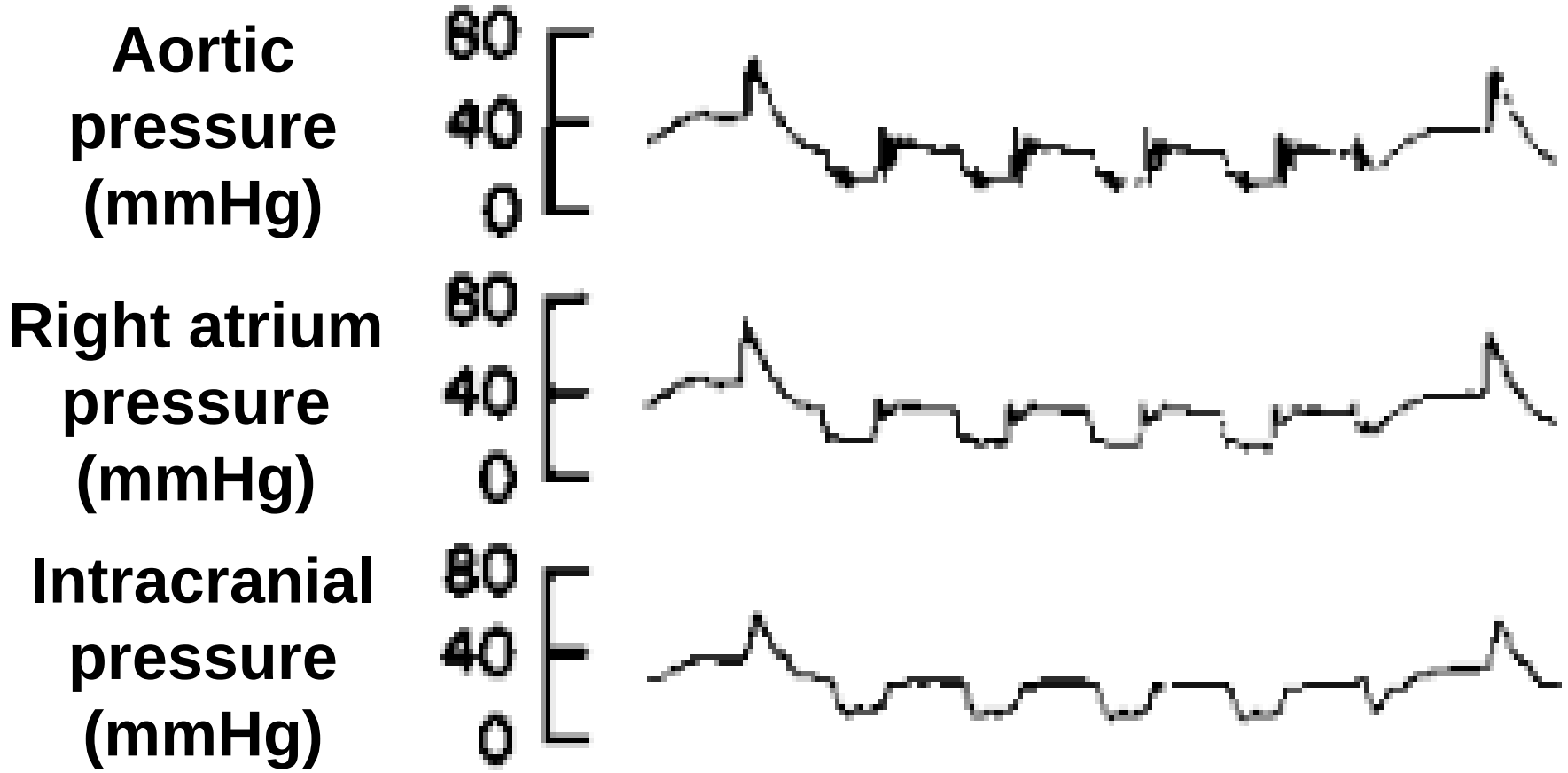


Neurosurgeon must tap the shunt to lower ICP during CPR

www.google.com/search?q=VP+shunt+tap+picture

Arrest with Ventricular Shunt Malfunction

- Increasing thoracic pressures during chest compressions raise the intracranial pressure and could compromise the cerebral perfusion pressure



Guerci AD, et al. *Circ Res* 1985

Spine Fusion and Craniofacial Reconstruction

Hypovolemia

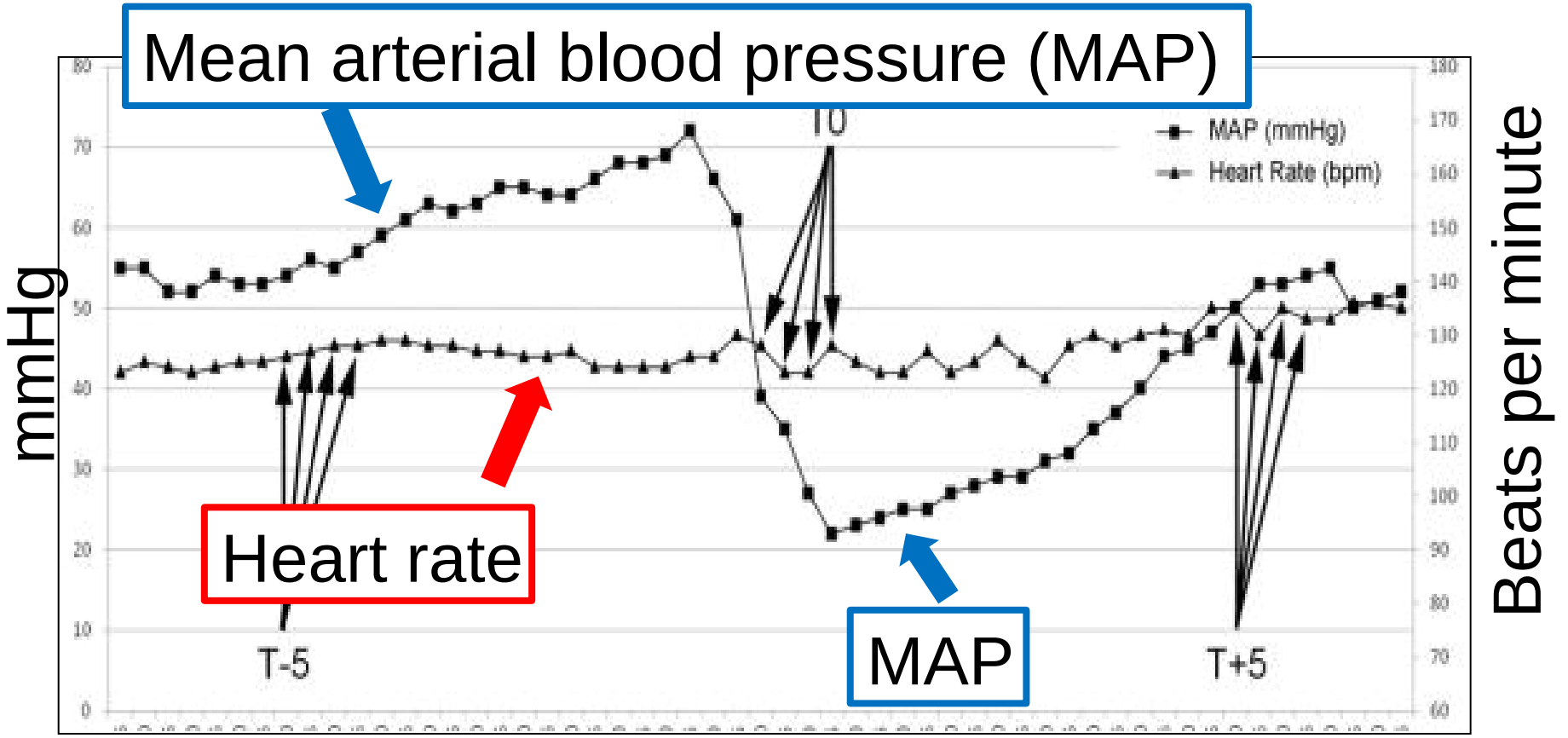
- Hypotension
- PEA (pulseless electrical activity)
- Decreased $ETCO_2$
- Decreased CVP

Venous Air Embolism (VAE)

- Hypotension
- PEA
- Decreased $ETCO_2$
- Increased CVP with VAE in pulmonary vasculature
- Increased end-tidal Nitrogen
- Bubbles on precordial Doppler

Have adequate central venous and large PIV access!

Craniofacial Reconstruction (<2 yrs old)



Heart rate did *not* correlate to intravascular volume depletion and hypotension

Stricker PA, et al. Anesth Analg 2012

Cardiac Arrest From Hypovolemia (POCA registry; n = 23)

- Spinal fusion, craniotomy/craniectomy, craniofacial reconstruction cases
- Underestimate blood loss (48%)
- Inadequate peripheral venous access (22%)
- Central venous catheter not present or not transduced (22%)
- Arterial catheter not present or malfunctioning (17%)

Bhanaker SM *Anesth Analg* 2007

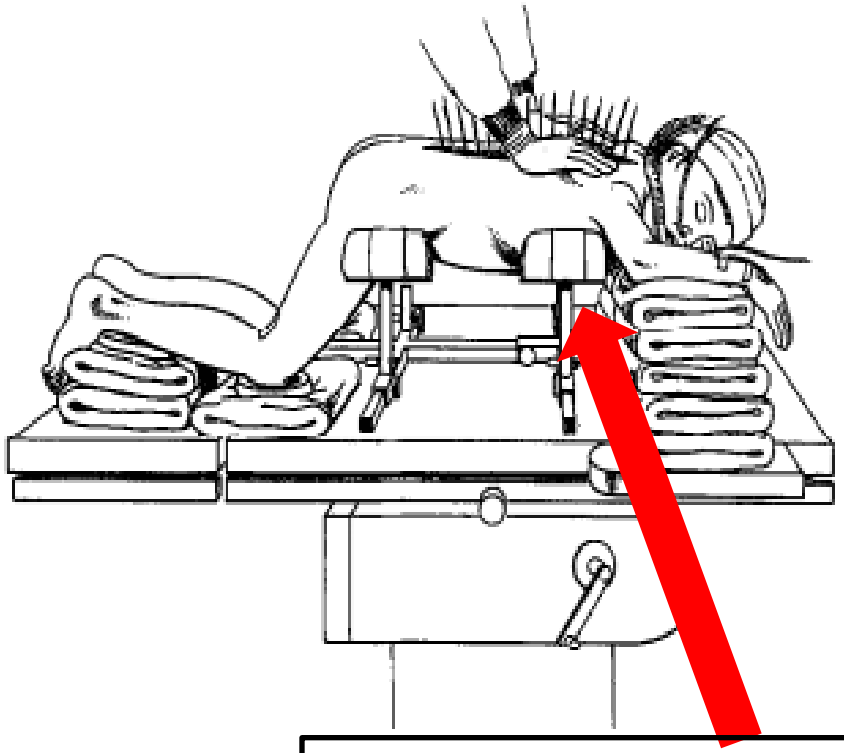
Venous Air Embolism

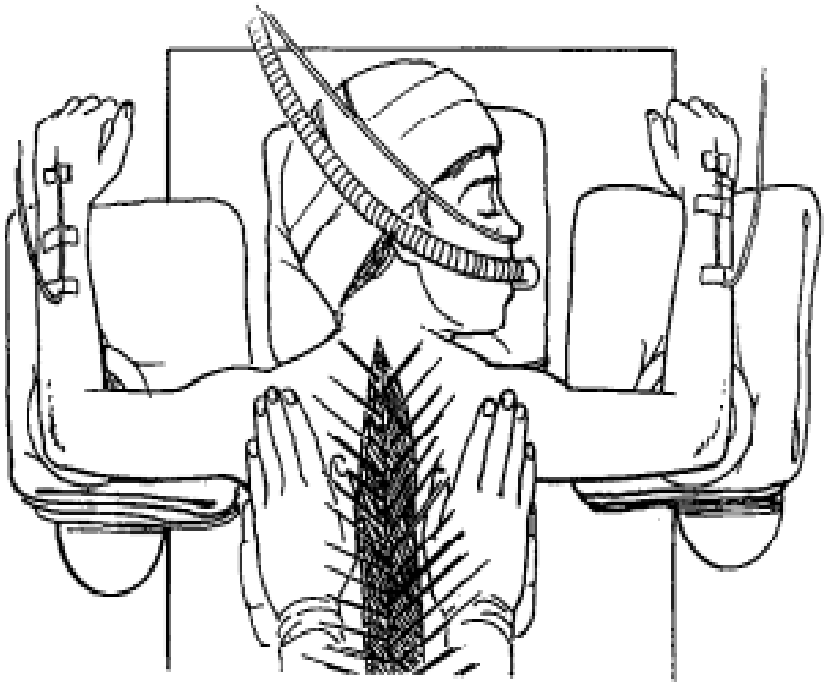
1. Tell the surgeons
2. 100% oxygen
3. Stop nitrous oxide and inhaled anesthetics
4. Stop air entry
   - Lower the surgical site below the level of the heart
   - Irrigate and seal wounds
   - Trendelenburg position (raise intravascular pressure)
   - Fluid administration (raise intravascular pressure)

Venous Air Embolism

5. Reduce air entry into the pulmonary circulation
   - Tip operating table so patient's left side is down to trap air in the right side of the heart
6. Aspirate air from central line
7. CPR
8. Vasopressors

Prone Chest Compressions
Midline Incision



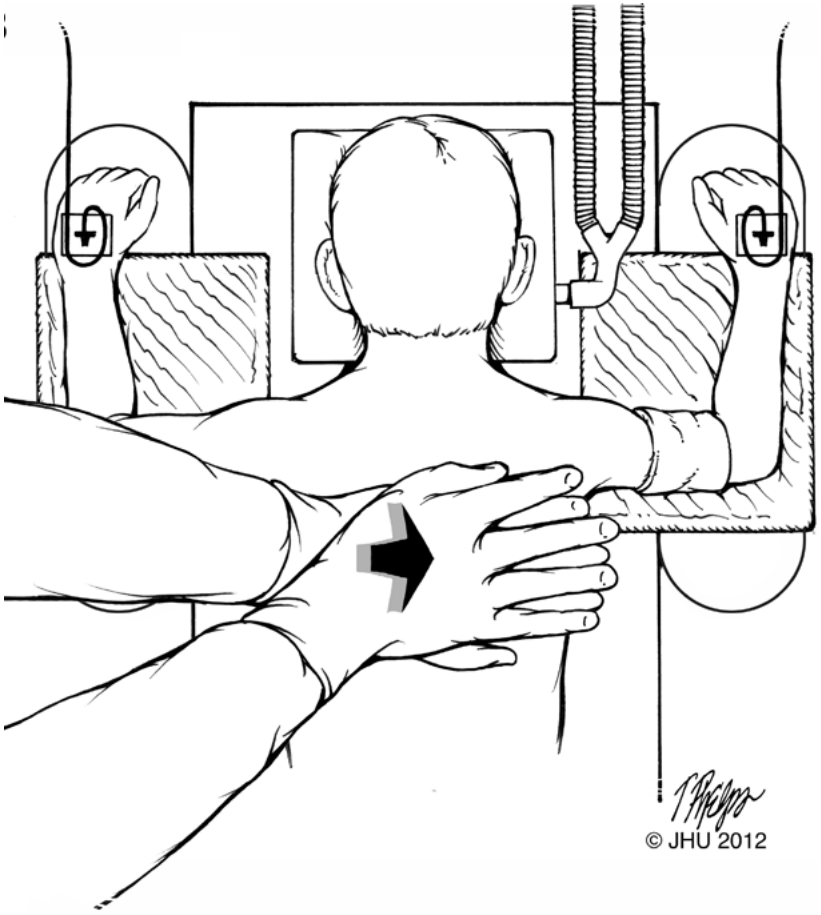


Support under the sternum

Goal: minimize no-flow time until can turn supine

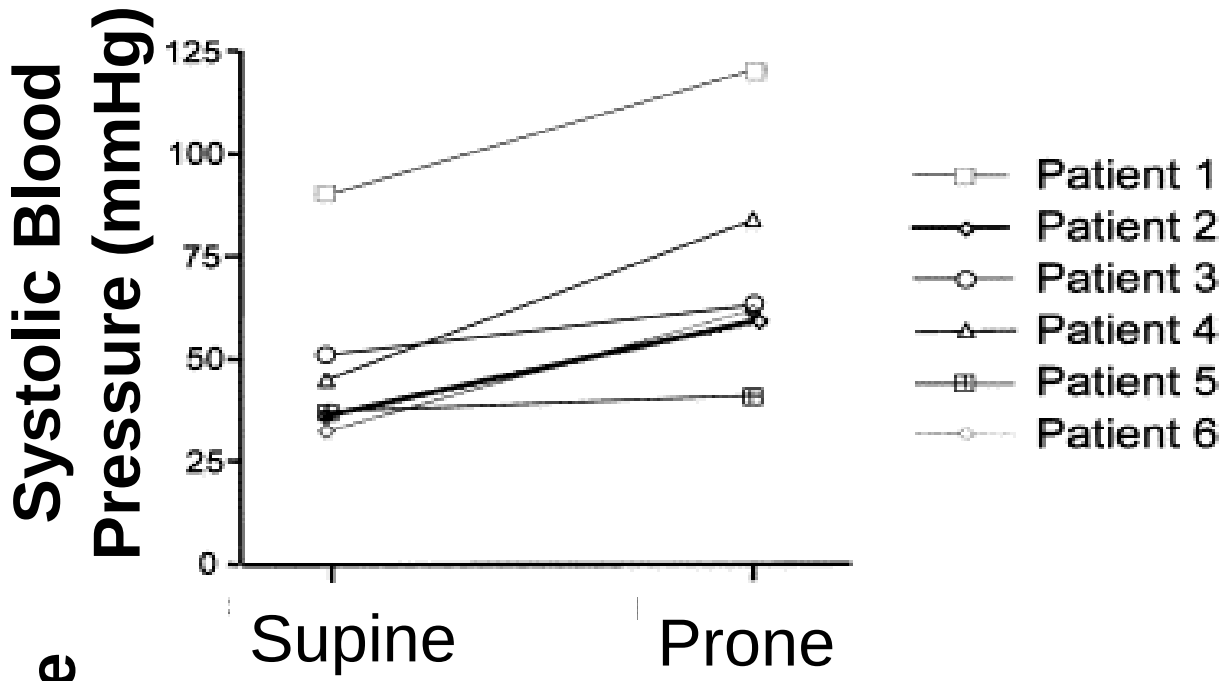
Tobias JD, et al. *J Pediatr Surg* 1994

Prone Chest Compressions
No Midline Incision

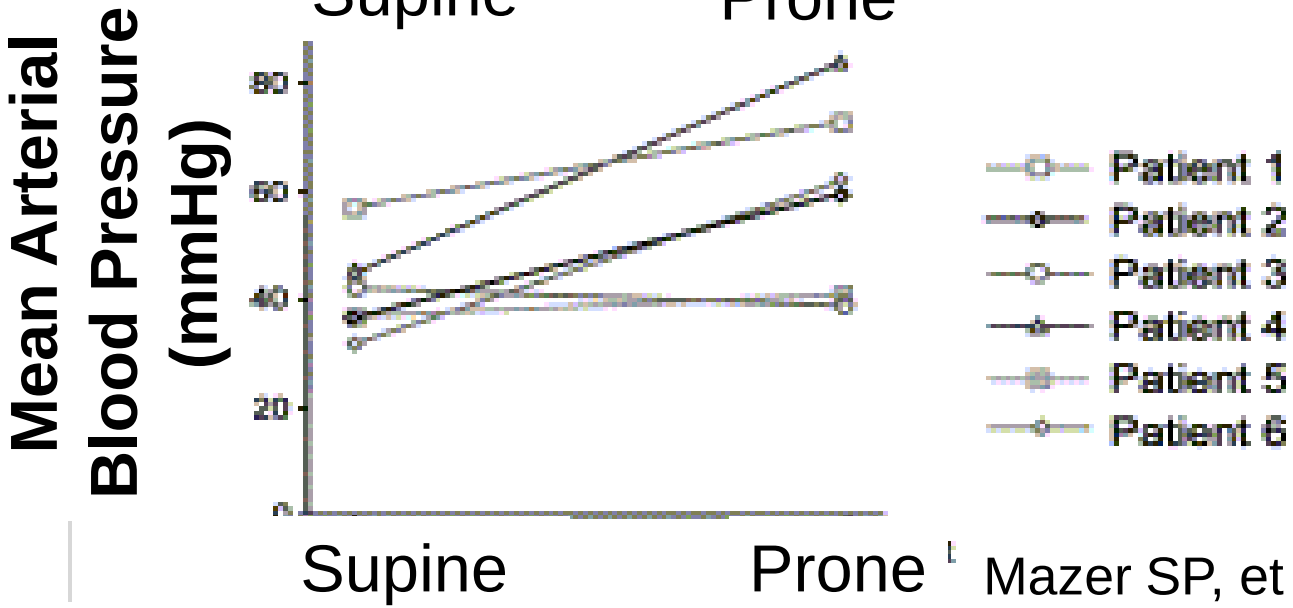


Shaffner DH, et al. *Anesth Analg* 2013

Supine vs. Prone Chest Compressions



n = 6 Adults

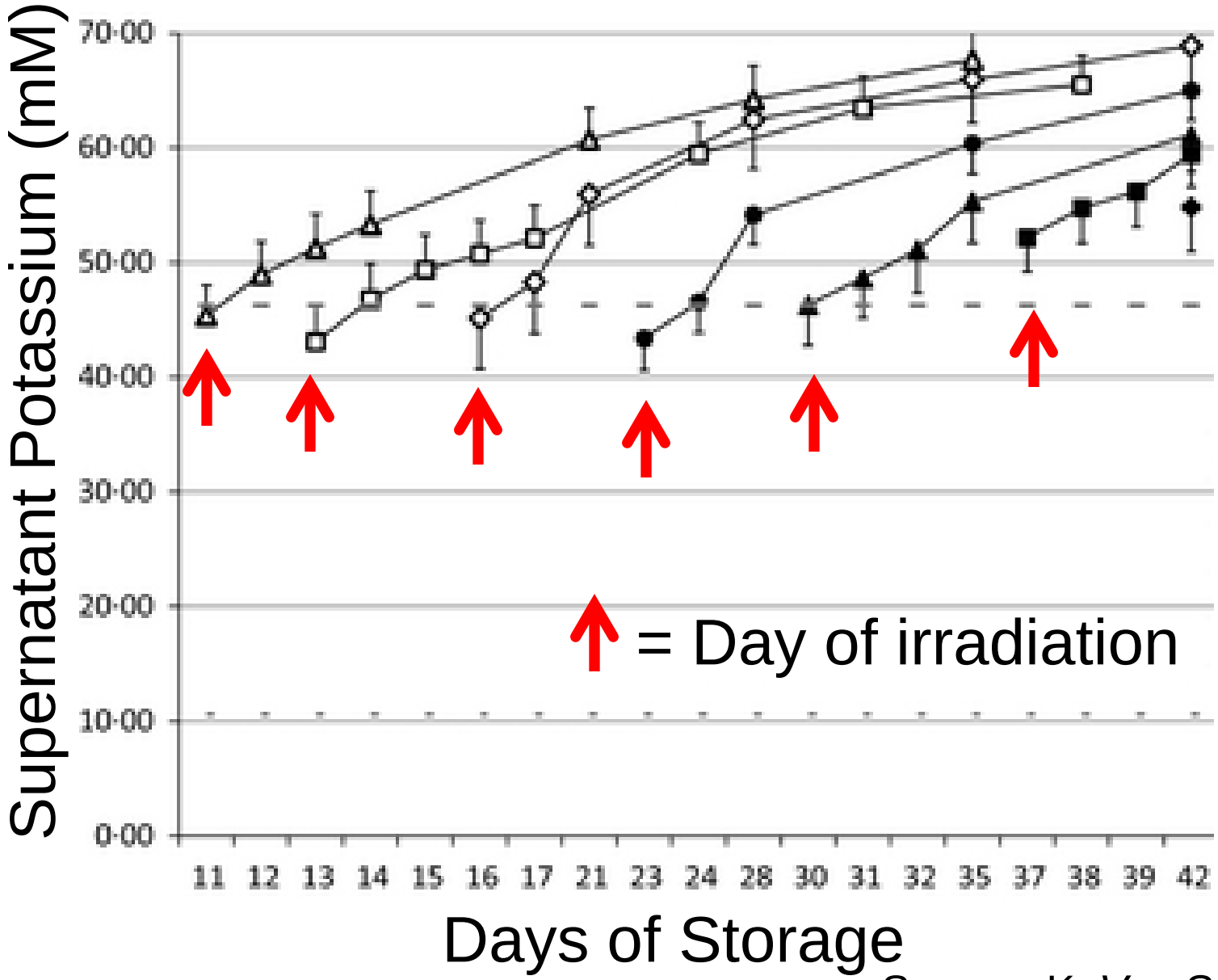


Mazer SP, et al. *Resuscitation* 2003

Hyperkalemia

- Ventricular arrhythmias, V-fib, asystole
- Hyperalimentation
- Red blood cell (RBC) transfusions
  - Longer storage of RBCs
  - Irradiated RBCs (to prevent graft-versus-host reaction)
  - Young patients (particularly infants)

Hyperkalemia



Serrano K. *Vox Sang* 2013

Hyperkalemic Arrest

1. Drive potassium into cells
   - Induce alkalosis: hyperventilate, sodium bicarbonate (1 – 2 mEq/kg IV or IO)
   - Calcium: calcium chloride 20 mg/kg or calcium gluconate 60 mg/kg IV or IO
   - Glucose + insulin: D25 2 mL/kg + regular insulin 0.1 unit/kg
   - Albuterol

Note: Patient may re-arrest when potassium exits the cells

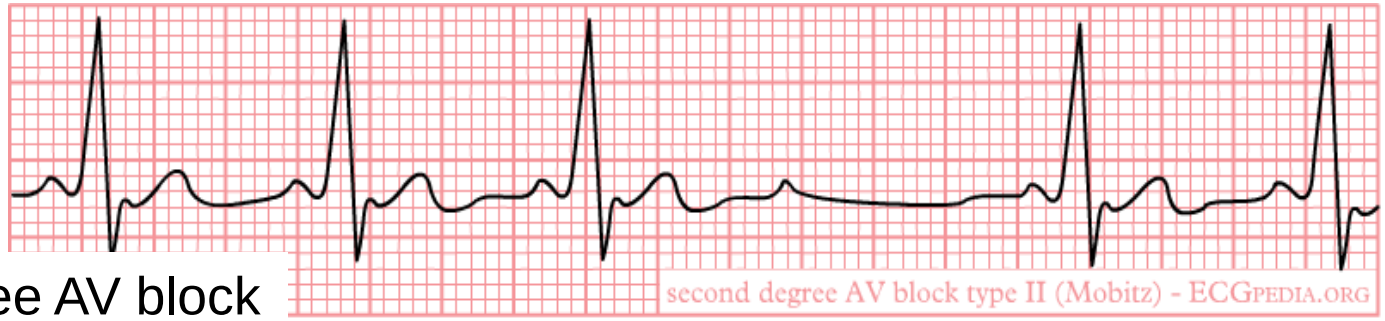
Hyperkalemic Arrest

2. Remove potassium from the body

   - Diuretics: lasix +/- IV fluid bolus
   - Sodium polystyrene: Kayexelate
   - Dialysis
   - ECMO

Local Anesthetic Toxicity

- Harder to detect in children receiving general anesthesia
  - Agitation, confusion, twitching, seizures are masked
- Prolonged PR interval on EKG
- Progressive bradycardia
- Cardiac conduction block
- Hypotension, decreased contractility
- Asystole



Type II second degree AV block

Local Anesthetic Toxicity

- Treat seizures with benzodiazepines (*not propofol*)
- Cardiac arrest
  - Chest compressions
  - Epinephrine (1 mcg/kg): higher doses may decrease efficacy of lipid emulsions
- Arrhythmias
  - Amiodarone

Local Anesthetic Toxicity: Intravenous Lipid Emulsion

1. 20% intralipid 1.5 mL/ kg bolus over 1 minute

2. Intralipid infusion at 0.25 mL/kg/min

   – Continue infusion for 10 minutes <u>after</u> reach hemodynamic stability

Neal JM, et al. *Reg Anesth Pain Med* 2012

Local Anesthetic Toxicity: Intravenous Lipid Emulsion

3. If still hemodynamically unstable, give second or third 1.5 mL/kg intralipid boluses

4. Increase intralipid infusion to 0.5 mL/kg/min

5. Maximum dose 10 mL/kg of intralipid over 30 mins

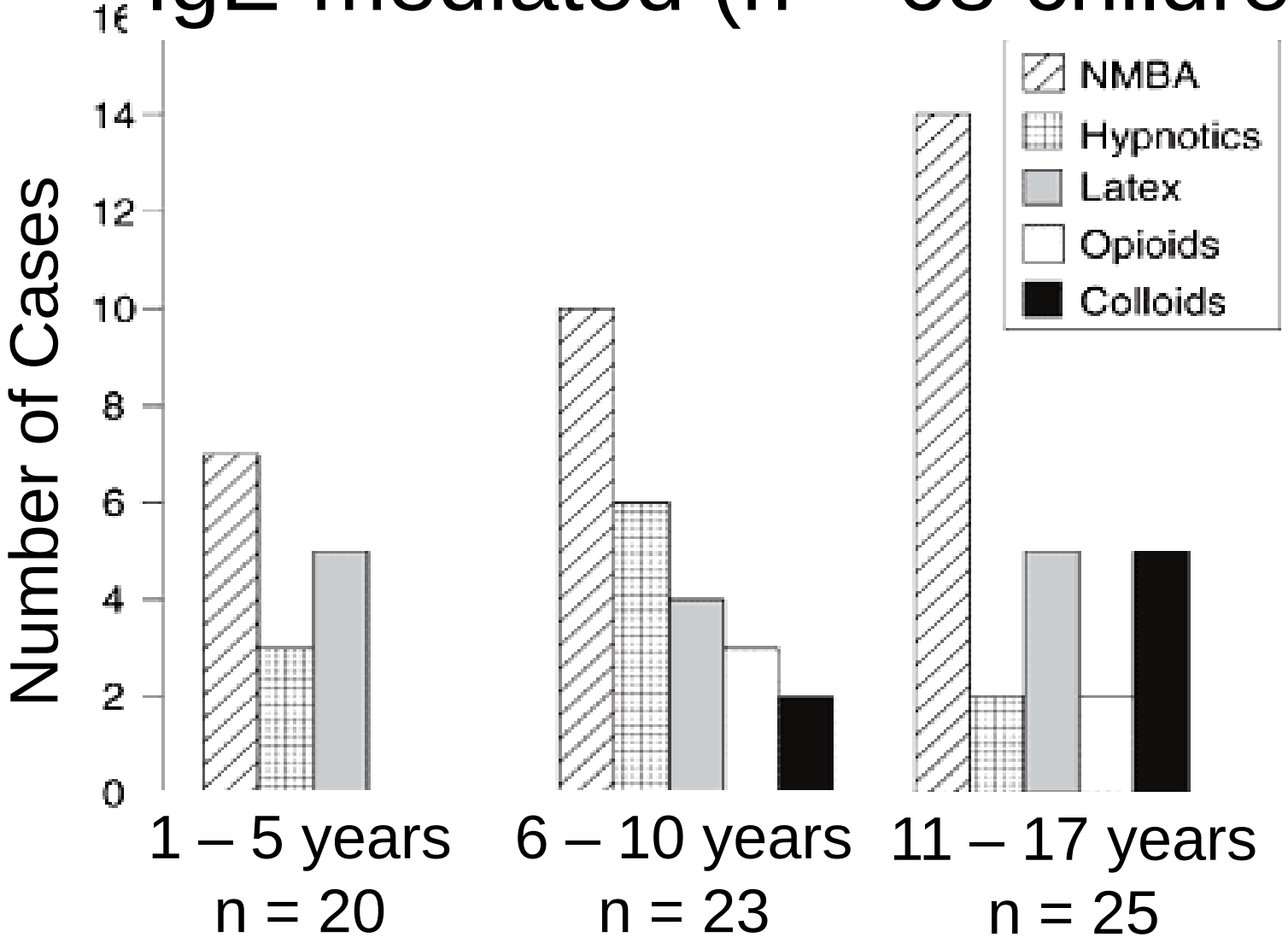
Neal JM, et al. *Reg Anesth Pain Med* 2012

Local Anesthetic Toxicity

Patient could re-arrest until the local anesthetic is metabolized

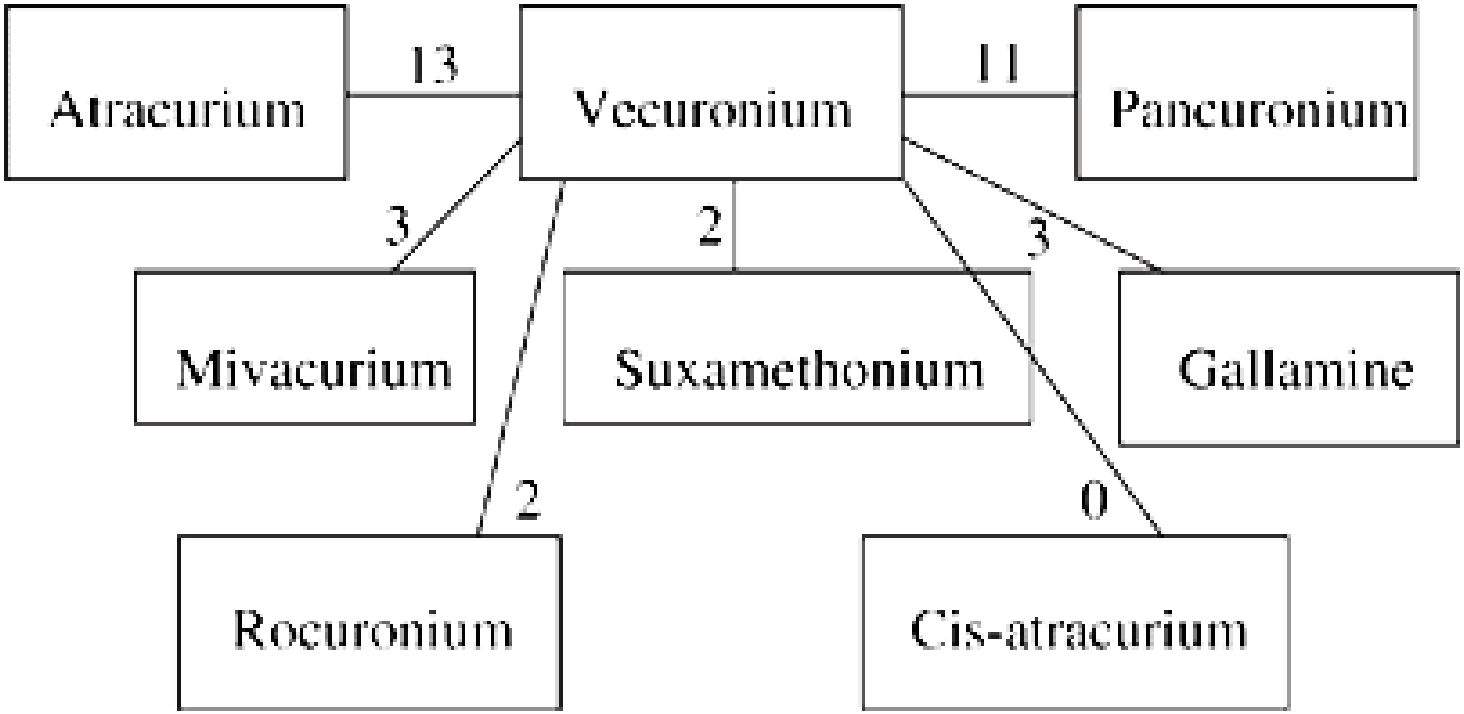
www.google.com/search?q=ecmo+machine+pictures

Anaphylaxis
IgE-mediated (n = 68 children)



Karila C, et al. *Allergy* 2005

Anaphylaxis
IgE-mediated



30 children had cross-sensitization between neuromuscular blocking agents

Karila C, et al. *Allergy* 2005

Anaphylaxis

1. Remove likely allergen(s)
2. Prepare to stop surgery
3. 100% oxygen
4. Reduce or stop anesthetics
5. **Epinephrine 10 mcg/kg IM**
   - Up to 0.5 mg/dose every 20 minutes
   - Infusion 0.1 to 1 mcg/kg/min

Anaphylaxis

6. IV fluid boluses
7. Trendelenburg position
8. Histamine blockers: ranitidine (1-2 mg/kg; max 50 mg), diphenhydramine (1-2 mg/kg; max 50 mg)
9. Corticosteroids
10. Albuterol if wheezing
11. Send serum tryptase level within 6 hours

Recommended Reference

- Shaffner DH, Heitmiller ES, Deshpande JK. Pediatric perioperative life support. *Anesth Analg* 2013; 117(4): 960-979.