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
  - Estrogens
  - Plasma volume
  - Oncotic pressure
  - Thrombocytopenia
- Cardiovascular Changes
- Gastrointestinal Changes
- Hematologic Changes

ACLS Considerations in the Pregnant Patient

- Airway/Breathing
- Circulation
- Defibrilation
- Drug
- Delivery

Etiology of Cardiac Arrest in Pregnancy

- Obstetric cause
- Non-obstetric cause

Respiratory Changes

- Mechanics of respiration
  - Chest compliance ↓
    - Relaxin
    - Enlarged breasts
- FRC ↓20% (↓25% in the supine position near term)

- 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
  - $\text{PaO}_2 \downarrow$
  - $\text{PaCO}_2 \uparrow$
- Intrapulmonary shunting $\uparrow$ (up to 13.9%)
- Fetal hemoglobin oxygen affinity $\uparrow$
- Placental health

Cardiovascular Changes
- Systemic vascular resistance $\downarrow$
  - Systolic BP $\downarrow$
  - Diastolic BP $\downarrow$
  - Pulse pressure $\uparrow$
- Heart rate $\uparrow$ (20% ~ 30%)
- Blood volume $\uparrow$ (30% ~ 50%)
- Cardiac output $\uparrow = \text{Heart rate} \times \text{Stroke volume}$ (30% ~ 60%)

Cardiovascular Changes
- 17% cardiac output $\rightarrow$ Uterine circulation
- Aortocaval compression $\uparrow$ (latter ½ pregnancy)
  - Preload $\downarrow$
  - Hypotension
  - Bradycardia
  - *Lateral decubitus position*
- 500 cc of blood from uterus circulation into the systemic circulation (during labor)

Gastrointestinal Changes
- Hormone change
  - Gastric pH $\downarrow$
  - Gastric emptying $\downarrow$
  - Lower esophageal sphincter $\downarrow$
- Gravid uterus
  - Intra-gastric pressure $\uparrow$
- Gastric transit time $\downarrow$
- Aspiration of stomach contents $\uparrow \uparrow$
  - Bag-mask ventilation would worsening

Hematologic Changes
- Relative physiological anemia
  - Inadequate iron intake
  - Red cell mass $\uparrow$
- Oncotic pressure $\downarrow$
  - Preeclampsia
  - Intravascular volume $\downarrow$
  - Extravascular overload $\uparrow$

Table II. Physiological Changes of Pregnancy Affecting ACLS Protocol

<table>
<thead>
<tr>
<th>System</th>
<th>Change</th>
<th>Affect on ACLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td>Hypoxemia and vocal cord edema</td>
<td>Need for smaller ETT, increased minute ventilation</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Increased cardiac output</td>
<td>United cardiac output with CVP (partially diverted to s v)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Diabetic gastroparesis</td>
<td>Increased intragastric pressure</td>
</tr>
<tr>
<td>Hematologic</td>
<td>Anemia</td>
<td>Need for 100% oxygen</td>
</tr>
</tbody>
</table>

Abbreviations: ACLS, advanced cardiac life support; CVP, central venous pressure; ETT, endotracheal tube; PRC, functional residual capacity.
ACLS Considerations in the Pregnant Patient

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

• Airway/Breathing
  – Heimlich maneuver
    • The thrust 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

• 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

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 defibrillation
Drugs

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

Medication for arrhythmia

<table>
<thead>
<tr>
<th>Medication</th>
<th>Advantage/side effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amiodarone</td>
<td>Fetal goiter, transient hypothyroidism, and mental delay (rare)</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>Safely used without adverse fetal outcomes</td>
</tr>
<tr>
<td>Procainamide</td>
<td>Maternal lupus-like syndrome</td>
</tr>
<tr>
<td>β-blocker</td>
<td>Fetal bradycardia and low birth weight?</td>
</tr>
</tbody>
</table>

Medication for sedation

<table>
<thead>
<tr>
<th>Medication</th>
<th>Advantage/side effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fentanyl</td>
<td>Cross the placenta freely without any adverse neonatal effects</td>
</tr>
<tr>
<td>Midazolam</td>
<td>Less fetal effects</td>
</tr>
<tr>
<td>Diazepam</td>
<td>1. Congenital anomalies↑</td>
</tr>
<tr>
<td></td>
<td>2. &quot;Floppy infant syndrome&quot;</td>
</tr>
</tbody>
</table>

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 (warning)
    - Fetal anoxia
    - Pharyngitis
    - Higher fetal pH
- 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
- 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
- Theoretically, 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

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

<table>
<thead>
<tr>
<th></th>
<th>0-5 mins</th>
<th>5-15 mins</th>
<th>15-45 mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Material</td>
<td>0</td>
<td>2 maternal survivals (1 with vascular dementia and cognitive impairment)</td>
<td>All dead</td>
</tr>
<tr>
<td>Fetal</td>
<td>0</td>
<td>3 neonates (2 were discharged with healthy)</td>
<td>2 neonates (1 with neurological damage)</td>
</tr>
</tbody>
</table>

- 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 technique 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
Etiology of Cardiac Arrest in Pregnancy

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

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

<table>
<thead>
<tr>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway</td>
</tr>
<tr>
<td>Breathing</td>
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<tr>
<td>Circulation</td>
</tr>
<tr>
<td>Defibrillation</td>
</tr>
<tr>
<td>Drugs</td>
</tr>
<tr>
<td>Delivery</td>
</tr>
</tbody>
</table>

Alert appropriate neonatologist and obstetrician of arrest as soon as cardiac arrest occurs.

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

<table>
<thead>
<tr>
<th>Cause</th>
<th>Rate per 100,000 pregnancies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrombosis and thromboembolism</td>
<td>1.94</td>
</tr>
<tr>
<td>Pre-eclampsia/Eclampsia</td>
<td>0.85</td>
</tr>
<tr>
<td>Sepsis</td>
<td>0.85</td>
</tr>
<tr>
<td>Amniotic fluid embolism</td>
<td>0.80</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>0.66</td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th>Cause</th>
<th>Rate per 100 000 pregnancies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac</td>
<td>2.27</td>
</tr>
<tr>
<td>Psychiatric</td>
<td>0.85</td>
</tr>
<tr>
<td>Malignancy</td>
<td>0.47</td>
</tr>
<tr>
<td>Other (eg, diabetes mellitus, epilepsy, asthma)</td>
<td>4.12</td>
</tr>
</tbody>
</table>

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 sympathetic tone)
  - Other
    - Peripartum cardiomyopathy
    - Prostaglandin use

- Nonobstetric Causes
  - Cardiovascular disease
    - Myocardial infarction (#1) → PCI
    - Aortic dissection (#2)
  - Congenital heart disease with pulmonary hypertension (#3)
  - Anhydremic 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