When the Heart Stops:
A Review of Cardiac Arrest in Pregnancy

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Introduction

- The most recent UK confidential enquiry reporting an incidence of cardiac arrest in 1:20000 pregnancies.
- 10% of maternal deaths present as cardiac arrest
- Purpose: a practical approach to cardiac arrest in the pregnant patients

- Physiological Considerations
  - Respiratory Changes
  - Cardiovascular Changes
  - Gastrointestinal Changes
  - Hematologic Changes
- ACLS Considerations in the Pregnant Patient
  - Airway/Breathing
  - Circulation
  - Defiberation
  - Drug
  - Delivery
- Etiology of Cardiac Arrest in Pregnancy
  - Obstetric cause
  - Non-obstetric cause

Respiratory Changes

- Airway hyperemia and friability
  - Estrogens
  - Plasma volume
  - Oncotic pressure
  - Thrombocytopenia
- Pharyngolaryngeal and vocal cord edema

Intubation difficulty

Respiratory Changes

- Mechanics of respiration
  - Chest compliance ↓
    - Relaxin
    - Enlarged breasts

FRC↓20%
(↓25% in the supine position near term)

Respiratory Changes

- Oxygen consumption and metabolic rate
  - Increased requirements
    - Fetus
    - Placenta
    - Maternal organs
  - Progesterone drive

Ventilation↑

1. PaCO2↓
2. Mild respiratory alkalosis

Respiratory Changes

- If alveolar hypoventilation
  - PaO2↓
  - PaCO2↑
- Intrapulmonary shunting↑(up to 13.9%)
- Fetal hemoglobin oxygen affinity↑
- Placental health

Cardiovascular Changes

- Systemic vascular resistance↓
  - Systolic BP↓
  - Diastolic BP↓↓
  - Pulse pressure↑
- Heart rate↑(20% ~ 30%)
- Blood volume↑(30% ~ 50%)
- Cardiac output↑= Heart rate X Stroke volume(30% ~ 60%)

Cardiovascular Changes

- 17% cardiac output → Uterine circulation
- Aortocaval compression↑(latter ½ pregnancy)
  - Preload↓
  - Hypotension
  - Bradycardia
  - ***Lateral decubitus position***
- 500 cc of blood from uterus circulation into the systemic circulation (during labor)

obtain IV access above the diaphragm

Gastrointestinal Changes

- Hormone change
  - Gastric pH↓
  - Gastric emptying↓
  - Lower esophageal sphincter↓
- Gravid uterus
  - Intragastric pressure↑
- Gastric transit time↓
- Aspiration of stomach contents↑↑

bag–mask ventilation would worsening

Hematologic Changes

- Relative physiological anemia
  - Inadequate iron intake

Red cell mass↑
Blood volume↑↑

- Oncotic pressure↓
  - Preeclampsia
    - Intravascular volume↓
    - Extravascular overload↑

Table 1. Physiological Changes of Pregnancy Affecting ACLS Protocol

System	Change	Affect on ACLS
Respiratory	Hyperemia and vocal cord edema	Need for smaller ETT
	Increased minute ventilation	Accelerated hypoxemia
	Decreased FRC	Increased difficulty with bag-mask ventilation
	Decreased chest wall compliance	
	Increased oxygen consumption	
Cardiovascular	Increased cardiac output with 17% diversion to gravid uterus	Limited cardiac output with CPR (partially diverted to uterus)
	Aortocaval compression from gravid uterus	Decreased preload
		Decreased effectiveness of chest compressions
		Need to displace uterus
	Increased cardiac output following delivery	Benefit to maternal hemodynamics of fetal delivery
Gastrointestinal	Delayed gastric emptying	Increased risk of aspiration, therefore importance of cricoid pressure and early intubation
	Increased intragastric pressure	
	Relaxation of lower esophageal sphincter	
Hematologic	Anemia	Need for 100% oxygen

Abbreviations: ACLS, advanced cardiac life support; CPR, cardiopulmonary resuscitation ; ETT, endotracheal tube; FRC, functional residual capacity.

Table 2. Checklist for Pregnant Patients at Risk for Cardiac Arrest

Checklist
☐ Providers needed at time of arrest Code team: Intensivisit: Obstetrician: Pediatrician/neonatologist:
☐ Periodic update to various resuscitative teams of patient's condition
☐ Airway management kit
☐ Cesarean delivery kit
☐ Neonatal resuscitation kit
☐ Crash cart and defibrillator
☐ Wedge
☐ http://www.nichd.nih.gov/about/org/cdbpm/pp/prog_epbo/epbo_case.cfm [67]

ACLS Considerations in the Pregnant Patient

- ACLS protocol
  - Airway
  - Breathing
  - Circulation
  - Defibrillation
  - Drugs (ABCDDs)
  - Delivery (ABCDDD)

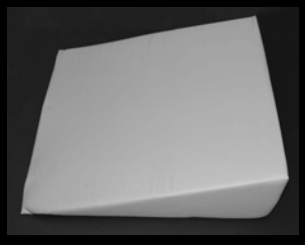
ACLS Considerations in the Pregnant Patient

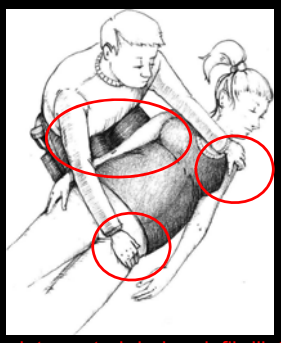
- Airway/Breathing
  - *Heimlich maneuver*
    - The thrusts site: **upward to the chest**, avoiding the sternum
  - 100% oxygen
    - *Bag–mask ventilation* with cricoid pressure
    - Early intubation
  - Intubation
    - Fail rate↑(X8 risk of surgical patient)
    - Most experienced provider
    - A smaller sized ETT
  - Alternative airway device
    - Supraglottic airway device
    - Combitube
    - Laryngeal mask airways
    - Videolaryngoscopy

ACLS Considerations in the Pregnant Patient

- Circulation
  - Tilt the body at an angle of 27°
    - The impact of the gravid uterus on cardiac output↓
    - 80% of the supine force was achieved
    - Remain controversy of actual benefit
  - Chest compression hand placement
    - Slightly superior hand positioning than normal

Cardiff wedge and Human wedge





being interrupted during defibrillation

Defibrillation

- No significant difference in mean transthoracic impedance noted before or after delivery
- The risk of defibrillation to the fetus is felt to be small
  - Internal and external fetal monitors are removed during defiberation

Drugs

- GFR↑
- Volume of distribution change
- Protein binding↓
- Renal clearance↑
- Metabolic clearance of vasopressin↑(X4)

Medication for arrhythmia

Medication	Advantage/side effect
Amiodarone	**Fetal goiter**, **transient hypothyroidism**, and **mental delay** (rare)
Lidocaine	Safely used without adverse fetal outcomes
Procainamide	**Maternal lupus-like syndrome**
CCB	Safe in pregnancy with little fetal effect
β-blocker	**Fetal bradycardia** and *low birth weight*?

Medication for sedation

Medication	Advantage/side effect
Fentanyl	Cross the placenta freely without any adverse neonatal effects
Midazolam	Less fetal effects
Diazepam	**1. Congenital anomalies ↑** **2. "Floppy infant syndrome"**

Other medication

- Sodium bicarbonate
  - Maternal
    - Acidosis↓
    - Compensatory hyperventilation↓
    - PaCO2 ↑ to normal value
  - Fetal
    - PaCO2 ↑
    - Fetal acidosis↑
- α-Adrenergic agent + α-,β-agonist (for hypotension)
  - Uteroplacental vasoconstriction
  - Fetal oxygenation↓; hypercarbia↑
    - Ephedrine
      - Heart rate↑
      - Maternal nausea / vomiting ↑
      - Fetal acidosis↑
    - Phenylephrine
      - Higher fetal pH

Delivery

- "*Lex Regis de Inferendo Mortus*" in 715 BC
- Katz et al in 1986: Initiation of cesarean section at 4 minutes, delivery of infant at 5 minutes
  - Irreversible brain damage from anoxia occurs within 4 to 6 minutes of inadequate cerebral perfusion

Delivery

- Confidential Enquiry into Maternal and Child Health (CEMACH) 2003-2005 report
  - Fetal survival as early as 24 ~ 27 weeks↑
  - Maternal hemodynamics to be significantly affected by a fetus > 24 weeks of gestation
- Ultrasound
  - Determine approximate gestational age
  - Determine whether the fetus is dead / alive

Delivery

- Benefit the fetus
- Theorically, the benefit of maternal
  - Aortocaval compression relief
    - Venous return
    - Cardiac output
    - Redistribution of cardiac output with a reduction in the flow to the uterus
  - Improving compliance of lung
  - Respiratory mechanics
  - Oxygenation

Recent papers

- Katz et al, 38 cases of perimortem delivery
  - **14 women survive**
    - 12 had improvement after CS
  - **28 of perimortem delivery** resulted in **34 live births**

Recent papers

- The Netherlands, 55 pregnant women who underwent CPR over 15 years
  - 12 had a perimortem cesarean section

	0-5 mins	5-15 mins	15-45 mins
Case	0	4	8
Materal	0	2 maternal survivals; (1 with vascular dementia and cognitive impairment)	All dead
Fetal	0	3 neonates (2 were discharged with healthy)	2 neonates (1 with neurological damage)

Recent papers

- A case report
  - Fetal survival without neurological damage after 30 to 45 minutes of maternal death
- CEMACH 2003-2005
  - 52 infants delivered by perimortem delivery with 20 survivals
    - Proximity to an operating room or delivery suite
    - Advanced gestational age (preferably greater than 35 weeks gestation)

Delivery

- *Perimortem delivery is recommended within 5 minutes of cardiac arrest*
  - Perimortem cesarean section equipment pack available on crash carts
  - Educational programs
  - Regular drills
  - The surgical techique that the operators most comfortable with

Post-Arrest Care

- Case report of a GA 13 wks patient was resuscitated and underwent therapeutic hypothermia → able to deliver a healthy baby at term
- Consider **continuous fetal monitoring** throughout the treatment

Table 3. Modifications to Standard ACLS Protocol Necessary in Pregnant Patients

	Modification
Airway	Early intubation
	Cricoid pressure until intubation achieved
Breathing	100% oxygen
Circulation	Leftward displacement of the uterus (manual or by use of a wedge at 27°)
	Caudal placement of hands for CPR
Defibrillation	Standard ACLS protocol
	Ensure removal of fetal monitors
Drugs	Standard ACLS doses
	Caution with sodium bicarbonate
	Caution with alpha-adrenergic agents
Delivery	Initiate perimortem delivery at 4 minutes if resuscitation unsuccessful
	Alert appropriate neonatologist and obstetrician of arrest as soon as cardiac arrest occurs

Etiology of Cardiac Arrest in Pregnancy

Table 4. Direct Causes of Maternal Mortality Based on the UK Confidential Enquiry (CEMEACH) 2003-2005

Cause	Rate per 100,000 pregnancies
Thrombosis and thromboembolism	1.94
Pre-eclampsia/Eclampsia	0.85
Sepsis	0.85
Amniotic fluid embolism	0.80
Hemorrhage	0.66

Etiology of Cardiac Arrest in Pregnancy

Table 5. Indirect Causes of Maternal Mortality Based on the UK Confidential Enquiry (CEMACH) 2003-2005

Cause	Rate per 100 000 pregnancies
Cardiac	2.27
Psychiatric	0.85
Malignancy	0.47
Other (eg, diabetes mellitus, epilepsy, asthma)	4.12

Etiology of Cardiac Arrest in Pregnancy

- Obstetric Causes
  - Preeclampsia/eclampsia(#2)
    - Hypertension→CVA
    - Intravascular depletion→CPR↓
    - MgSO4 use → cardiac arrest
  - Sepsis
    - Puerperal sepsis
    - Genital tract sepsis
    - Lemierre syndrome
  - Anaphylactoid syndrome
    - 1/8000 to 80000 pregnancies
    - mortality rate: 50% ~ 80%
    - 87% of these cases involving a cardiac arrest

1. Calcium gluconate 30 ml in 10% solution IV /IO
2. Calcium chloride 10 mL in 10% solution IV/IO

Etiology of Cardiac Arrest in Pregnancy

- Obstetric Causes
  - Hemorrhage(#1)
    - Placental abruption
    - Placenta previa
    - Placenta accreta
    - Uterine atony
    - Disseminated intravascular coagulation (DIC)
    - Coagulation defect
  - Anesthesia
    - Difficult intubations
    - Neural axial blockade (high sympathectomy)
      - Vasodilation
      - Redistribution of blood
      - High level blockage of T1-T4
  - Other
    - Peripartum cardiomyopathy
    - Prostaglandin use

1. **Hypotension**
2. **Bradycardia**
3. **Ventricular arrhythmias**
4. **Myocardial infarctions**
5. **Coronary vasospasm**
6. **Cardiac arrest**

Etiology of Cardiac Arrest in Pregnancy

- Nonobstetric Causes
  - Cardiovascular disease
    - Myocardial infarction(#1)→PCI
    - Aortic dissection(#2)
    - Congenital heart disease with *pulmonary hypertension*(#3)
    - Arrythmogenic conditions
  - Other
    - Trauma
    - Psychiatric disease
    - Chronic hypertension
    - Cerebrovascular disease
    - Morbid **obesity**

Conclusions

- All persons should be trained in ACLS with adjustments needed for pregnant women
- Key alterations
  - Early intubation
  - Superior hand placement for CPR
  - Left lateral displacement of the uterus
  - Obtain IV access above the diaphragm
  - Caution with sodium bicarbonate
  - Initiation of cesarean section by 4 minutes if the fundal height ≥ the umbilicus