

Basic Hemodynamic Monitoring



BHM 1

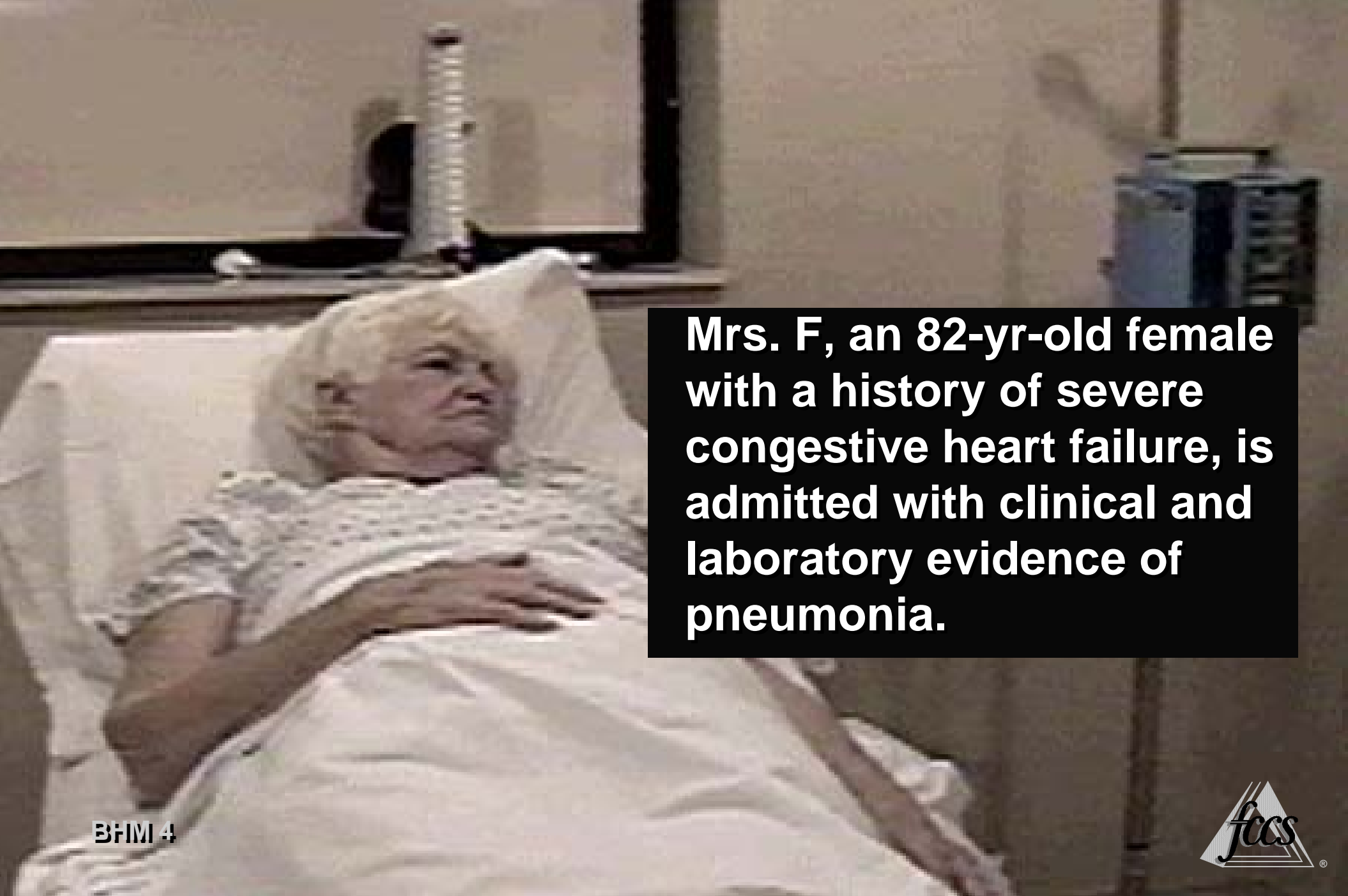


Objectives


- Review indications and/or limitations of devices and measurements
 - Pulse oximetry
 - Automated blood pressure devices
 - Arterial, central venous, and pulmonary artery catheters
 - Cardiac output and oxygen delivery variables

General Principles

- **Sensors must accurately detect the signal**
- **Monitoring is never therapeutic and rarely diagnostic**
- **Evaluate risk-benefit ratio for using a monitor**
- **Monitoring is a team process**



Mrs. F, an 82-yr-old female with a history of severe congestive heart failure, is admitted with clinical and laboratory evidence of pneumonia.

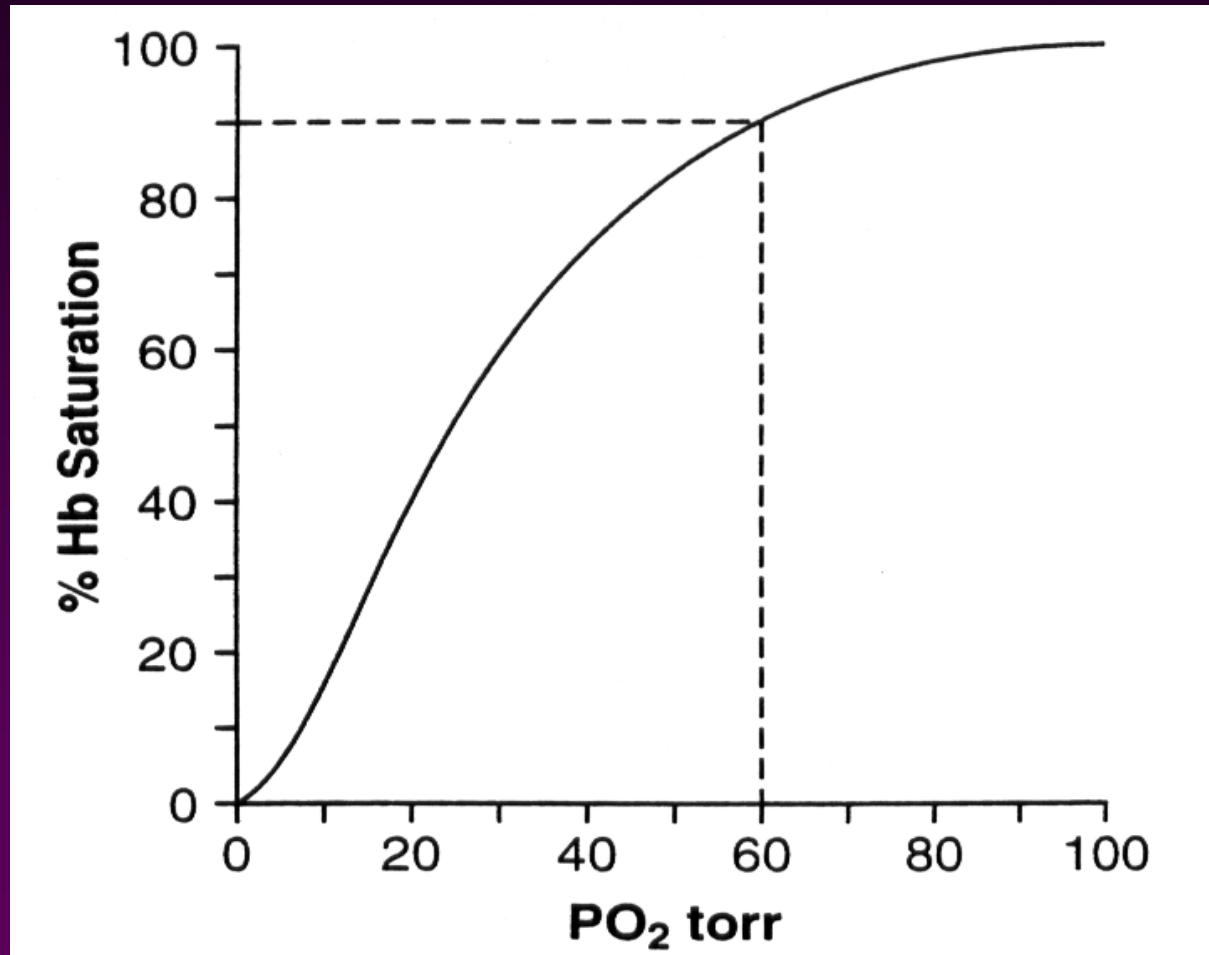
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- **Goals**
 - **Confirm diagnosis**
 - **Initiate treatment**
 - **Monitor for improvement or worsening in her condition**

Pulse Oximetry

- Estimates oxyhemoglobin as SpO₂
 - Goal 92%–94%
- Heart rate displayed should = pulse rate or ECG heart rate



Oxyhemoglobin Saturation Curve



Pulse Oximetry – Sources of Error

- **Physiologic/anatomic**
 - Vasoconstriction/poor perfusion
 - Abnormal hemoglobin
 - Skin pigmentation
 - False nails and polish
- **External**
 - Motion of sensor
 - Extraneous light

Automated Blood Pressure Devices

- Intermittent measurements
- Appropriate cuff size necessary
- Less accurate during hypotension, mechanical ventilation, arrhythmias

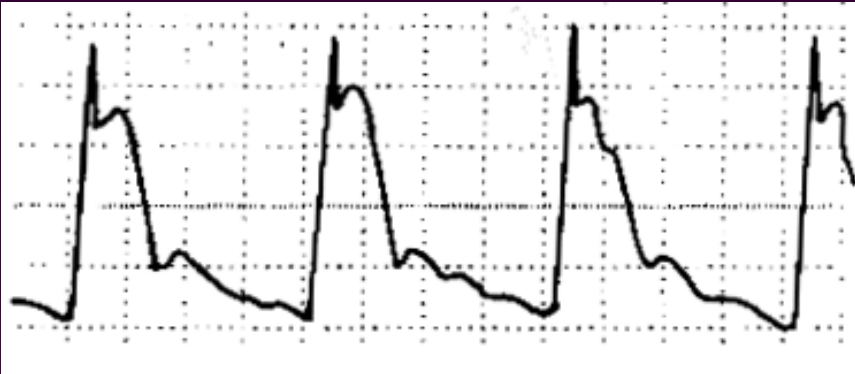


Mrs. F. continued to be hypotensive despite fluid therapy. Her urine output is marginal, she is confused, her extremities are mottled, and her heart rate is elevated. The decision is made to obtain more direct measurements of her intravascular pressures and hemodynamic status.

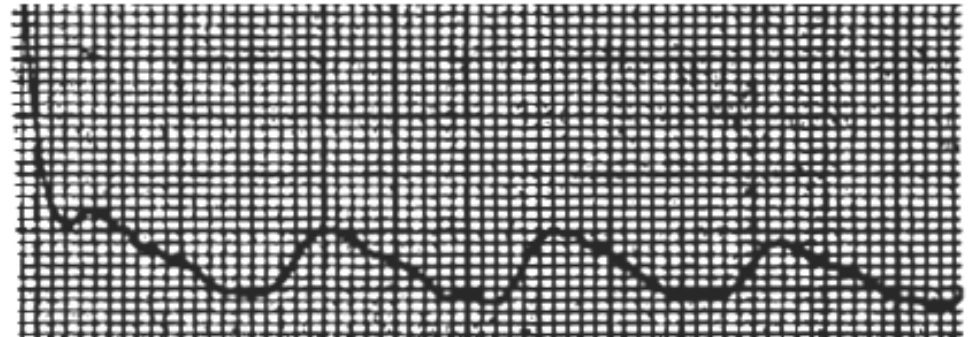
Arterial Cannulation

- **Indications**
 - Multiple arterial blood samples
 - Continuous blood pressure
- **Sites**
- **Complications**
 - Hematoma/blood loss
 - Thrombosis/distal ischemia
 - Arterial injury
 - Infection

Waveform Distortions



Underdamped



Overdamped

Central Venous Cannulation

- **Indications**
 - Measure central venous pressure
 - Access for resuscitation
 - Drug administration
 - Placement of pulmonary artery catheter
- **Complications**
 - Hematoma/vessel injury/blood loss
 - Pneumothorax/hemothorax
 - Cardiac arrhythmias
 - Infection

Assessment Goals

- Balance of O₂ supply ($\dot{D}O_2$) and O₂ demand ($\dot{V}O_2$)
- Determinations require invasive monitoring with pulmonary artery catheter
 - Arterial and venous O₂ content
 - Cardiac output
- Appropriate expertise required

Assessment Goals for Mrs. F.

Evaluate if oxygen supply (DO_2) and/or oxygen demand (VO_2) are abnormal or imbalanced

- O_2 supply

- $\text{DO}_2 = \text{cardiac output} \times \text{CaO}_2 \times 10$

- $\text{CaO}_2 = (\text{Hgb} \times 1.37 \times \text{SaO}_2) + (0.003 \times \text{PaO}_2)$

- O_2 consumption

- $\text{VO}_2 = \text{cardiac output} \times (\text{CaO}_2 - \text{CvO}_2) \times 10$

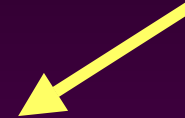
- $\text{CvO}_2 = (\text{Hgb} \times 1.37 \times \text{SvO}_2) + (0.003 \times \text{PvO}_2)$

Determinants of Cardiac Output

afterload

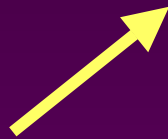


contractility

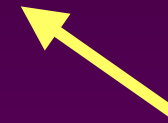


**Cardiac
Output**

preload



heart rate

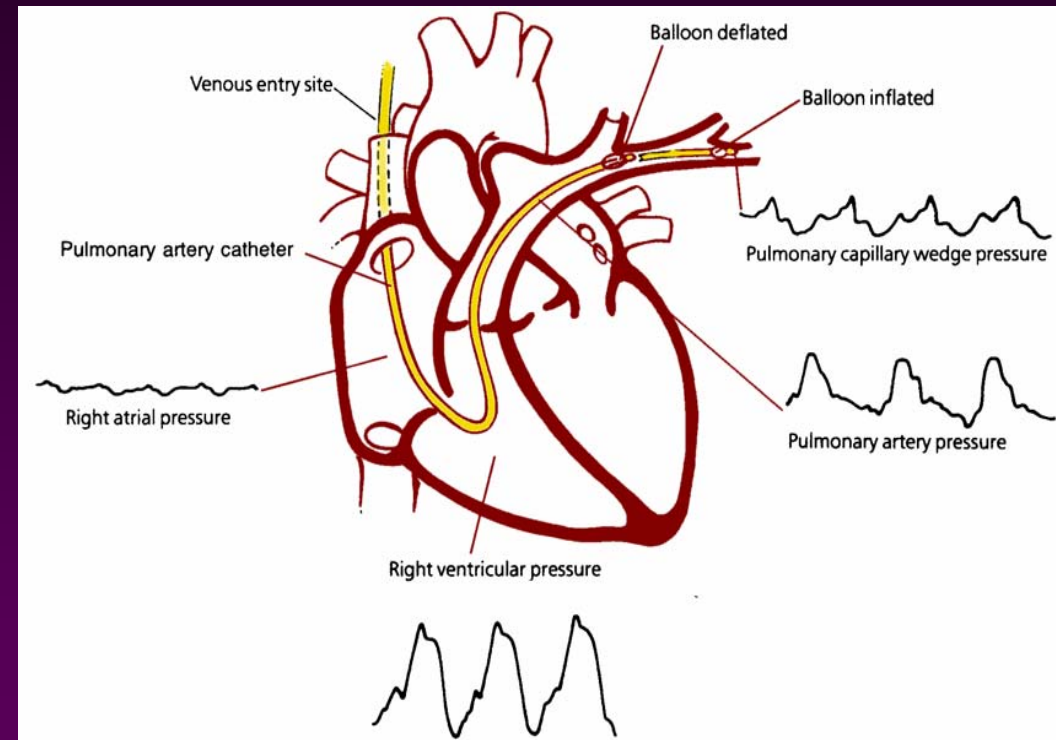


Assessment Goals for Mrs. F.

- **Determinants of cardiac output**
 - **Heart rate and rhythm**
 - **Preload – neck vein distension, lung findings, blood pressure, CVP, PAOP**
 - **Afterload – mean arterial blood pressure, systemic vascular resistance**
 - **Contractility – LVSW, ejection fraction, echocardiography**

Pulmonary Artery Catheter

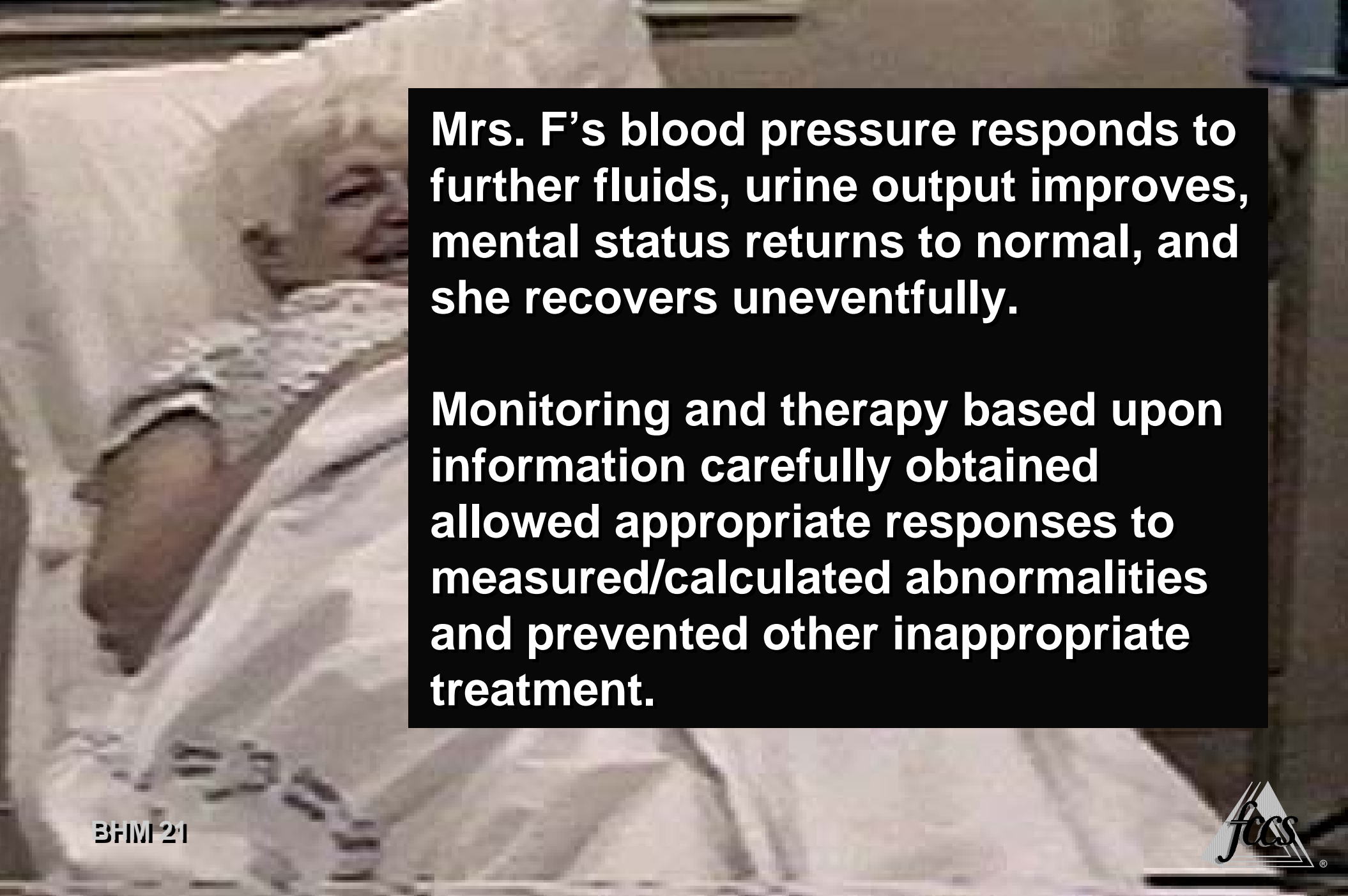
- CVP and PAOP measure end-diastolic pressure
- Estimate of end-diastolic volume
- Volume/pressure relationship affected by ventricular compliance



A pulmonary artery catheter was placed in Mrs. F. Data obtained: PAOP 10 mm Hg, CVP 8 mm Hg, CO 7 L/min; SVR slightly low, calculated DO_2 above normal, and VO_2 slightly below normal.

Interpretation: a hyperdynamic state (despite history of CHF), suggestive of distributive changes accompanying a systemic response to inflammation/infection.

Intervention for decreased BP: additional iv fluid



Mrs. F's blood pressure responds to further fluids, urine output improves, mental status returns to normal, and she recovers uneventfully.

Monitoring and therapy based upon information carefully obtained allowed appropriate responses to measured/calculated abnormalities and prevented other inappropriate treatment.

Pediatric Considerations

- **Reduced catheter sizes**
- **Lower concentration heparin in flushes and smaller flush volumes**
- **Higher risk of pneumothorax in children <2 yrs due to more cephalad lung apex**
- **Tip of central venous catheter should rest just proximal to SVC-right atrial junction**

Cardiopulmonary/Cerebral Resuscitation

Objectives

- Identify patients likely to benefit from resuscitation
- Propose a process for delegating responsibilities
- Discuss treatment issues in cardiopulmonary arrest
- Emphasize goals for brain protection and recovery
- Review specific cardiorespiratory events in ventilated patients

Who Should Be Resuscitated?

- **No set of variables accurately predicts outcome**
- **Level of support should be discussed with patient, family and/or surrogate**
- **Do not attempt resuscitation orders**
 - **Document rationale**
 - **Continue other care**
- **Slow codes inappropriate**

The hospital paging operator has just announced a cardiac arrest in a nearby patient care area. What actions are needed to begin a successful resuscitation?

- **Assess if a leader has taken responsibility**
- **Prepare to take a delegated role**
- **Assume a leadership role**

Primary Assessment

- **Assess patient responsiveness**
- **Assess pulse, respiratory effort, circulation**
- **Consider primary defibrillation**
- **Change ventilated patient to bag-mask-valve ventilation**

Delegation of Duties

- **Airway management**
- **Chest compressions with relief person; monitor effectiveness**
- **ECG monitoring/defibrillator operation**
- **IV access**
- **Medication administration**

Delegation of Duties

- **Medical record review**
- **Notify attending physician**
- **Remove unneeded equipment and people**
- **Team conducts the resuscitation**

Continuing Resuscitation

- Obtain critical laboratory data
- Review chart for potential causes of arrest
- Reconfirm appropriateness of CPR
- Confer with admitting physician or team
- Inform family directly or via surrogate
- Anticipate successful resuscitation and transfer needs

Cerebral Resuscitation



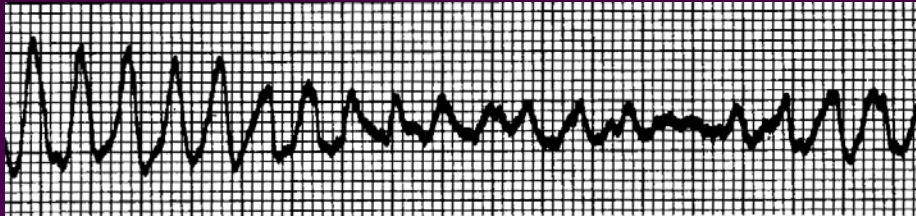
- Effectiveness of special or alternative methods during resuscitation not proven
- Early restoration of perfusion most effective
- Prevent hyperthermia
- Treat seizures aggressively

Respiratory Arrest

- Often associated with pulseless electrical activity or bradycardia/asystole
- Assess for signs of impending respiratory failure
- Disconnect patient from ventilator
- Assess endotracheal tube placement
- Consider tension pneumothorax

Arrhythmia Review

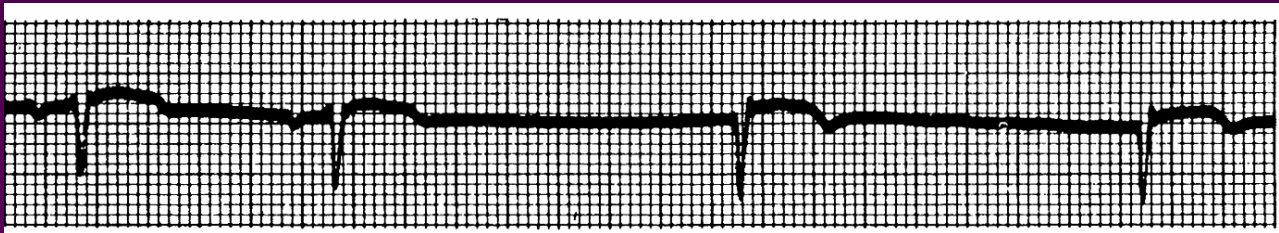
Ventricular fibrillation



- Defibrillate up to 3 times
- Epinephrine 1 mg iv
- Vasopressin 40 U iv
- Antiarrhythmic agents
 - Amiodarone
 - Lidocaine
 - Magnesium
 - Procainamide

Pulseless Electrical Activity

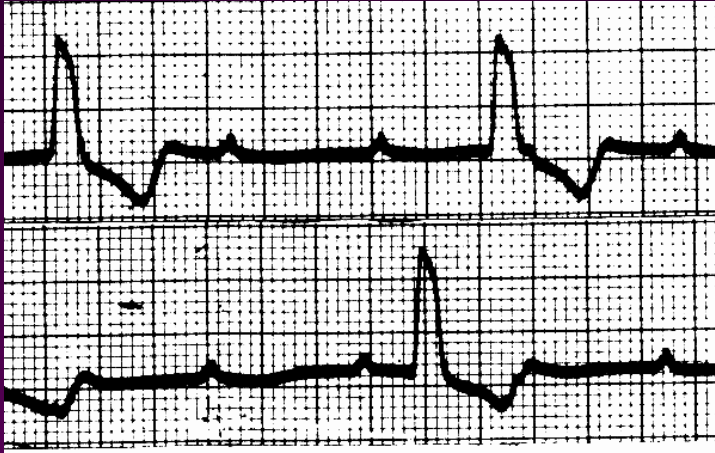
- Search for reversible causes and treat if possible
- Epinephrine
- Atropine for absolute or relative bradycardia



Asystole

- **Search for reversible causes and treat if possible**
- **Consider transcutaneous pacing**
- **Epinephrine**
- **Atropine**

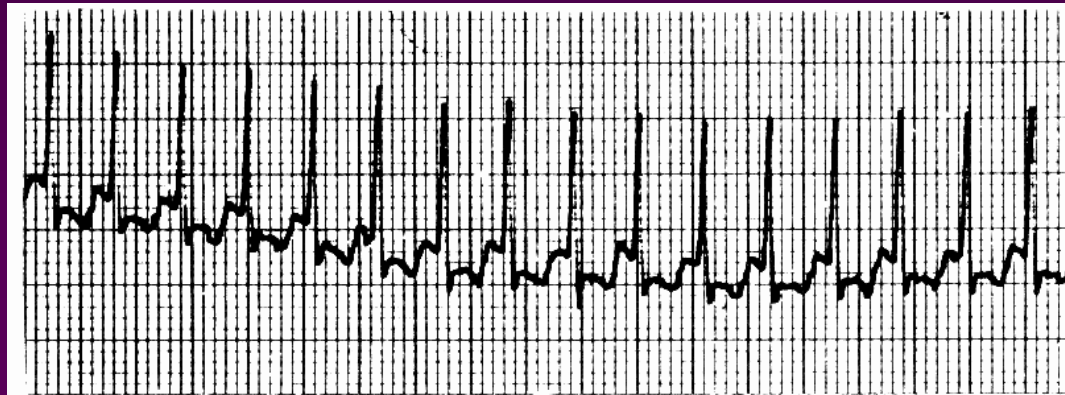
Bradycardia – Patient Not in Arrest



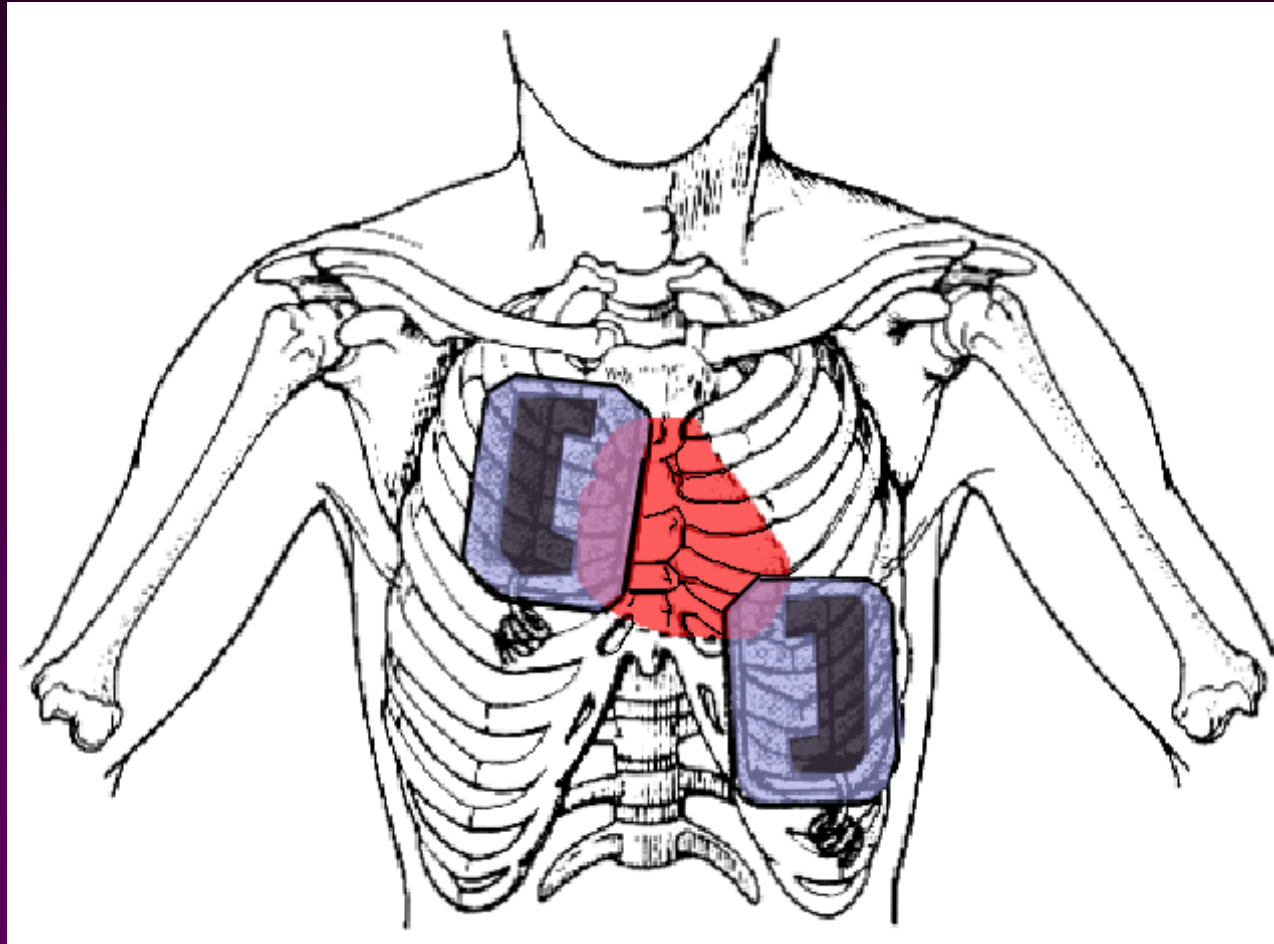
- Atropine
- Transcutaneous pacing
- Dopamine
- Epinephrine
- Transvenous pacing

Tachycardia with Serious Signs/Symptoms

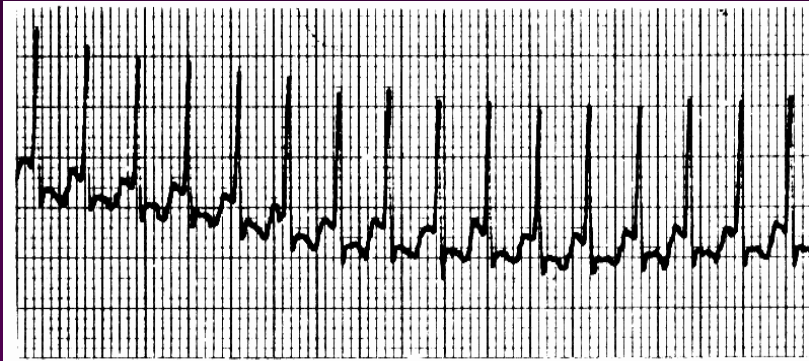
- Immediate cardioversion
- Premedicate when possible
- Synchronized setting



Paddle Positions – Defibrillation or Cardioversion

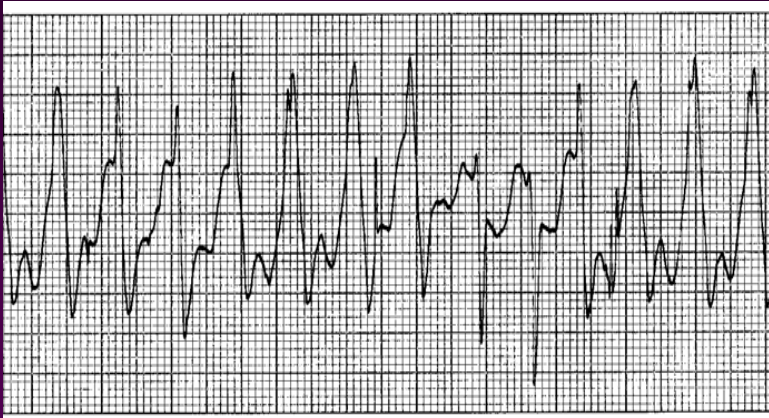


Stable Supraventricular Tachycardia



- **Narrow-complex**
 - Adenosine
 - Diltiazem
 - Amiodarone
 - β -blockers
 - Digoxin
- **Consider cardiac function**
- **Synchronized cardioversion**

Stable Ventricular Tachycardia



- **Monomorphic**
 - **Amiodarone**
 - **Lidocaine**
 - **Procainamide**
 - **Sotalol**
- **Consider cardiac function**
- **Synchronized cardioversion**

Pediatric Considerations

- **Respiratory failure is major cause of cardiac arrest**
- **Intraosseous access as alternative route of fluid and medication delivery**
- **PALS algorithms**

Trauma and Burn Management



Objectives

- Review initial assessment of the trauma patient
- Outline treatment of life-threatening injury
- Discuss use of radiography to identify injury
- Outline response to changes in patient's status
- Discuss early burn management

Trauma Care Principles

- **Simultaneous assessment and treatment through a standardized approach**
- **If no improvement or decline in status, start over at primary assessment**
- **Early surgical involvement**

Primary Assessment – Airway / Breathing

- Assume cervical spine injury
- Airway assessment and management
- Effects of facial/mandibular fracture
- Laryngeal/tracheal injury – ecchymosis, hoarseness, edema, subcutaneous air
- Flail chest from rib fractures
- Pneumo- / hemothoraces

rib fractures

Primary Assessment – Circulation

- Hemorrhage is most common cause of shock
- Establish large-bore venous access
- Initiate fluid resuscitation with lactated Ringer's solution
- Follow with packed red blood cells after 2–3 L of crystalloid
- Control external hemorrhage by compression
- Monitoring – data flow sheet, vital signs, ECG, pulse oximetry, CVP, arterial line

Hemorrhage Classification

| Hemorrhage class | Blood loss (mL) | Blood loss (%) |
|------------------|-----------------|----------------|
| I | <750 | <15 |
| II | 750–1500 | 15–30 |
| III | 1500–2000 | 30–40 |
| IV | >2000 | >40 |

Hemorrhagic Shock

- **Chest – hemothorax; drain and monitor**
- **Abdominal**
 - **Intraperitoneal (lavage or sonography)**
 - **Retroperitoneal (CT scan)**
 - **Operative intervention**
- **Pelvis – usually venous; consider embolization, external stabilization**

Nonhemorrhagic Shock

- **Tension pneumothorax**
 - **Tube thoracostomy**
- **Cardiac tamponade**
 - **Consider mechanism of injury**
 - **Venous hypertension with shock**
 - **Pericardial window preferred over needle pericardiocentesis**

Nonhemorrhagic Shock

- **Blunt cardiac injury**
 - Consider mechanism of injury
 - ECG nonspecific
 - Cardiac enzymes rarely helpful
 - Monitor at least 4 hours
- **Neurogenic shock**
 - Cervical/thoracic spinal cord injury
 - Associated bradycardia

Secondary Assessment

- Identify potentially life-threatening injuries
- History of event, medical history, drugs, allergies, tetanus immunization
- Head to toe examination
 - Fully expose patient
 - Correct and prevent hypothermia
 - Assess for signs of urethral injury
 - Neurovascular integrity

Secondary Assessment

- **Laboratory data – arterial blood gas, blood counts, electrolytes, coagulation studies, type and cross-match, urinalysis, toxicology, etc**
- **Radiograph review**
 - **Cervical spine – complete survey**
 - **Chest – mediastinal evaluation; tubes/catheters**
 - **Pelvis – major fractures**
 - **Cystogram/urethrogram**
 - **Skeletal exam**

Secondary Assessment

- CT scan of head
- CT scan of abdomen if indicated
- Other issues
 - Nasogastric tube
 - Tetanus prophylaxis
 - Antibiotic indications
 - Specialty consultation

Tertiary Assessment

- Detailed examination to detect all injuries
- Serial examinations over time to detect change and occult injuries
- Return to primary/secondary survey strategies for worsening status
- Surgical consultation/transfer planning

Compartment Syndromes

- **Abdomen**
 - **Compromise of venous return due to high intra-abdominal pressure**
 - **Secondary to free blood, fluid, edema of abdominal contents**
 - **Evaluate with measure of intrabladder pressure**
 - **Surgical decompression**

Compartment Syndromes

- **Extremity**
 - **Serial examinations**
 - **Pain, pallor, pulselessness, paresthesias, paralysis**
 - **Fasciotomy**

Burn Injury – Primary Assessment

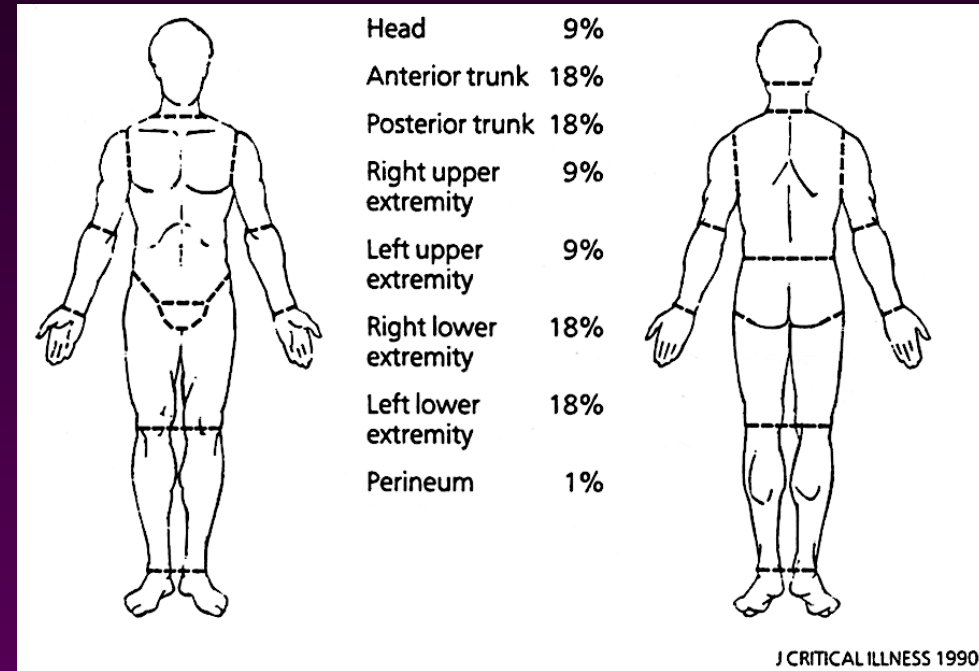
- **Airway/breathing**
 - Upper and lower airway injury
 - Carbon monoxide exposure
 - Bronchoscopy for evaluation
 - Consider early intubation
 - Avoid succinylcholine

Burn Injury – Primary Assessment

- **Circulation**
 - Establish intravenous access
 - Crystalloid resuscitation based upon extent and severity of burns
 - Assess for circumferential injury
 - Evaluate for other injuries

Assessment of Burn Severity

- **First-degree**
 - Erythema and pain
- **Second-degree (partial-thickness)**
 - Red, swollen, blisters, weeping, painful
- **Third-degree (full-thickness)**
 - White, leathery, painless



Rule of Nines

Resuscitation – Burn Shock

- **Primary fluid loss from wound**
- **Secondary nonburn edema**
- **Principles**
 - **Avoid excess fluid resuscitation but maintain organ perfusion**
 - **Replace components of fluids lost as well as volume**
- **Replace blood as needed**

Resuscitation – Burn Shock

- Lactated Ringer's solution – crystalloid of choice
- Various formulae for amount and type of crystalloid and colloid resuscitation
- Parkland formula: $4 \text{ mL/kg} \times \% \text{ of second- and third-degree burn estimates} \times \text{body weight}$ in first 24 hrs; deliver one-half calculated volume in first 8 hrs
- Aim for urine output 0.5-1 ml/kg/hr
- Cautious use of analgesia

Burn Wound Care

- Gently wash and cover prior to transport
- Remove rings, bracelets
- Burn dressings controversial before transfer
- Consultation for specific wound care

Chemical Burns

- **Injury is caused by concentration of agent and duration of exposure**
- **Remove patient from source**
- **Remove clothing**
- **Brush off dry agent**
- **Irrigate copiously with water**

Electrical Injury

- **Entry and exit wounds**
- **Secondary skin burns**
- **Flame burns from clothes**
- **Cardiac arrest**
- **Secondary injury – falls, muscle contraction, etc.**
- **Rhabdomyolysis and compartment syndromes**



Pediatric Considerations

- Same general principles as for adults
- Orotracheal intubation with in-line stabilization
- Greater risk of injury after cricothyrotomy
- Diagnostic peritoneal lavage used less frequently
- ↑ Body surface area/body mass so higher risk of hypothermia

Pediatric Considerations

- Initial crystalloid bolus 20 mL/kg
- Hypotension is late finding of severe hypovolemia
- Blood added when crystalloid infusion >40 mL/kg
- Initial blood transfusion = 10 mL/kg

Pediatric Considerations

- Consider child abuse when discrepancies exist between history and physical examination
 - Laboratory
 - Skull and skeletal radiographs
 - Fundoscopic exam for hemorrhage

Key Points

