Hemodynamic Monitoring in Critical Care Transport

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Overview

- Introduction to Hemodynamic Monitoring
  - How it applies to CCT and Emergency Medicine
  - Patient population and clinical conditions
    - "Sickest of the sick"
- Types of Monitoring
- Systems and Equipment setup

Overview

- Hemodynamic Waveforms
  - Basic interpretation and differentiation
- Vasoactive agents and effects on patient hemodynamics
  - Specific continuous infusions
- Conclusion

Hemodynamic Monitoring

- Vital signs
  - Non-Invasive and Invasive
- Patient condition determines appropriateness
  - Trending specific parameters
  - Hemodynamically Stable
    - Multiple, relatively similar measurements over time
- Comparing Non-invasive and Invasive
  - reference for quality of perfusion and circulation

Non-Invasive Measurements

- Standards:
  - ECG
  - Heart rate/Pulse
  - Pulse Oximeter
  - Blood Pressure
  - Respirations
  - Capnography
  - Temperature
  - (Pain)
- What do the alterations tell you?
  - Each a different facet of the big picture

Invasive Monitoring

- Variation off of the Non-invasive
  - "From within the body"
- Measurements
  - Fluid flow properties
  - Location of port
  - Blood content

Application in CCT

- Most Useful: Arterial Blood Pressure
  - Correlate to non-invasive BP, then cuff can cycle less
  - Works when cuff does not
  - Continuous pressures, allow trending
  - MAP
  - “Pressure” versus “Flow”
  - Balloon pump
- Helpful for titration of high potency vasoactive infusions
  - Nitroglycerin
  - Epinephrine
  - Norepinephrine
  - Esmolol

Concerns in CCT

- Placed by physicians often prior to transport
  - ED to ICU or ICU to ICU
- Potential:
  - Source of bleeding
  - Route of infection
  - Thrombus

Concerns in CCT:

- Apply to a limited patient population
  - Cardiac and surgical
  - Trends more important than a single measure
- Treat the patient, not the monitor
  - Avoid tunnel vision
  - Keep the patient safe
- "Normal" values are based on supine and healthy

Safety

- The more invasive the monitoring, the more critically ill the patient
- Account for everything attached to the patient
  - Transduce the lines even if the values do not make sense
  - Important to secure connections, prevent air embolus, bleeding, movement of catheter

Critical Care Providers

- Provider skill and experience
- Emergency Department initiates critical care
  - Stabilizes the patient
- Emergency Physician:
  - Provides 15% of total critical care
    - Intubation
    - Central Line placement
    - Vasoactive meds
  - First "Intensivist"

Critical Care Providers

- Environment
  - Hospital
  - Transport
- Types
  - Paramedics
  - Nurses
  - Respiratory Therapists
- Credentials
  - CCEMTP, CCRN, CTRN, CFP, CFRN

Transport Considerations

- Location of lines and security of lines?
- Central lines verified by chest X-ray?
  - Internal Jugular
  - Subclavian
  - Swan-Ganz
  - Balloon Pump
- Interpretations?
- CD copies with interpretations with chart

Anatomy

- Heart
  - Atria and Ventricles
  - Coronary Arteries
  - Valves
    - Aortic and Pulmonic
    - Tricuspid (Right) and Mitral (Left)
- Pulmonary Vasculature
- Arteries
- Capillaries
- Veins
- Blood

Shock Comparisions

- Hypovolemic
- Cardiogenic
- Obstructive
- Distributive/Septic

- Hemodynamic monitor may narrow identification and differential diagnosis

Physiology

- Tank: blood vessels
  - Size; what has happened?
- Pump: Heart
  - Is it working? How effective?
- Fluid status: blood and hydration
  - Is the tank full?

Cardiac Cycle

- Ventricular Diastole
  - Isovolumic Relaxation: filling from sources
    - Vena cava, passive filling from pulmonary vessels
    - Closure of pulmonic and aortic valves
- Atrial Systole
  - “Kick” signals from SA to AV
- Ventricular Systole
  - Isometric contraction
  - Greatest myocardial expenditure and oxygen consumption

Stroke Volume

- Volume of blood ejected by the heart with each:
  - 60 to 130ml
- Preload
  - End-diastolic stretch on myocardial muscle fibers
- Afterload
  - Sum of all the forces against which the muscle fibers of both ventricles must work
- Contractility
  - Inotropic state of the myocardium
- Muscular Synchrony
  - Working together?

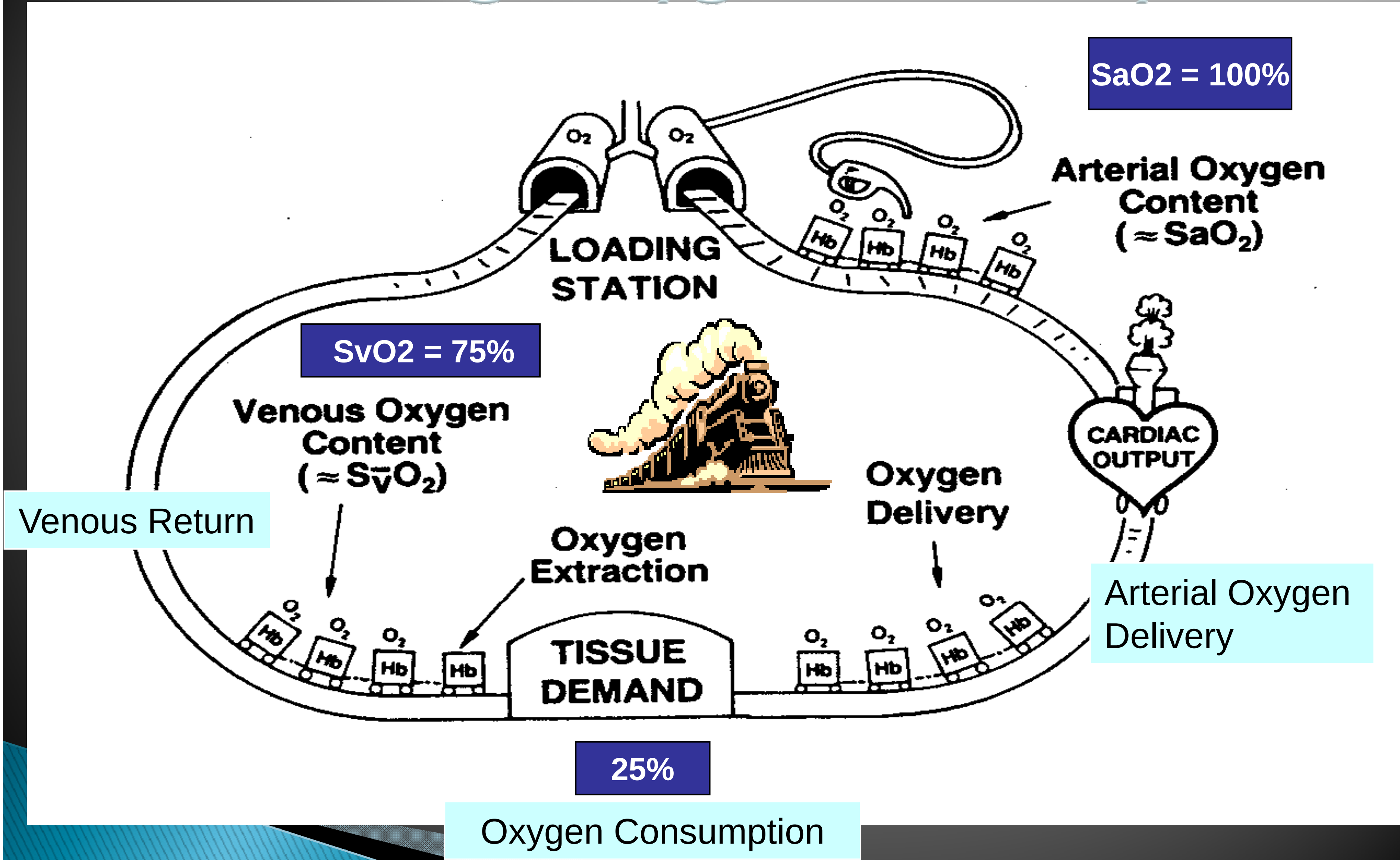
Key Components

- Preload
  - Starling's Law
- Afterload
- Systemic Vascular Resistance

Fick Principle

- Used in calculation of Cardiac Output
- Consumption of Oxygen by the cells
- Rate of consumption
- Freight train concept
- VO2=Oxygen consumption rate

Visualizing Oxygen Delivery



Invasive Monitoring

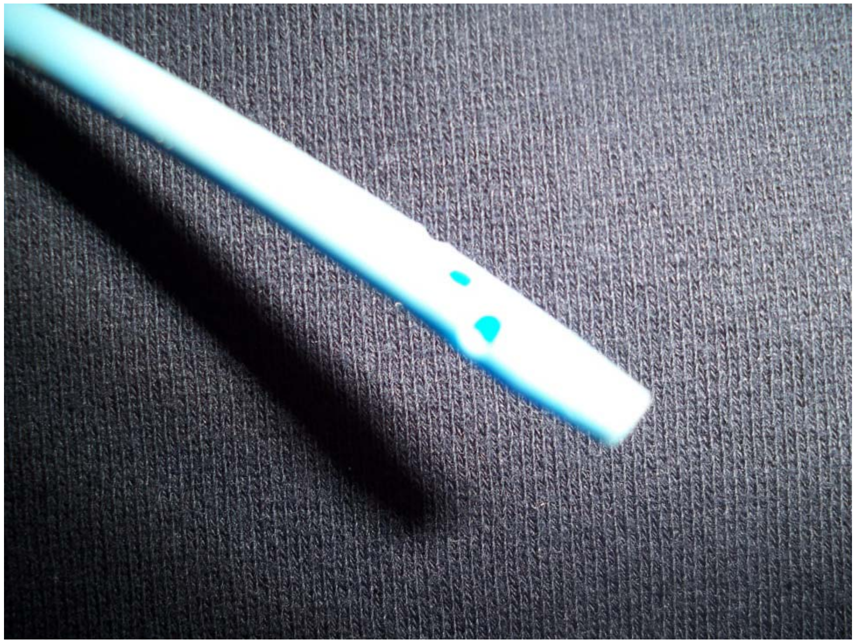
- Arterial Pressure
- Central Venous Pressure
- Pulmonary Artery Pressure
  - Pulmonary Artery Wedge Pressures
  - SWAN GANZ catheters

Additional Hemodynamic Parameters

- Mean Arterial Pressure
- Cardiac Output
- Cardiac Index
- Systemic Vascular Resistance
- Systemic Vascular Resistance Index

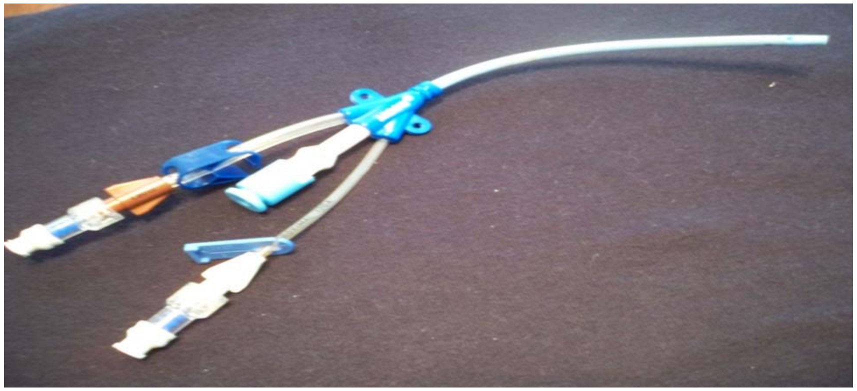
Invasive Monitoring

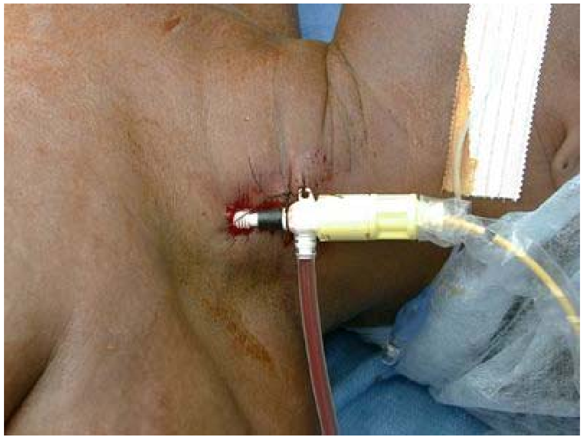
- Principle:
  - Pitot gauge or tube
  - Measures fluid flow velocity



Pressure Measurement Access Points

- Arterial lines
- Central Lines
  - Cordis: the line
  - Swan: inserted through the line
- Other pressures
  - ICP
  - Bladder





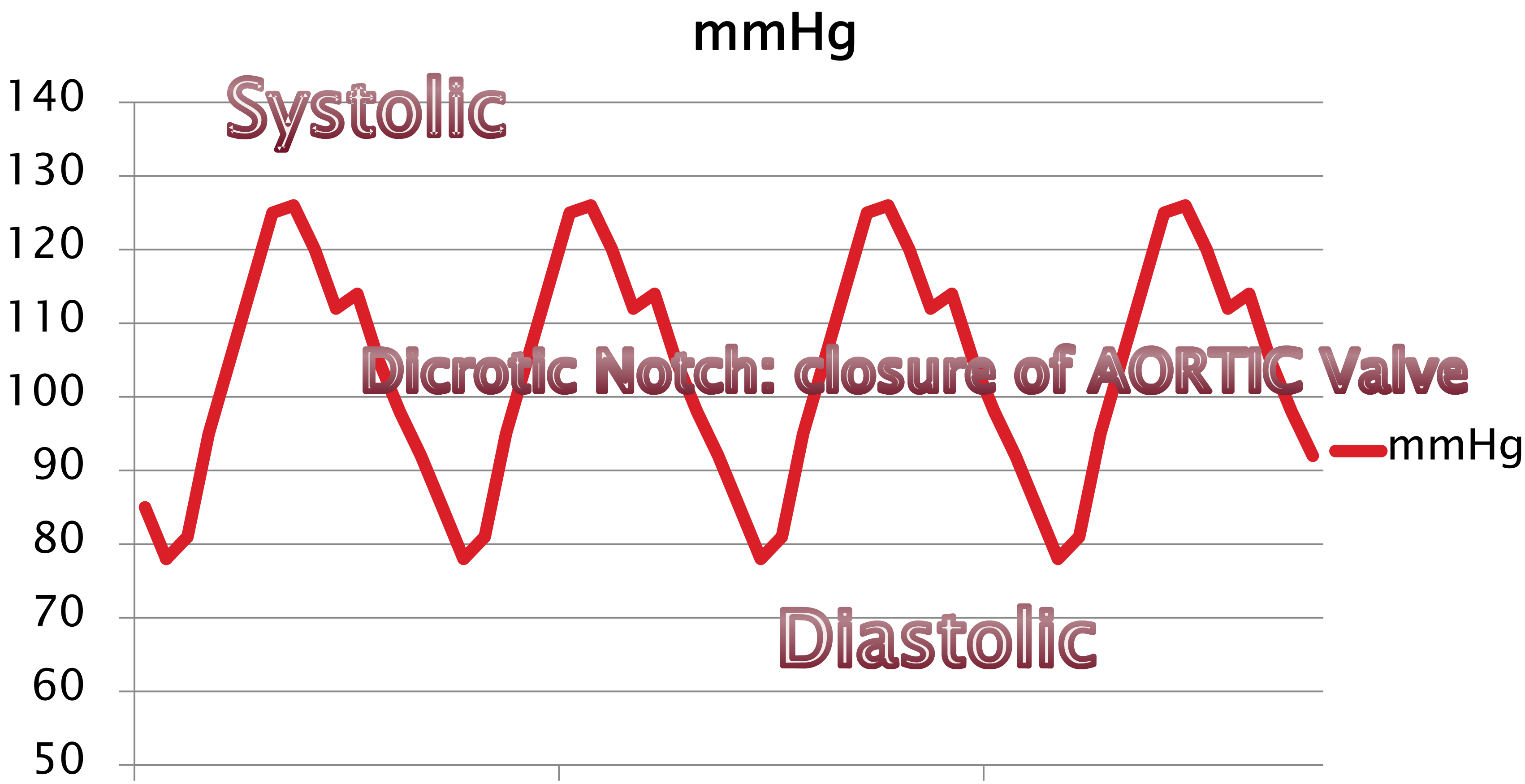
Arterial Pressure Lines

- Continuous Blood Pressure monitoring
  - “Instant” response to vasoactive agents
  - Correlate against the non-invasive blood pressure
    - Match to gauge accuracy
  - Common sites:
    - Radial Artery
    - Brachial artery
    - Femoral artery
  - Different sites may have a gradient difference

Indications: Intra-arterial Monitoring

- Critically ill or injured
- Major surgical procedures
- Major vasopressor or vasodilator support
- Intra-aortic Balloon Pump: IABP
  - Provides pressure trigger
- ICP Monitoring
- Serial Blood gas measurement
- Severe acid-base imbalance

Arterial Pressure Waveform

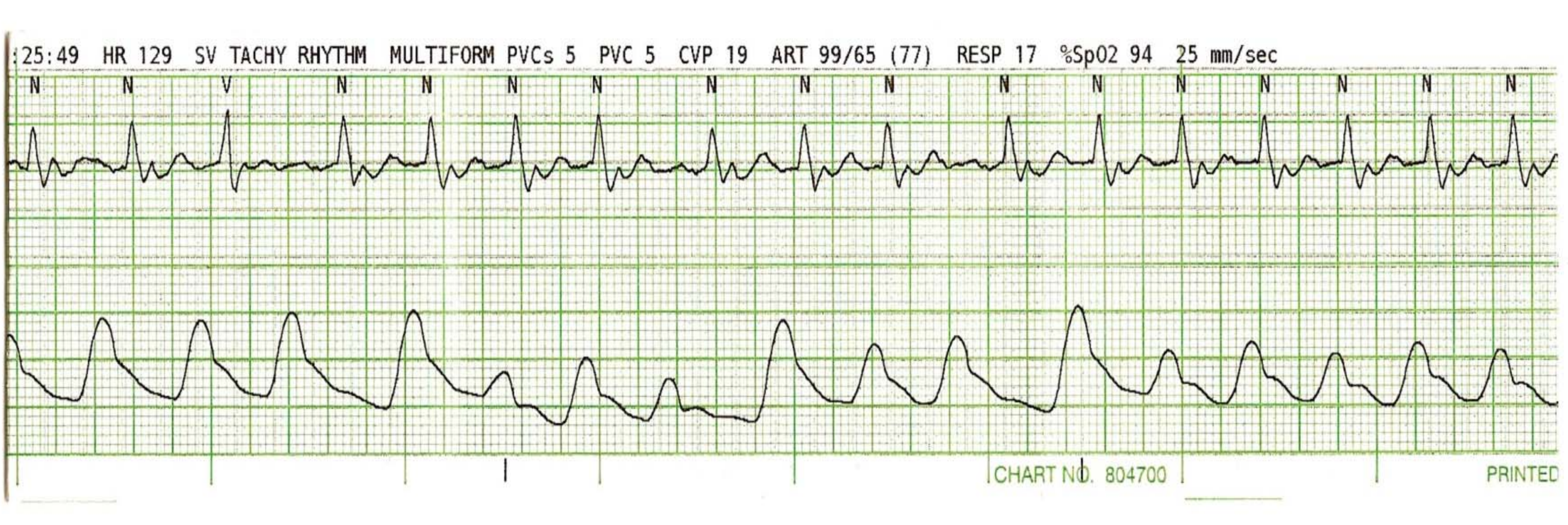


Waveform Qualities

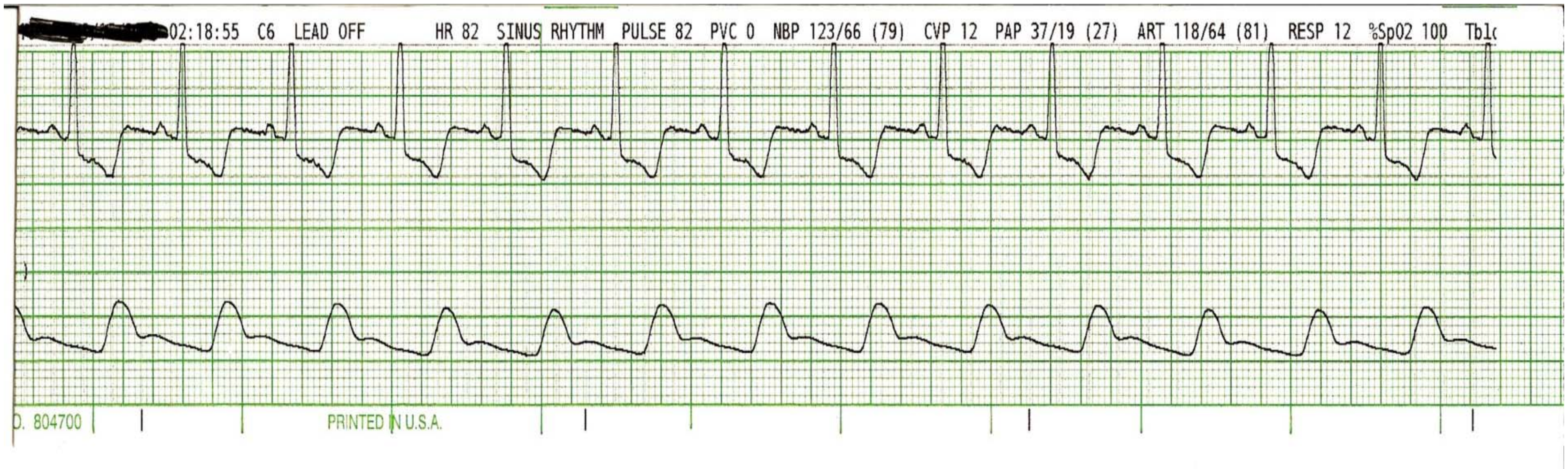
- Crisp: sharp, clear lines, flowing
  - ideal
- Dampened: blunted, smooth
  - Low flow states, air in line
- Hyperdynamic: spikes
  - Pinched, compliant tubing

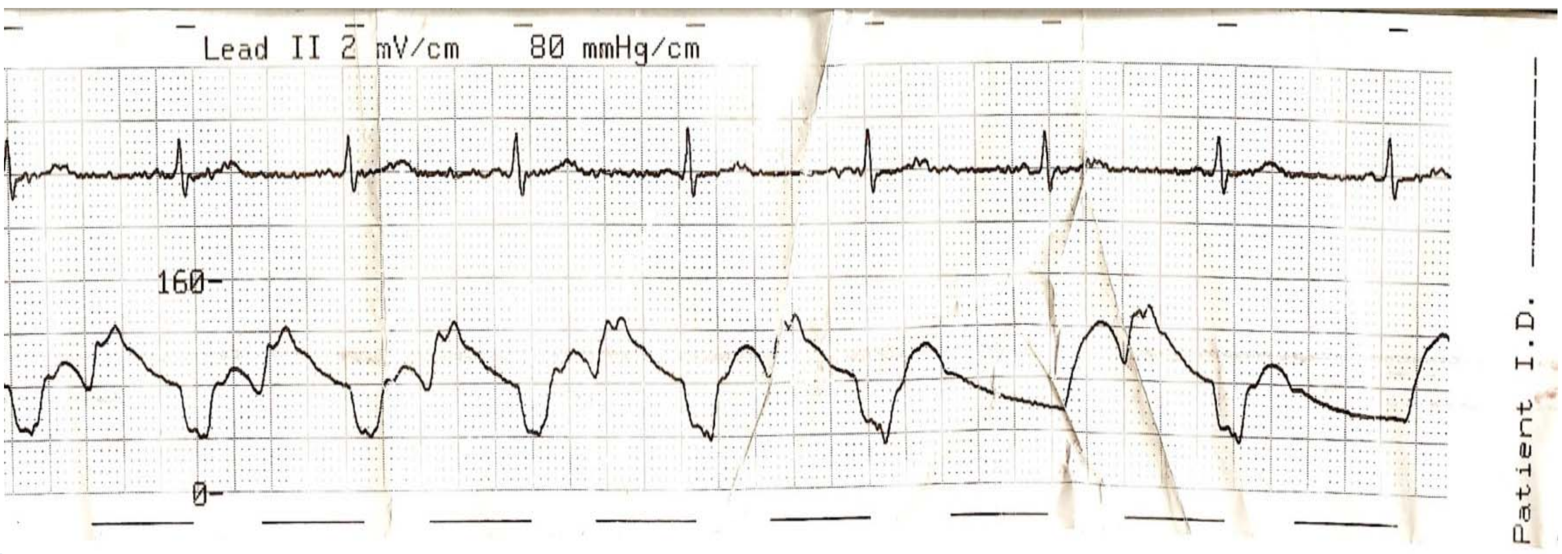
Patient Effects on Arterial Pressures

- Tachycardia
- Hypotension
- Atrial Fibrillation/Irregular Heart rate



Waveforms


[redacted] 02:18:55 C6 LEAD OFF HR 82 SINUS RHYTHM PULSE 82 PVC 0 NBP 123/66 (79) CVP 12 PAP 37/19 (27) ART 118/64 (81) RESP 12 %SpO2 100 Tbl
D. 804700
PRINTED IN U.S.A.


Lead II 2 mV/cm 80 mmHg/cm
160-
0-
Patient I.D.

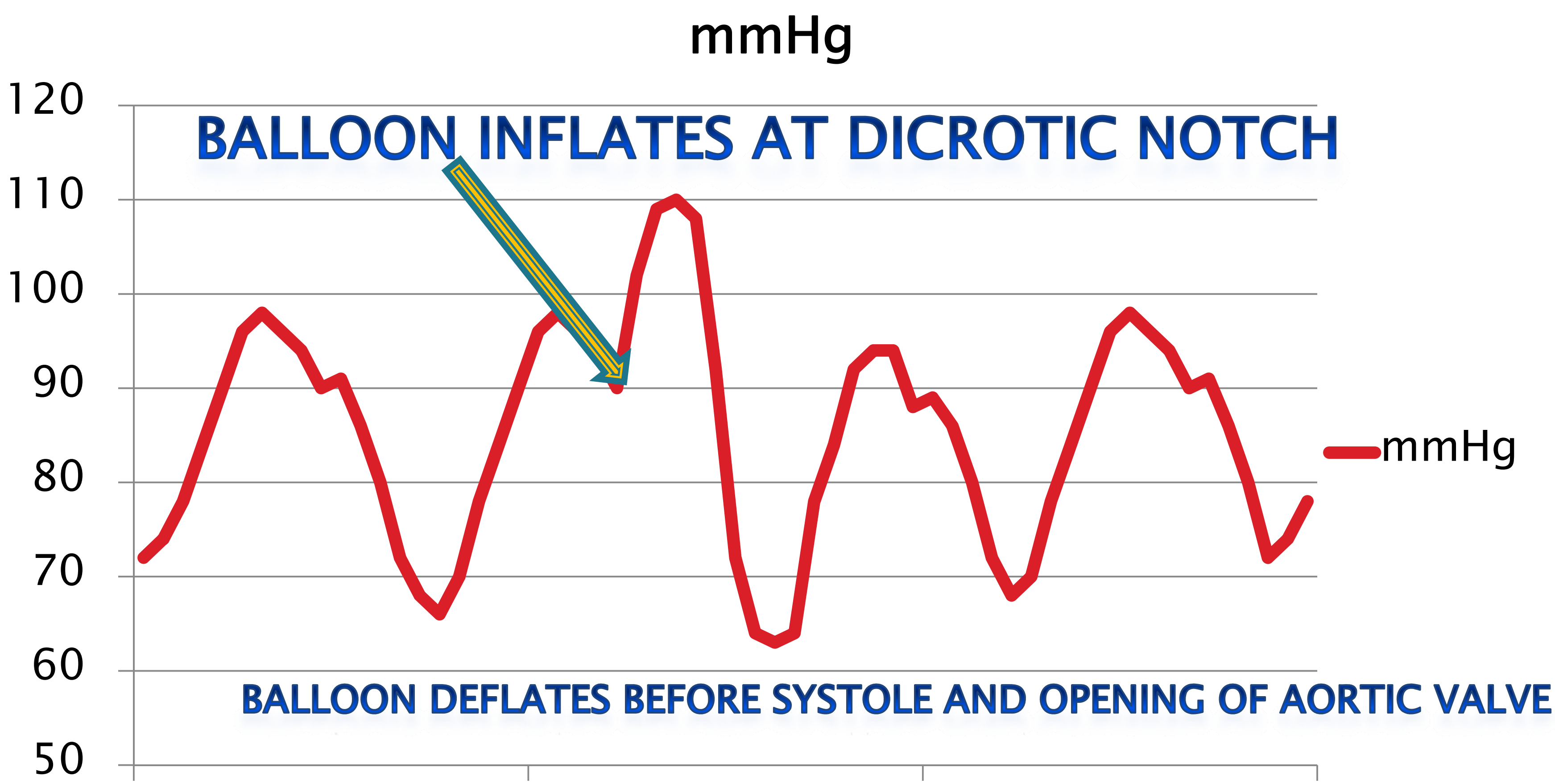
Invasive versus Non-invasive

- Pressure compared to Flow
- Continuous compared to point-in-time
- Positional
  - Noninvasive-higher pressures from a bent arm
  - Invasive-kinked lines

Balloon Pump

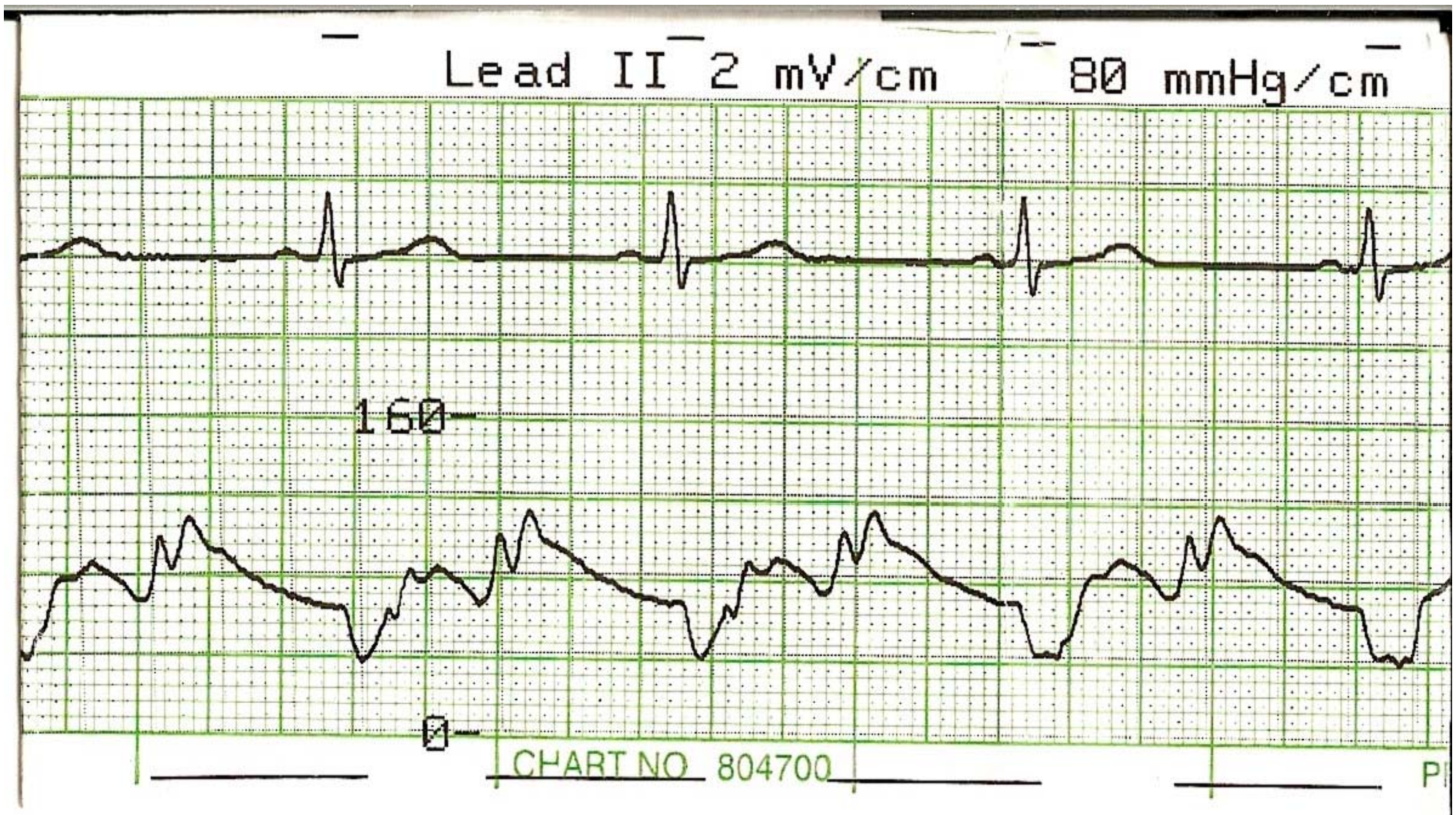
- Every IABP transport will use these skills
- Arterial pressure wave is one of three triggers for balloon sensing
  - ECG, internal, and Pressure (Fiberoptic)
  - Ratios: 1:1, 1:2, 1:3 depending
- Evaluation of waveform
  - Improved coronary perfusion (Augmentation)
  - Afterload Reduction
  - Assisted and Unassisted flows

Balloon Pump Waveform



Balloon Pump Waveforms

Balloon Pump Waveforms



Complications of Arterial Lines

- Ischemia to extremity
  - Especially in IABP
- Hemorrhage
  - Arterial
- Degraded signal in low flow states

Transport Consideration

- Secure transducer to stretcher or tape to patient's chest at phlebostatic axis
- Verify distal, collateral circulation
- Radial artery line
  - Skin color and cap refill, ulnar pulse palpable, place pulse oximeter on finger to monitor
- Femoral (IABP)
  - Dorsal pedis and posterior tibial pulses, foot warm to touch

Mean Arterial Pressure

- CO, SVR, and CVP factors
- Formula:
  - Systolic BP+ (2 x Diastolic BP)
- Formula 2
  - (CO x SVR)+CVP
    - http://www.cvphysiology.com/Blood%20Pressure/BP006.htm
- Goal or trend:65mmHg

Central Line Placement

- Large, definitive line placed under ultrasound
  - May be large bore, single or multi-lumen
- Catheter placed in large "central vein", near entrance to right atrium
- Benefits: central lines better for rapid infusions and less risk for highly concentrated medication
- Risks: placement increases risk for infection, bleeding, and pneumothorax

Indications for Central Line

- Monitoring CVP in hypovolemia and shock
- Infusion of caustic drugs
- TPN
- Aspiration of air emboli
- Insertion of transvenous pacing leads
- Venous access in patients with poor peripheral veins.
- Long term placement/infusions at home
  - PICC, Portacaths, etc.
    - Source: www.healthsystem.virginia.edu/anesthesiology-elective/cardiac/indications.cfm

Central Venous Pressure Monitoring

- Measures venous return to right atrium
  - Right atrial pressures
  - Right ventricular end-diastolic pressure
    - Correlates to the left end-diastole in healthy individuals
- Mean number; calculated from high and lows
  - "Normal" is 0 to 8mmHg
  - Critically ill often need to be higher
- Used to guide fluid resuscitation

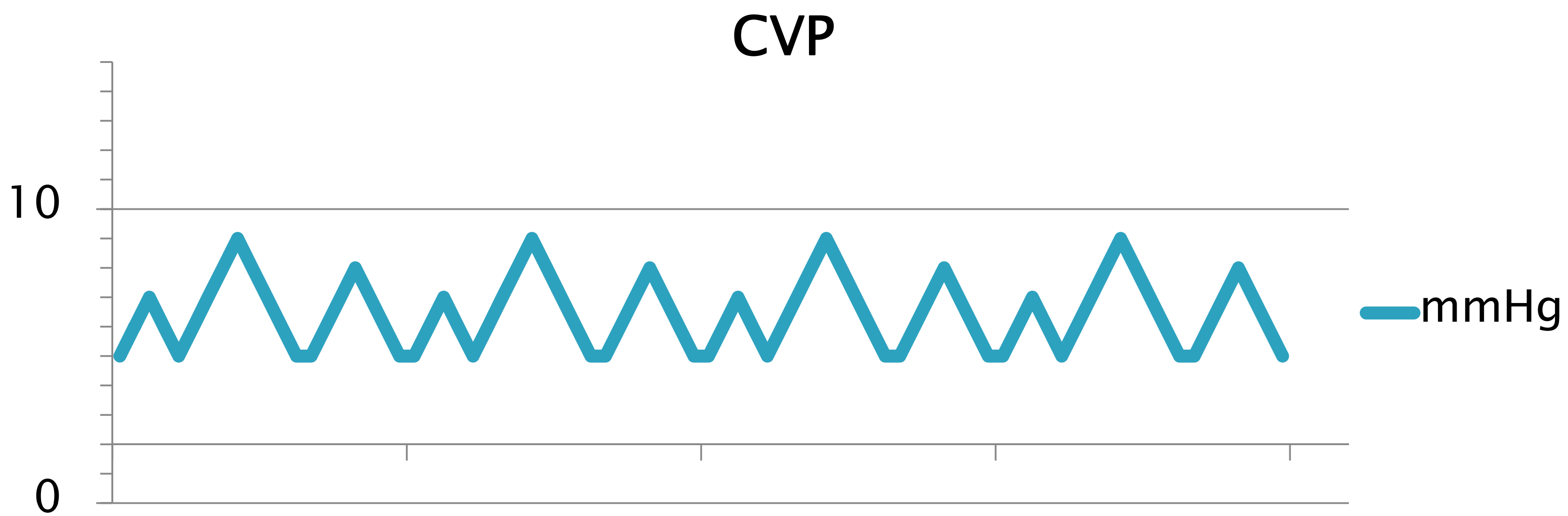
Clinical Significance

- Elevated CVP
  - Fluid Overload
  - Poor right ventricular function (stiff, non-compliant
- Decreased CVP
  - Dehydration
  - Poor peripheral vascular tone
- In CCT is least important of invasive monitors
  - Resource dependent
  - Other clinical signs will guide you

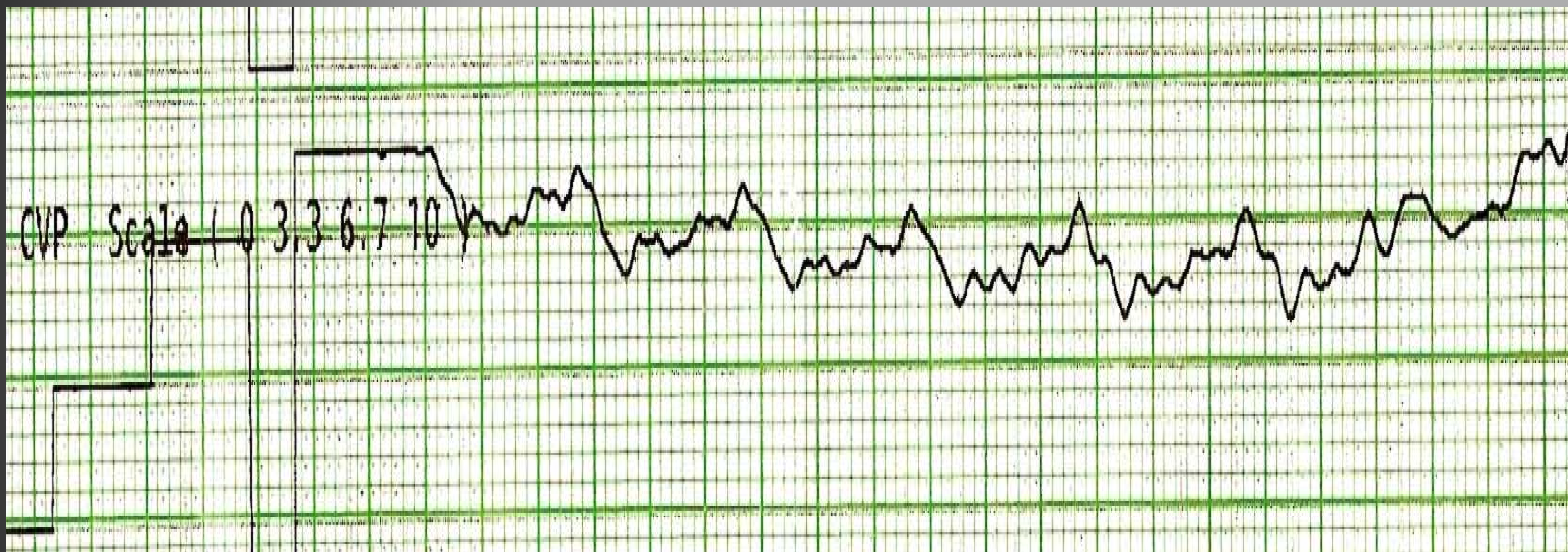
CVP Limitations

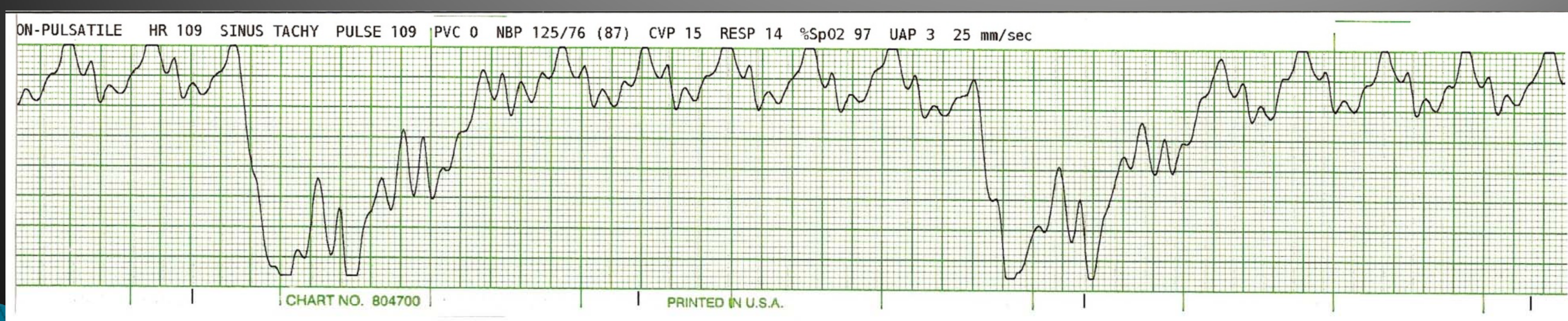
- Evaluate as a trend
- Systemic vasoconstriction can present a CVP elevated despite hypovolemia
- Mechanical ventilation:
  - Positive pressure ventilation increases thoracic and central venous pressures
  - Measure at end-expiration
- Spontaneous respirations
  - CVP Decreases slightly

Waveform

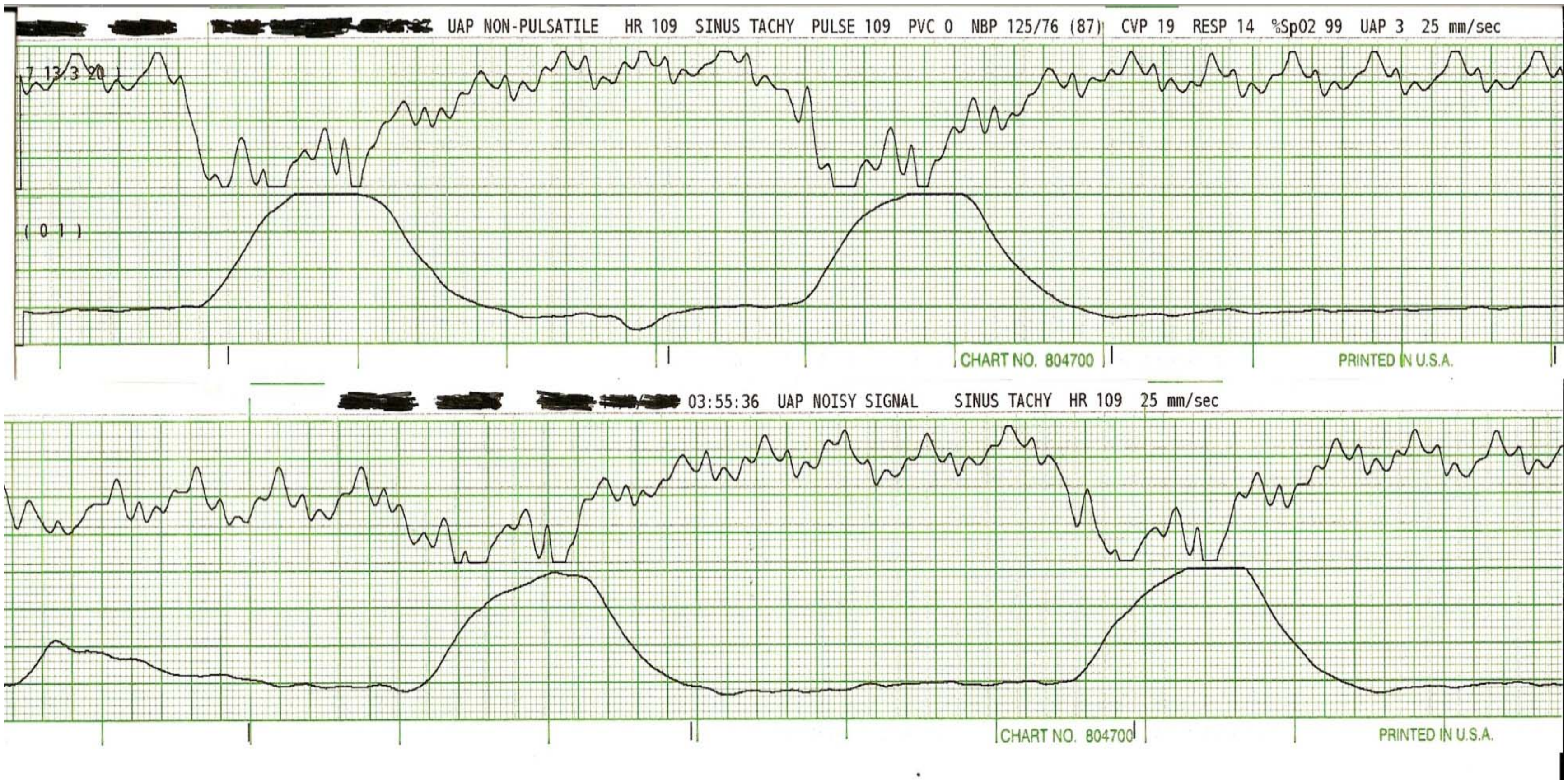


CVP waveform





CVP and Respirations

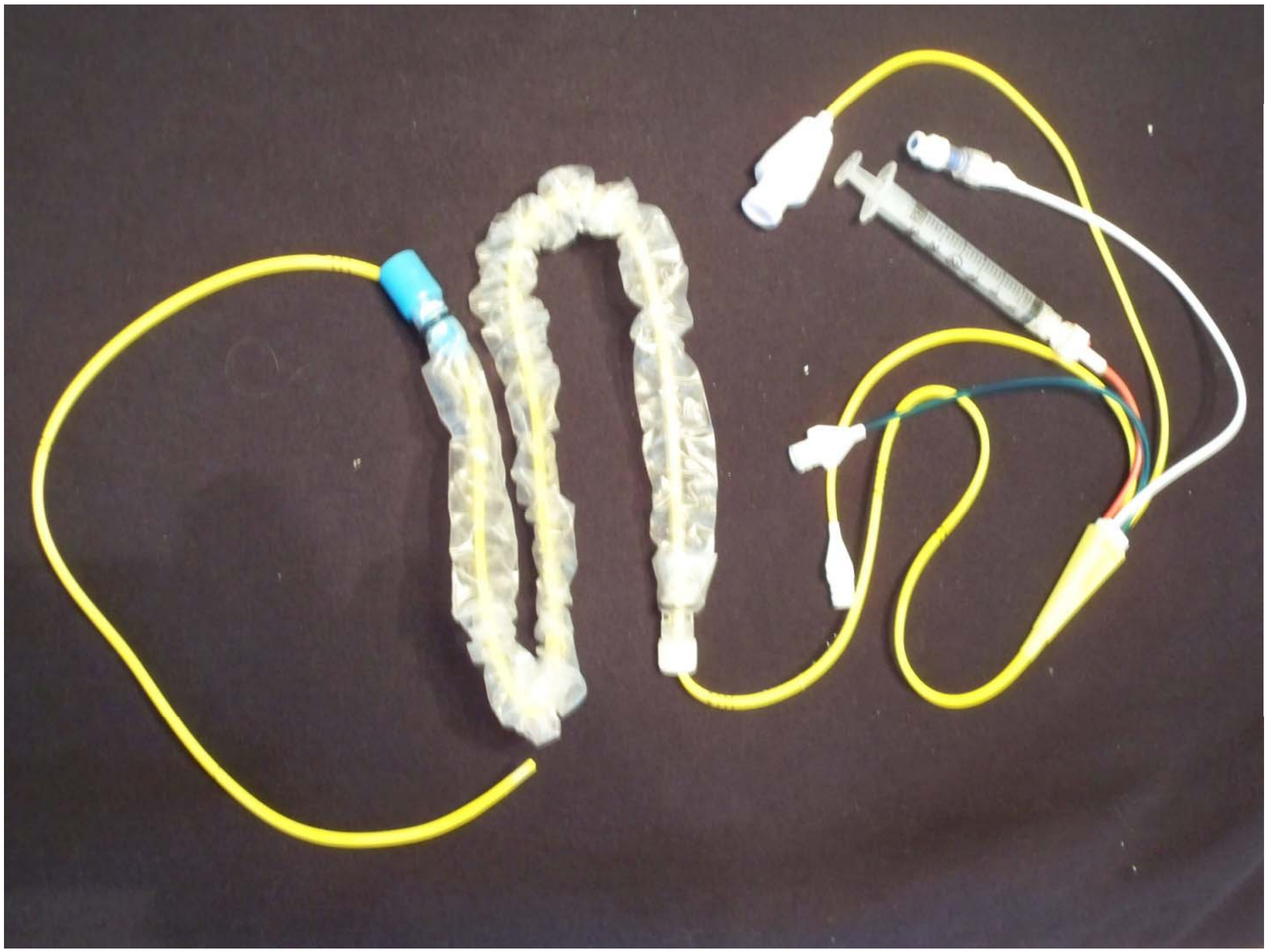


Spontaneous respirations

Complications of Central Lines

- Hemorrhage
- Vascular damage/erosion
- Arrhythmias
  - Catheter tickles the heart
- Infection: time in place
- Thrombo-embolic
  - Air embolus or thrombus of clot
- Pneumothorax

SWAN Ganz Pulmonary Artery Diagnostic Catheter

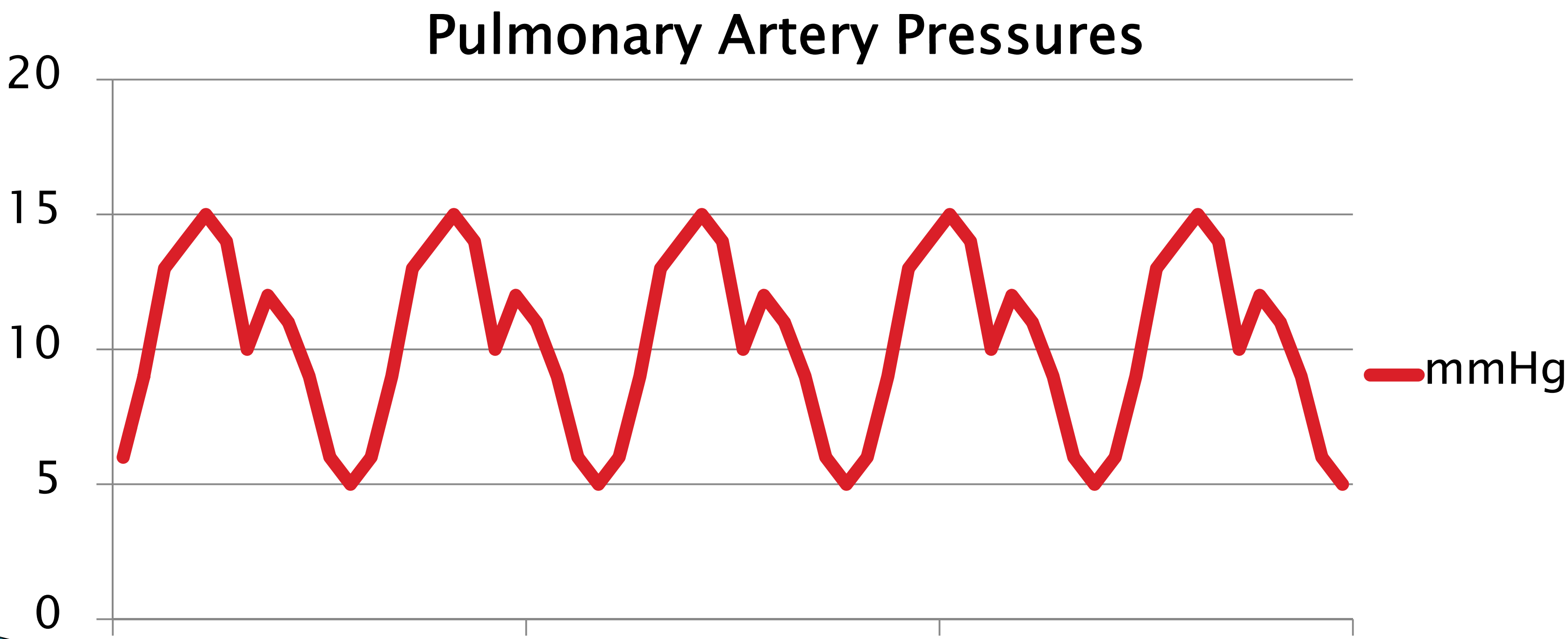


Pulmonary Artery Pressures

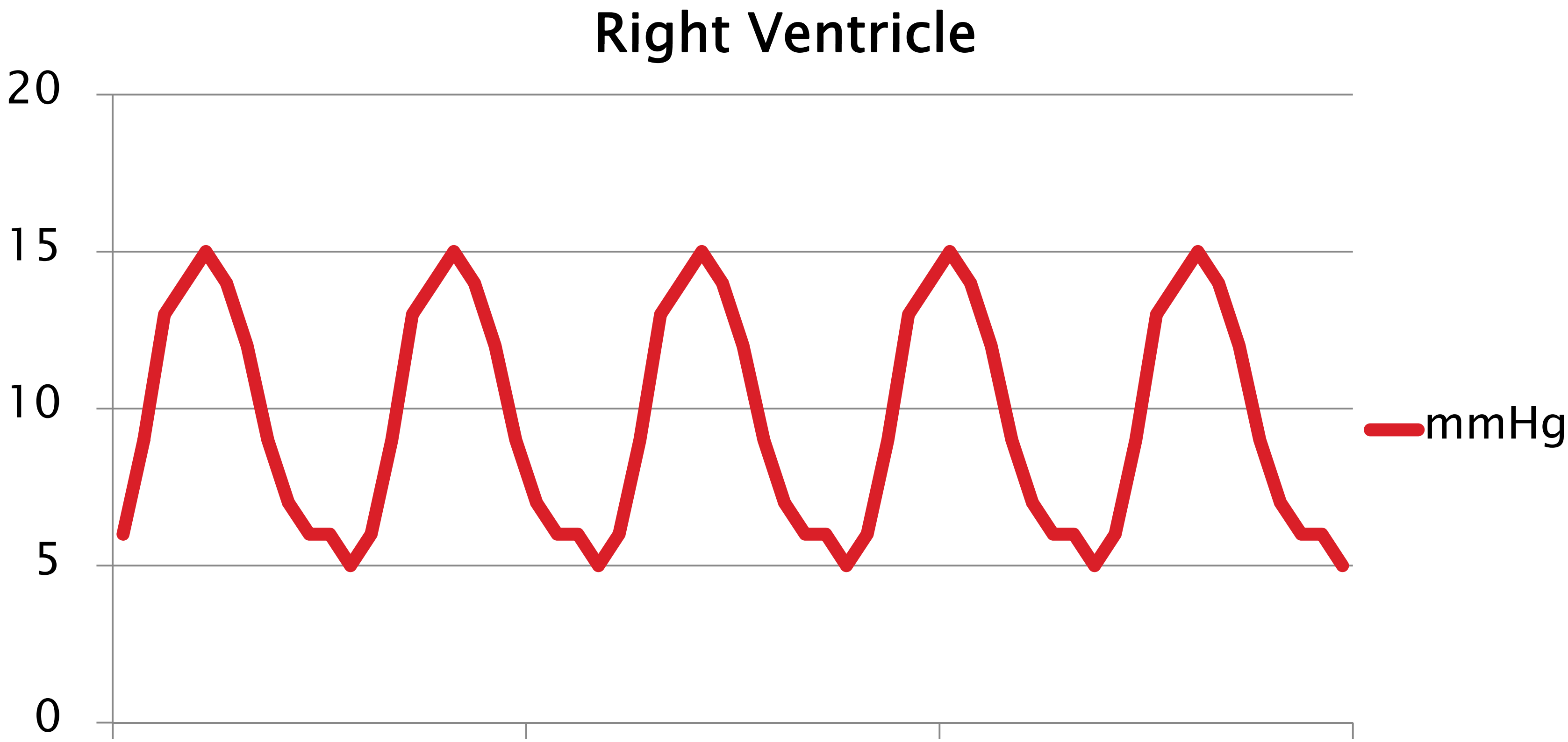
- Normal measures:
  - 15 to 25 systolic
  - 6 to 12 diastolic (CVP should never be lower)
- Indicator of left ventricular function and pulmonary vascular status
  - Increased in cases of COPD, ARDS, Sepsis,shock
  - Pulmonary hypertension occurring secondary to decreased left heart function
- CVP should never be lower than PAD

Pulmonary Artery Waveform

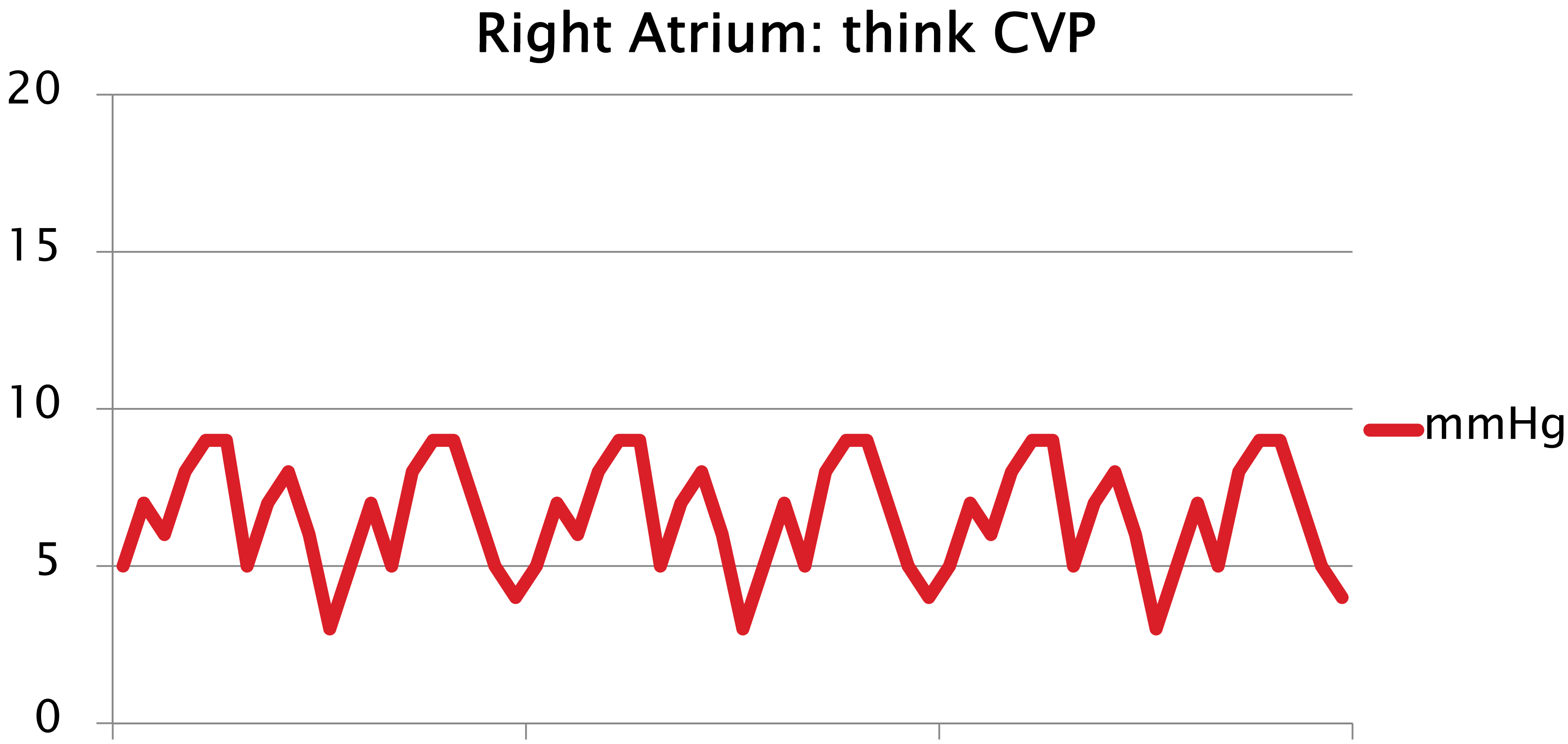
Note: “mitten” shape appearance, indicating PA placement



Swan Ganz Tip migration



Swan Ganz Tip migration



Pulmonary Artery Wedge Pressures

- Wedging is temporarily “Blocking” of the Pulmonary Artery
- “Looks” through the vasculature to the left atrium and the left ventricular end-diastolic pressure
  - Aortic valve is closed, just prior to opening
- In absence of pulmonary vascular disease, the pulmonary artery diastolic pressure equates to left atrial pressure

Pulmonary Artery Wedge Pressure

- Normal 4–12 mmHg
- Balloon inflated with 1.25 ml air, for less than 15 seconds

Inadvertent WEDGE is an EMERGENCY!

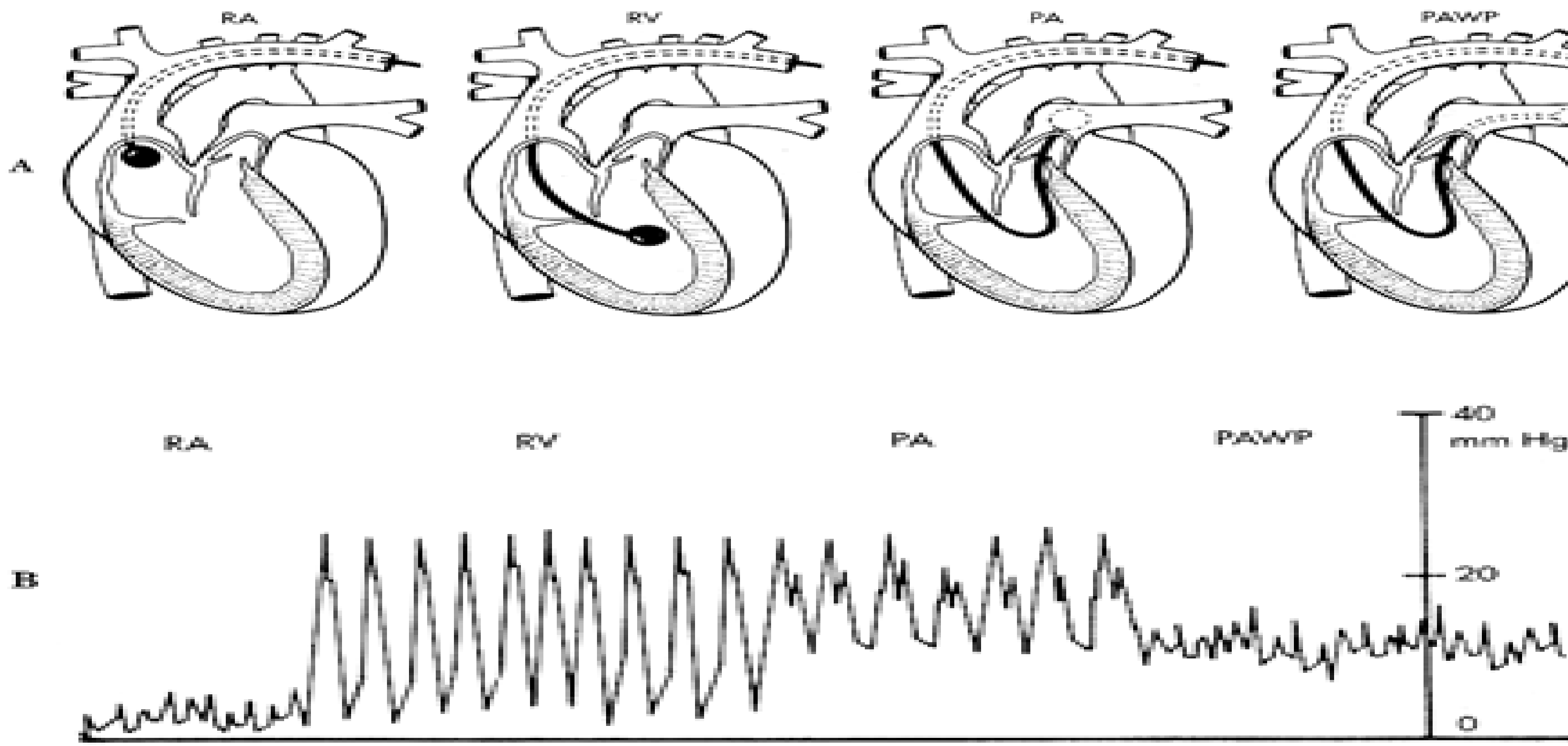
Inadvertent Wedge

- Recognize: the previous wave has changed
- Assess: are there any changes in patient condition?
  - All ABCs with ECG, SaO2, and EtCO2 if available
- Noninvasive: turn or move patient
  - Lift up head slightly, turn neck
- Contact medical control of receiving hospital
  - May advise withdrawing catheter

PA Wedge Dangers

- Creates pulmonary embolism/ischemic injury
  - Mechanical occlusion
- Over-inflation of balloon puts pressure on vessels and damages tissue
- Balloon Rupture

SwanGanz catheter waves on advancement



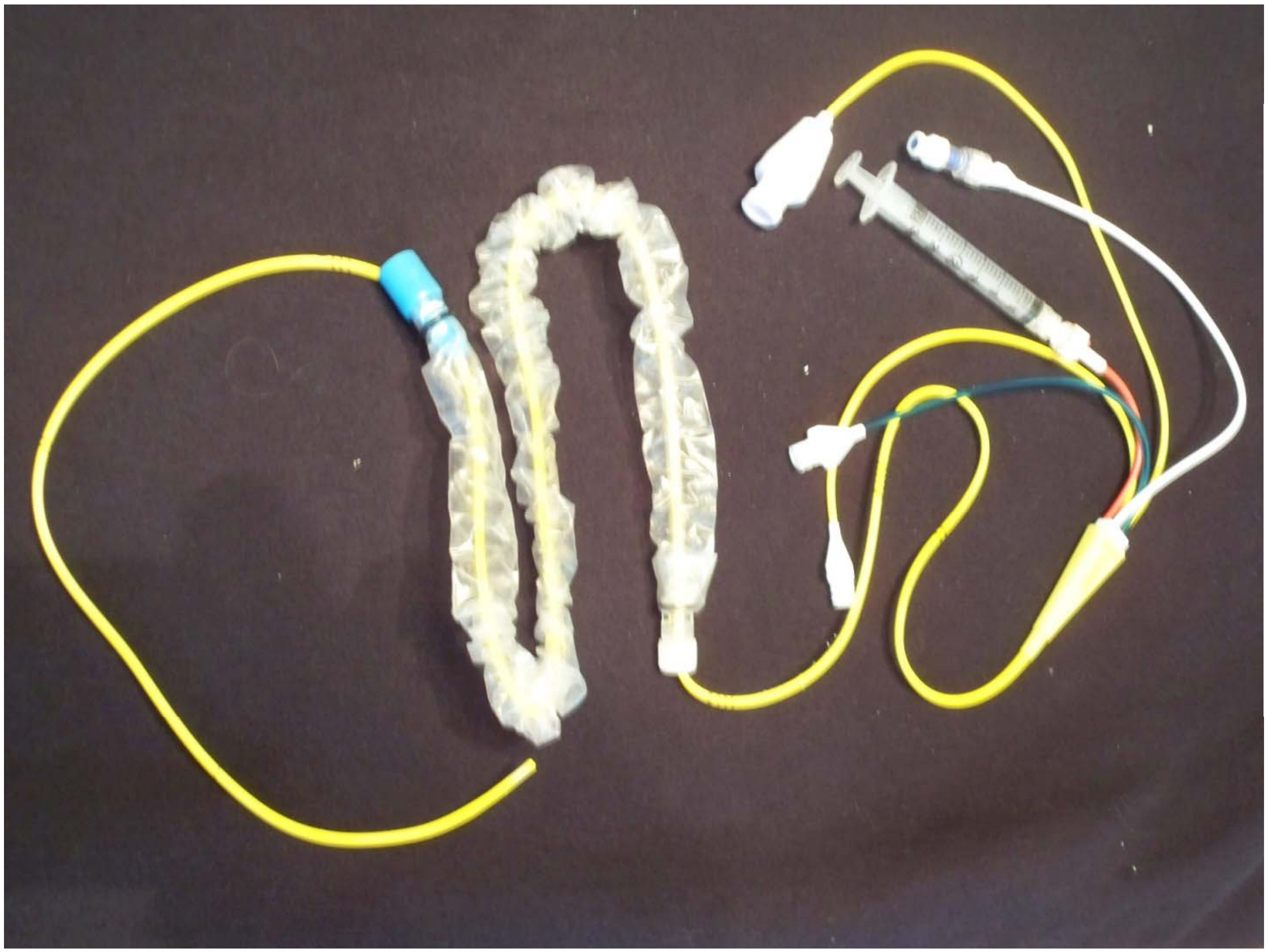
Swan Ganz VIP catheter

- Thermodilution catheter
  - Inject temperature measured fluid and calculate CO, CI, SVR, and SVRI off of values
- Floated through a large bore (Cordis) central line
  - Subclavian or Internal Jugular (RIJ most common)
- Tip sits in pulmonary artery

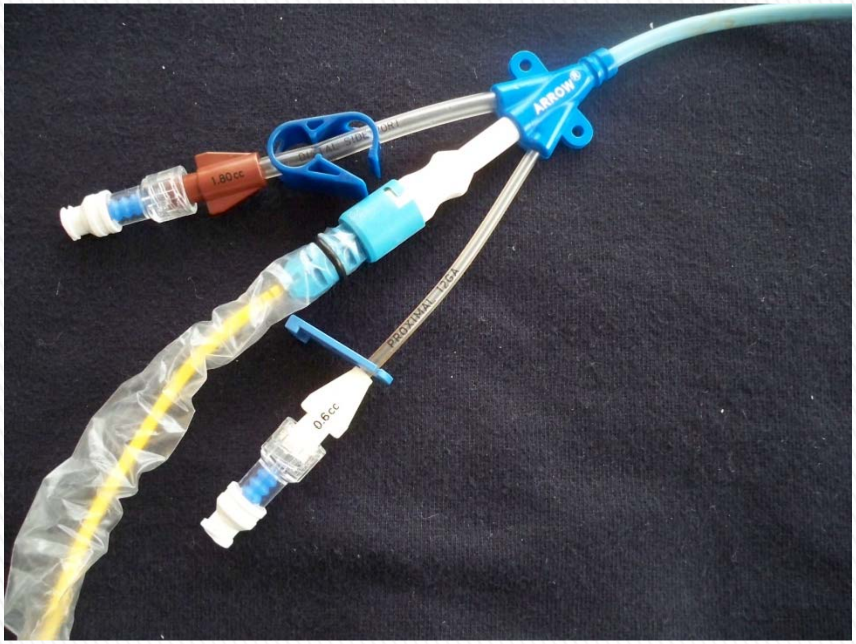
Swan-Ganz VIP Catheter

- Yellow, 110cm in length, marked in 10cm increments
- Multiple-pressure measure points
  - CVP
  - Right atrial and ventricular pressures
  - Pulmonary Artery Pressures
  - Invasive body Temperature
- Four to Five Lumens
- Thermistor for measuring temperature

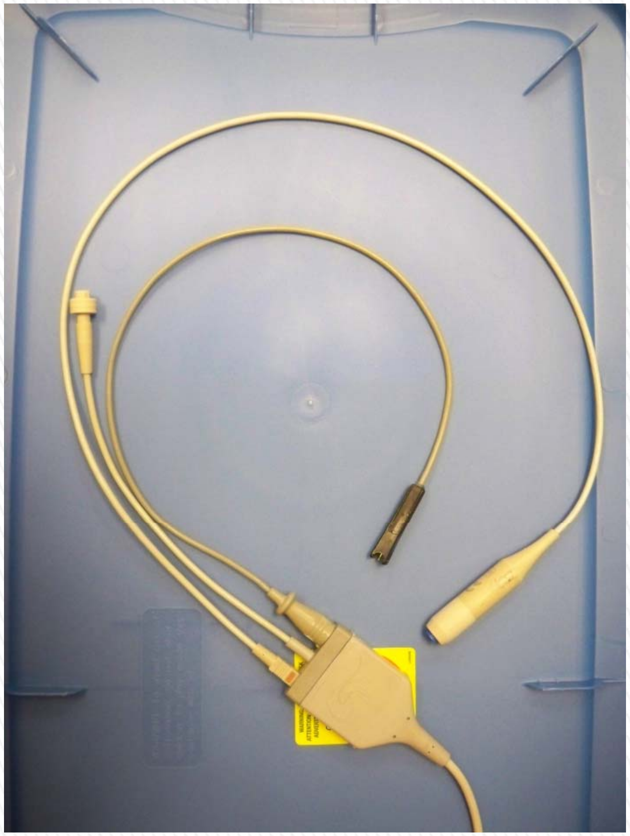
Tour of the SWAN Ganz



Tour of the Swan Ganz

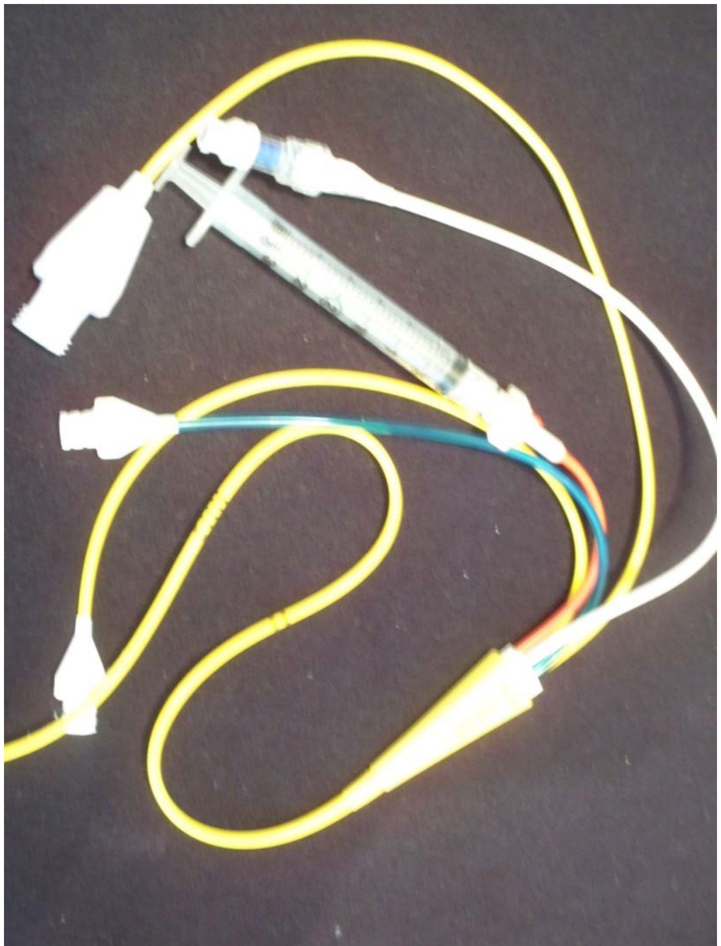


Swan through Cordis

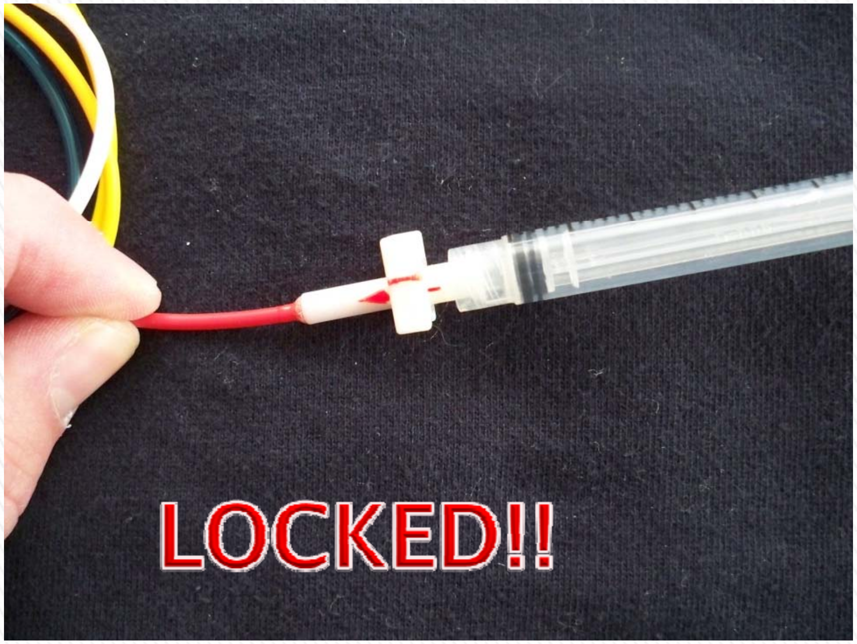


Monitor cable for Swan

Tour of the Swan Ganz

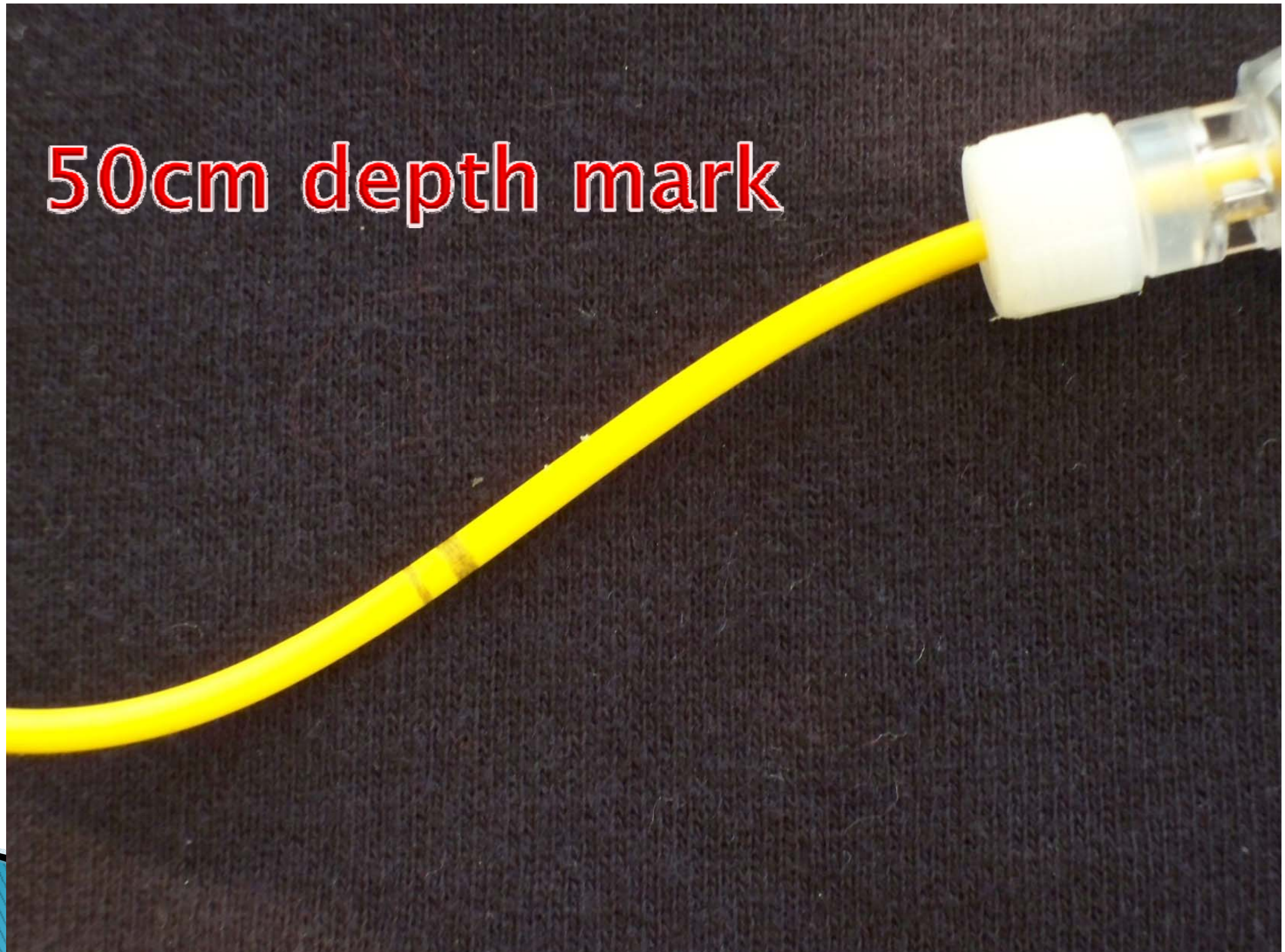


Swan Balloon port

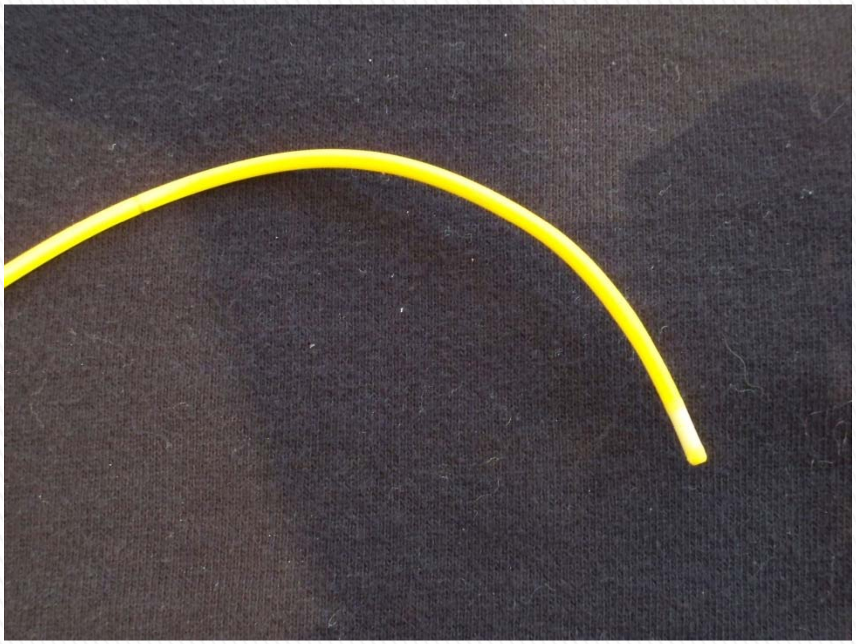


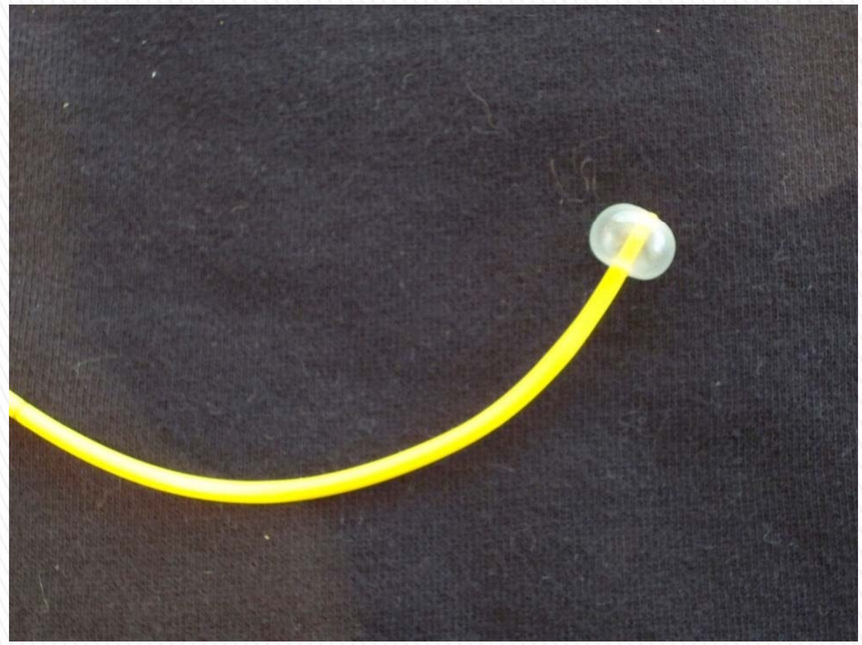
Syringe lock off: in line

Depth Measurement



Wedge balloon





Balloon deflated

Balloon Inflated

Transport the Swan Ganz

- Recognition
- Note depth and secure so it does not move or migrate deeper
- Transduce: establish a have a waveform
- Make sure it is NOT in “wedge”
  - Pull syringe to vacuum and lock off

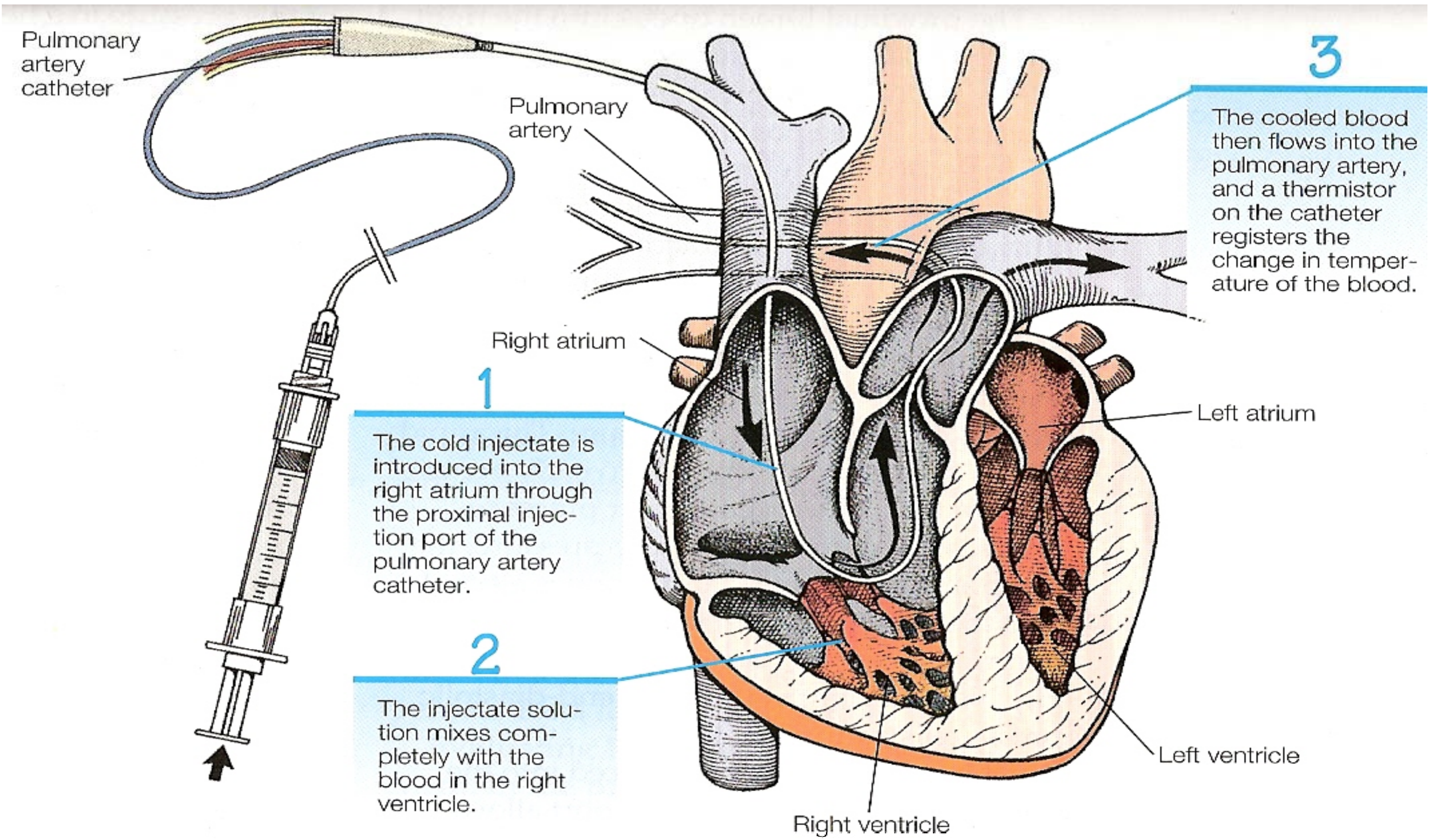
Hazards of the Swan Ganz

- Irritates the heart
- Too deep or balloon inflated too long:
  - Pulmonary embolism
- Obstruction and/or irritation of smaller blood vessels

Cardiac Output

- Amount of blood ejected from the ventricle in a minute: 4 to 8 L
- Heart Rate X Stroke Volume
- With Swan Ganz determined CO through ***Thermo-dilution***
  - Known volume of solution at known temperature
  - Injected rapid bolus through CVP port of catheter
  - “Downstream” temperature measured and the time difference calculation performed provides the cardiac output
- Cardiac Index: adjusts CO for BSI

Determining Cardiac Output: Thermodilution Method



Cardiac Output

- Non-invasive methods
  - Vigileo Flo-trac system
    - Uses the arterial pressure waveform
  - Cheetah NICOM
    - Skin scensors
- Echocardiograph
  - Creates visual image of flow
  - Bedside, in hospital

Cardiac Output

- USCOM (Ultrasound Cardiac Output Monitor)
- Continuous Doppler Wave
- Non-invasive
- Literature NOT fully supporting device, although some correlation exists

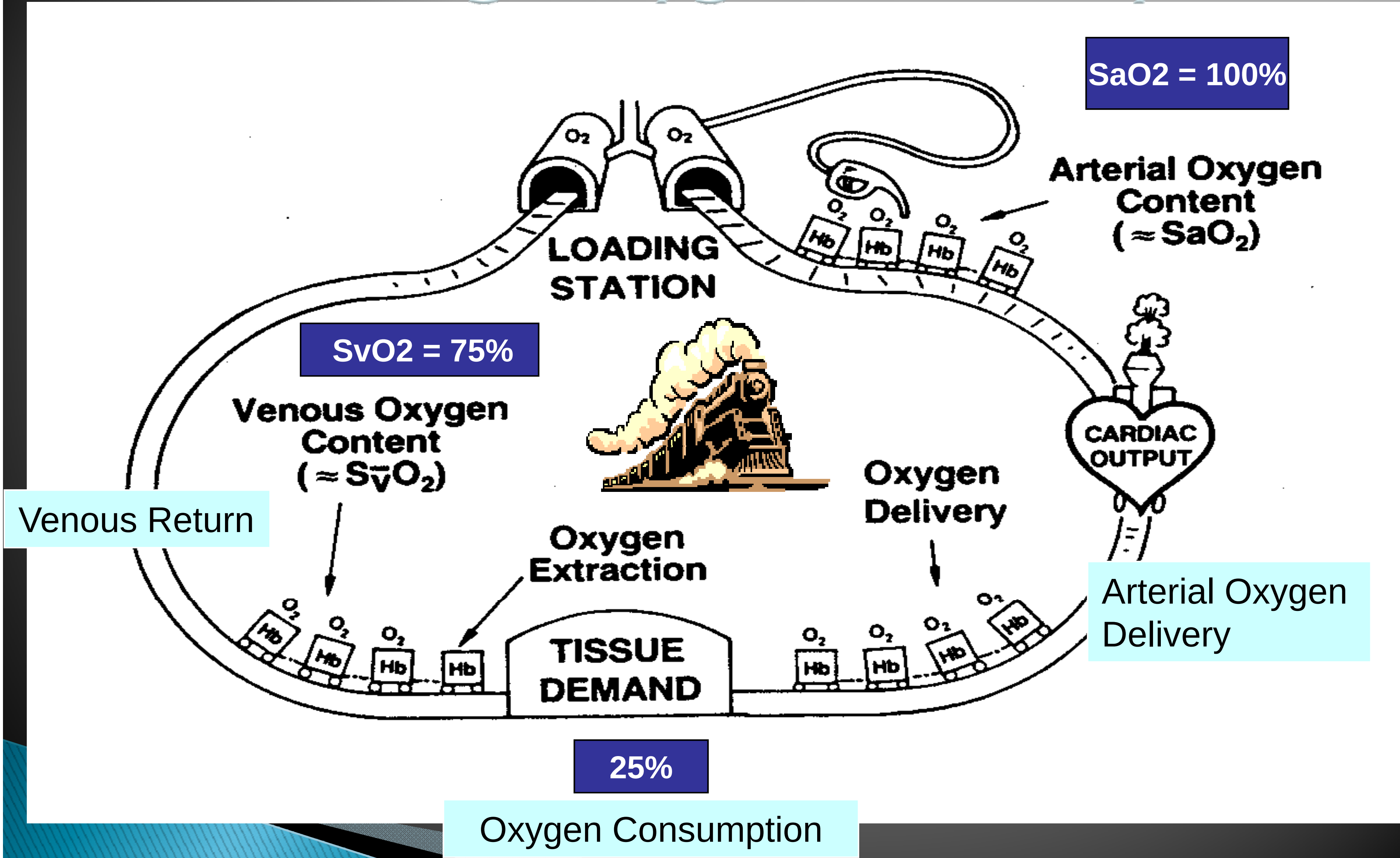
Systemic Vascular Resistance

- Cannot be measured directly
- Computed:
  - MAP minus CVP/Cardiac Output times 80
- Use of Swan or Vigileo monitor
- Normal: 770 to 1500 dynes/sec/cm^{-5}
- SVR Index: evaluates SVR as compared to BSI

Venous Oxygen Saturation

- Obtain from PA catheter
- Assesses tissue oxygenation
  - Reflects how well tissue is "taking up" oxygen
- "Normal" is 75%
  - SaO_2 is 96 to 99%
  - Body uses about 25% of the O_2 available
- Increased O_2 consumption: pain, agitation, fever, vasopressor medications
- Decreased O_2 consumption: hypothermia, assisted ventilations, narcotics

Visualizing Oxygen Delivery



Pressure line setup

Components of Pressure System

- Monitor
- Low Compliance Tubing
  - More rigid for reducing interference
- Transducer: interfaces the tubing with the monitor
- Fast flush
- Stopcock
- Pressure bag and fluid

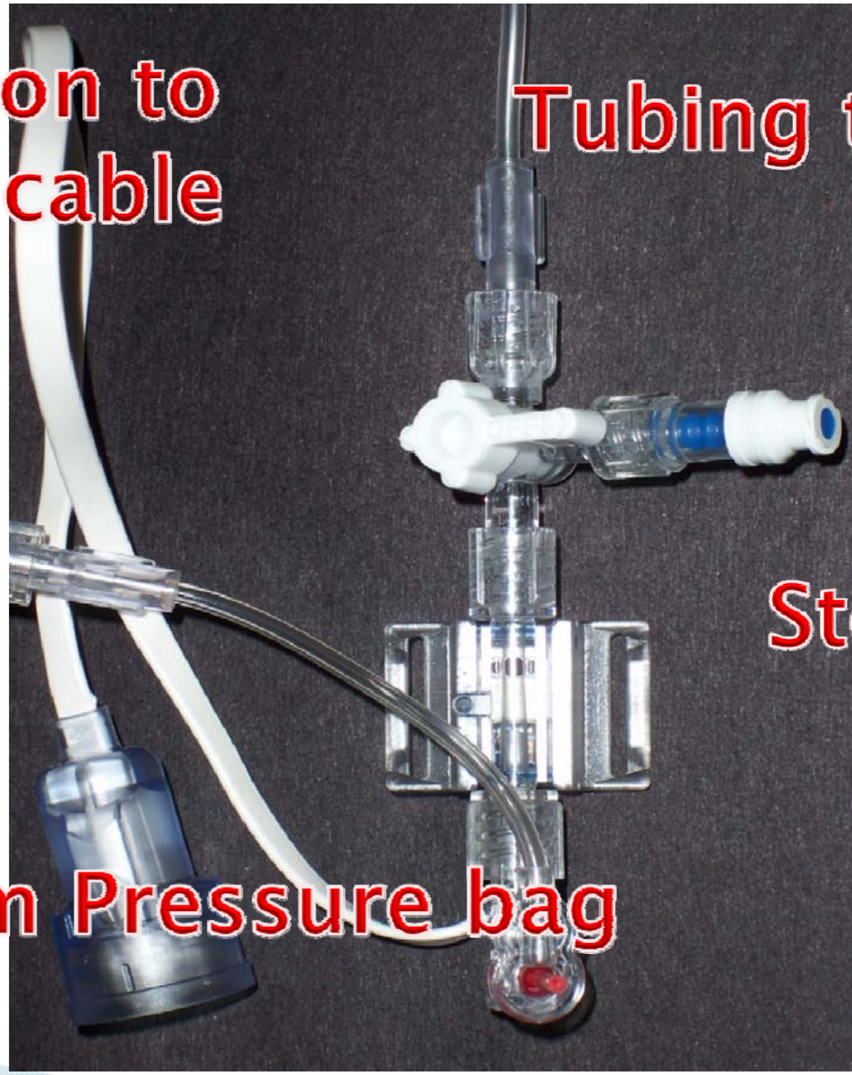
Components of Pressure System

- Monitor:
  - Cable adapted to transducer
  - Transport monitors include Zoll CCT, Lifepak 12, Propaq, Phillips
  - Must be configured; may have specific cables by manufacturer
  - Should be able to label waverform

Transducer

- "A substance or device, such as a piezoelectric crystal, microphone, or photoelectric cell, that converts input energy of one form into output energy of another."
  - *From Latin trānsdūcere, to transfer : trāns-, trans- + dūcere, to lead.*
- From Answers.com
  - http://www.answers.com/topic/transducer

Transducer


Connection to
monitor/cable
Tubing to Patient
Stopcock
Tubing from Pressure bag

Setup

- Tubing
- Isotonic Fluid:
  - Normal Saline
- Pressure bag for fluid size
  - 500ml usual
  - Trauma infusers usually for 1000ml
- Site appropriate
  - Arterial, CVP, ICP, etc.

Set up

- Tubing flushed: observe flush out of each port
- Pressure bag inflated to 300mmHg
  - Applies continuous pressure 3 to 6 microdrops per minute
- Leveled Phlebostatic Axis
- Labeled in Monitor and Connected
- Zero monitor

Tubing


Hospira, Inc.,
Lake Forest, IL 60045 USA
© Hospira 2004
Made in Costa Rica
Hospira
TRANSPAC® IV
MONITORING KIT


ARTERIAL
ARTERIAL
RA/CVP
RA/CVP
PA
PA
LAP
LAP

Differences

- Standard Tubing
  - Flexible
  - Ports may "Y" in or stopcock
  - Bore size differs with make, purpose
    - Blood tubing
  - Gravity flushes
- Monitor Tubing
  - Stiffer to touch
  - "In line" requirements
    - May use stopcocks
  - Small bore
  - Transducer has a pig tail for flushing
  - Setup requires diligent flushing of air

Pressure Bag and Flush

- Inflate to 300mmHg
- Most bags us a green marking or visible indicator
- Applies a constant pressure to infuse 3 to 6 minidrops per minute
- Essential to reduce risk for clot

- Flush by pulling pigtail

Phlebostatic Axis

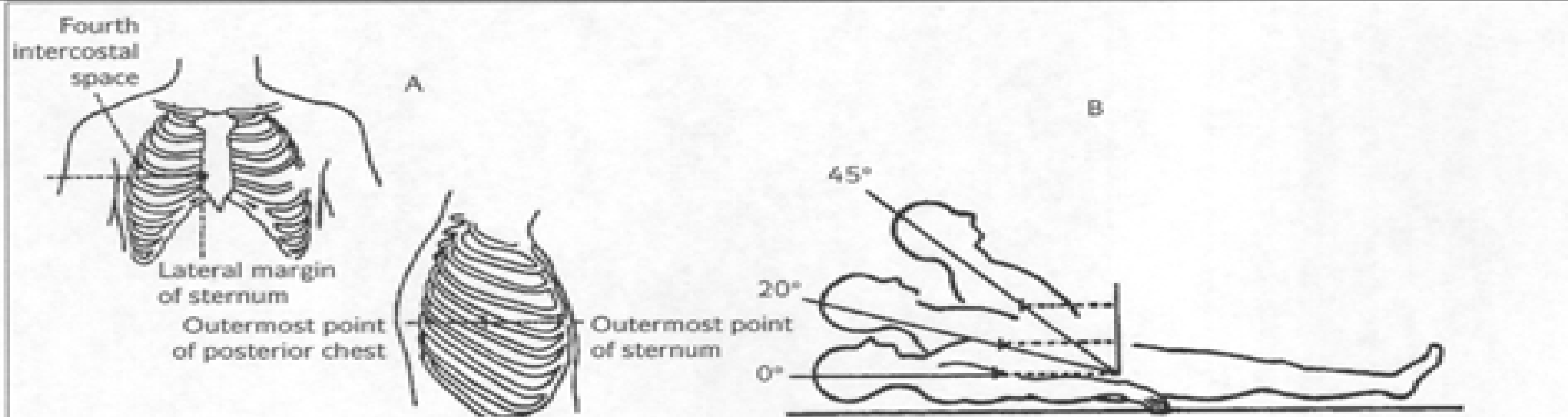
- Entrance Right Atrium
  - Location of CVP catheter
- Midaxillary and line and 4^{th} Intercostal space
- Key is consistency in transfer of care
  - Zero monitors based on what was previously used
  - OR account for variation (high or low)

Phlebostatic Axis

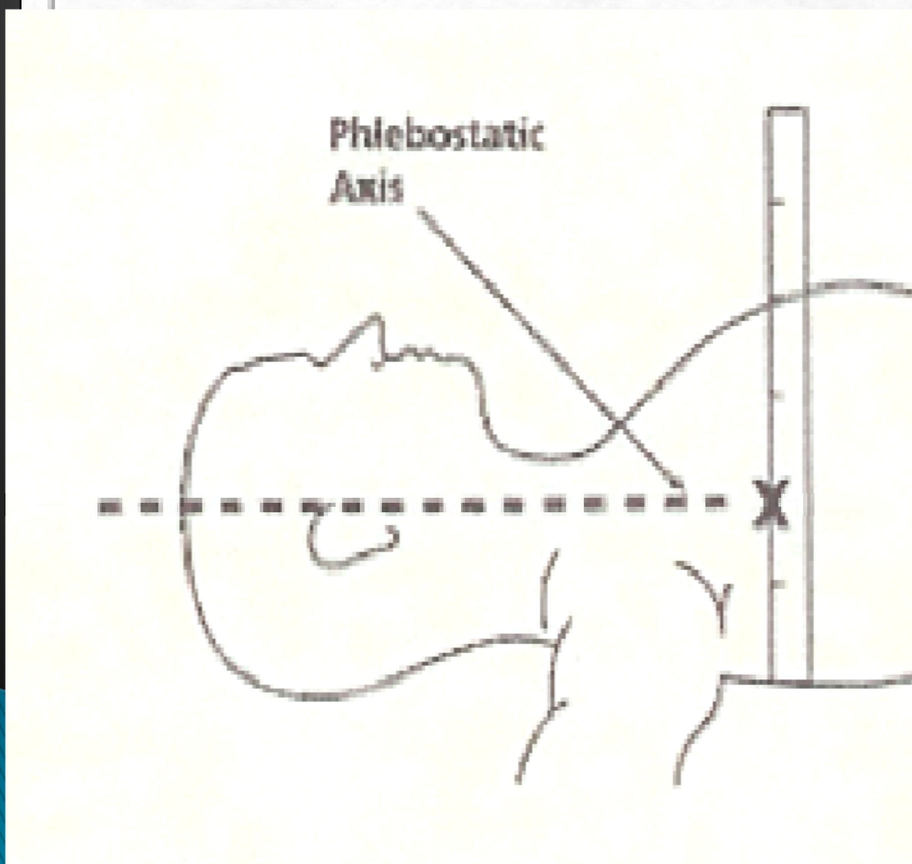
Using a level, a little high

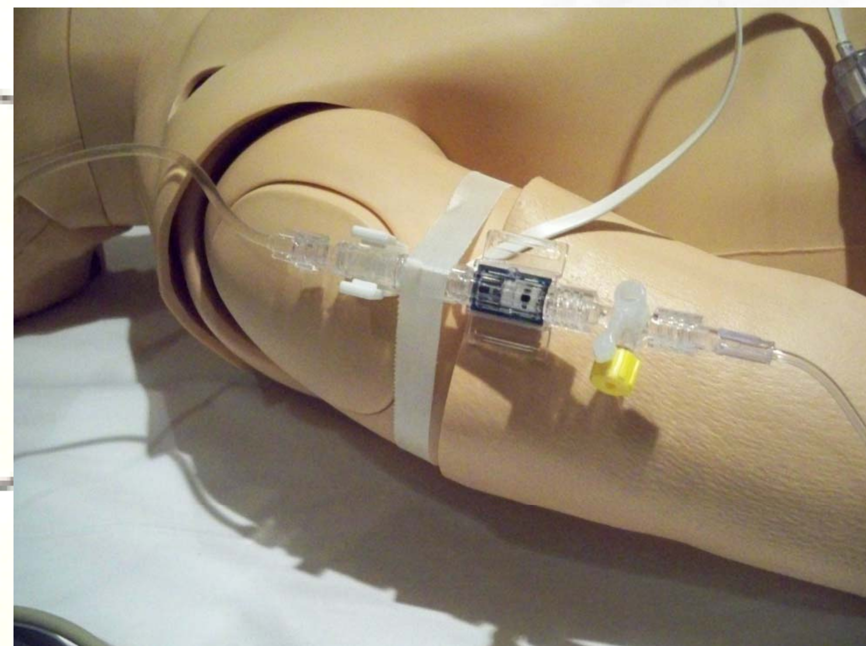
Phlebostatic axis

A little better



ence lines: (1) a line
n out to the side of the
t. B, The phlebostatic
st be level with this level



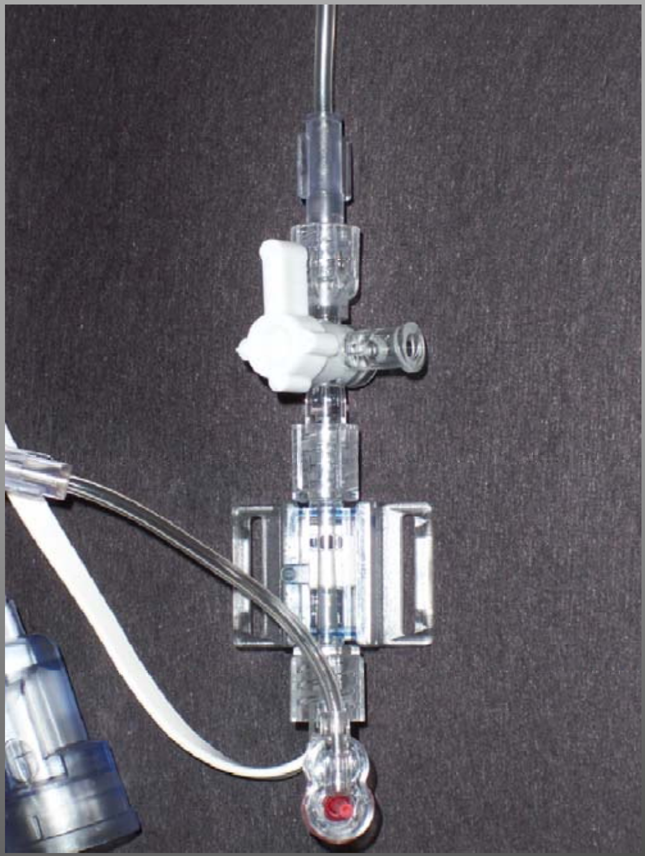


Zero Referencing

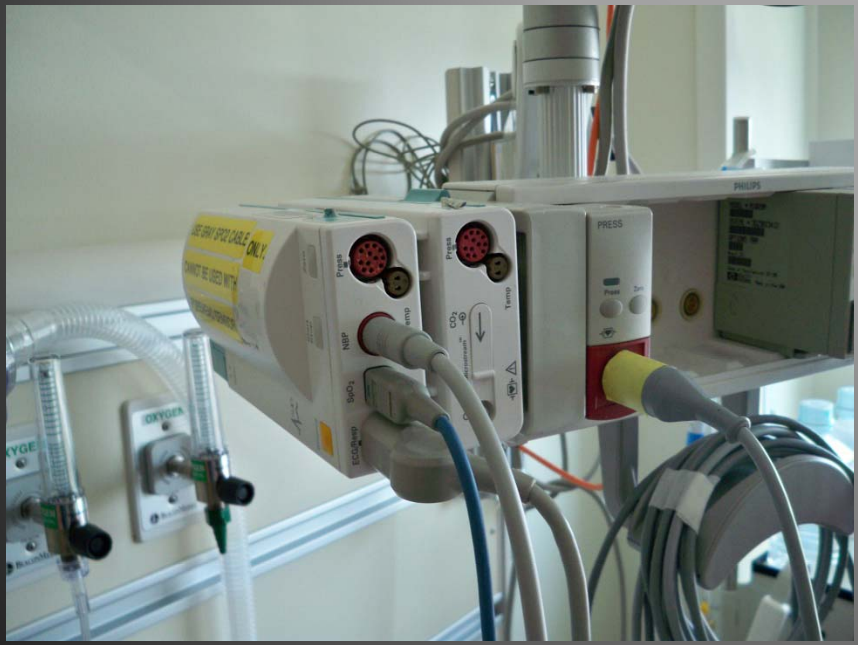
- Eliminates the effect of atmospheric pressure on the system
  - Atmospheric pressure: 760mmHg
  - Open system to air
- Eliminate hydrostatic pressure on system
  - Level to phlebostatic axis
  - Transducer placed at approximate level of the catheter tip within the body

Zero Monitor

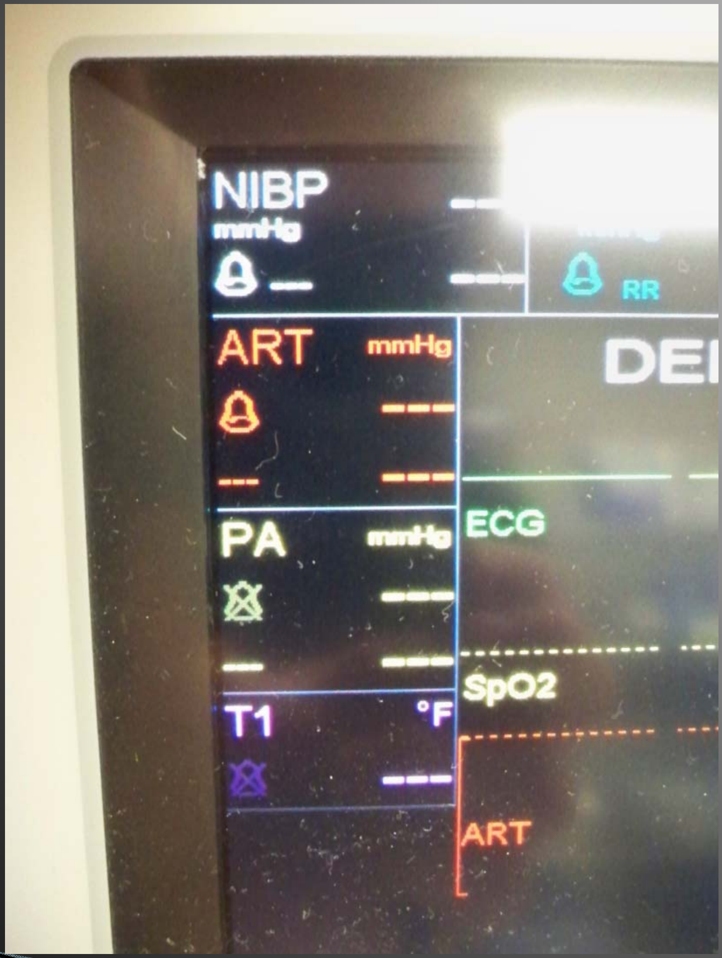
- Transducer stopcock
  - "OFF" to patient
  - "OPEN" to air
- "ZERO" from monitor menu



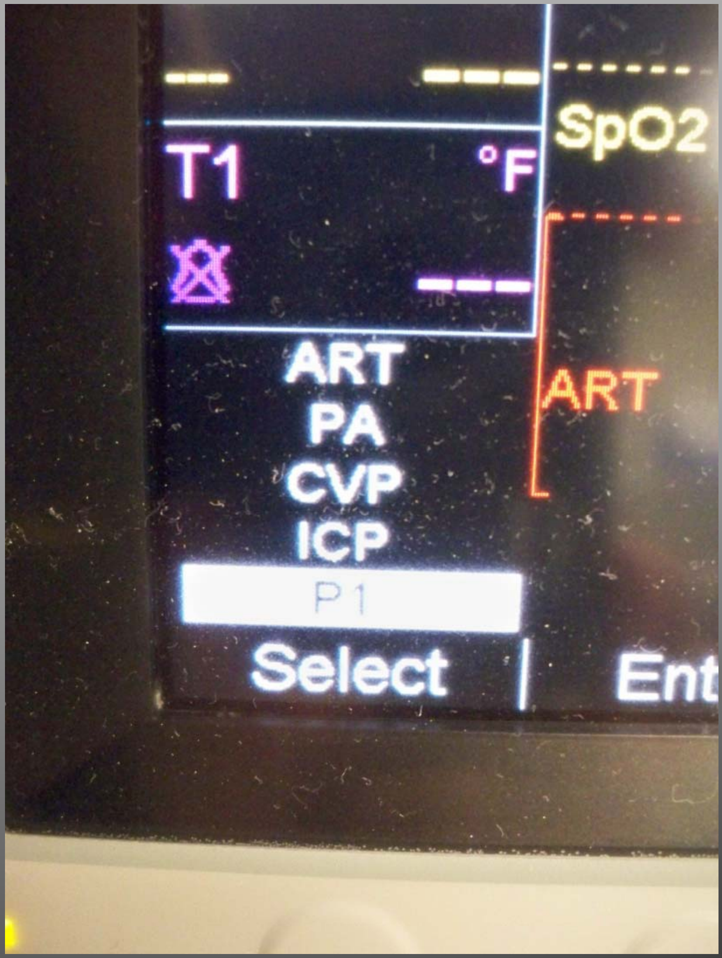
Connections



Labels



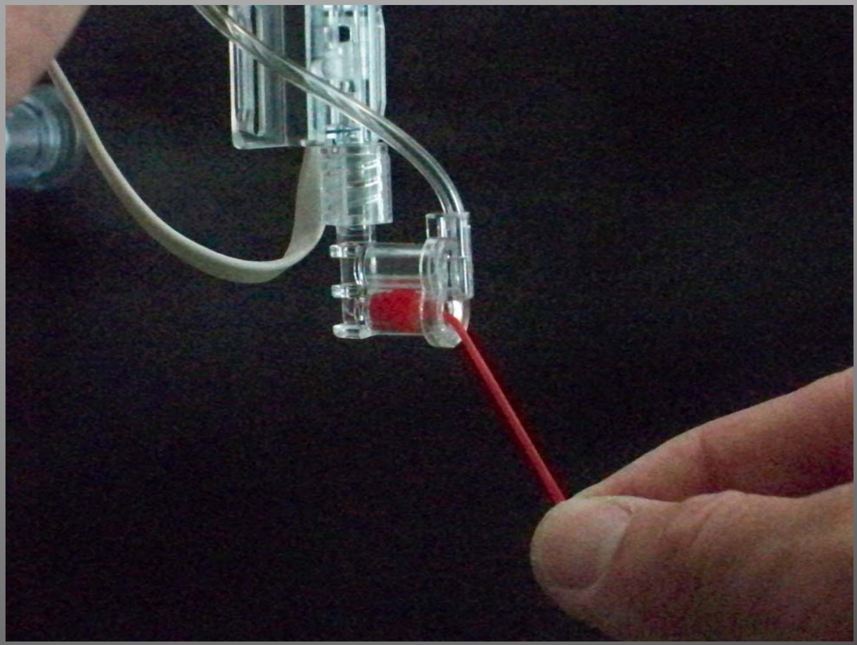
NIBP
mmHg
RR
ART
mmHg
DE
PA
mmHg
ECG
SpO2
T1
°F
ART



SpO2
T1
°F
ART
PA
CVP
ICP
P1
ART
Select
Ent

Flush

- Pulling red pigtail creates fast flush
  - clear system of air prior to connection to patient
  - Creates the “dynamic response” test to clear line of blood once connected



Technique

- Consistency from shift to shift and in transfer
  - Reassess and zero at handoff of possible
- In transport, match as close as practical
  - Tape transducer to patient if possible
  - Stretcher
- Account for this as potential variable

Problems of leveling

- Transducer below axis
  - Pressure increased over true pressure
- Transducer above axis
  - Pressure decreased below true pressure
- Factor: about 1 inch equals 2mmHg in pressure variant

Troubleshooting

- CHECK THE PATIENT FIRST
- Change in clinical condition may manifest in waveform change prior to outward physical change
  - Tension pneumothorax:
  - Hypotension
  - Excessive PEEP
- In transport patient may be sedated and not complain

Troubleshooting Pressure Systems

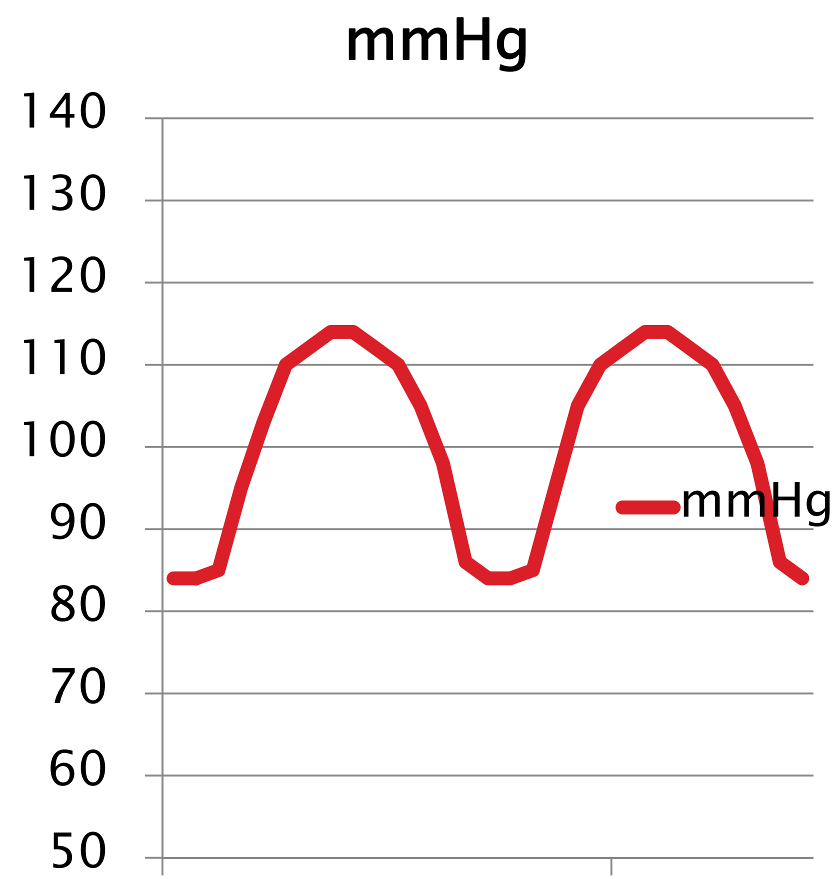
Problem	Solution
No waveform	Check monitor, power, pressure range, connected to proper line (CVP versus ABP), kinked tubing, loose tubing, aspirate blood
Artifact:	Electrical interference, patient movement, tubing movement or vibration

Troubleshooting

Problem	Solution
Unable to flush line	Check for kinks, pressure bag inflated to 300mmHg, stopcocks turned off
Reading too high	Level, flush, check for occlusion
Reading too low	Level, flush, air bubbles, blood, or other

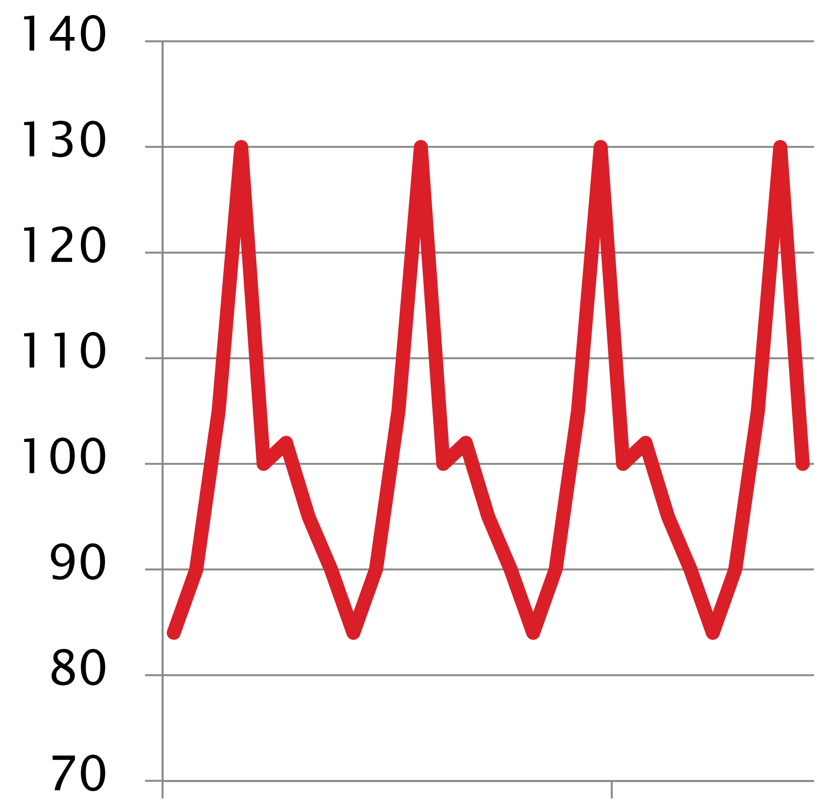
Troubleshooting

- Overdampening
  - Waveform blunted
  - Sine like or slurred appearance
  - False low systolic
  - False high diastolic
- Patient: clinical conditions that may cause this?
- Equipment issues?

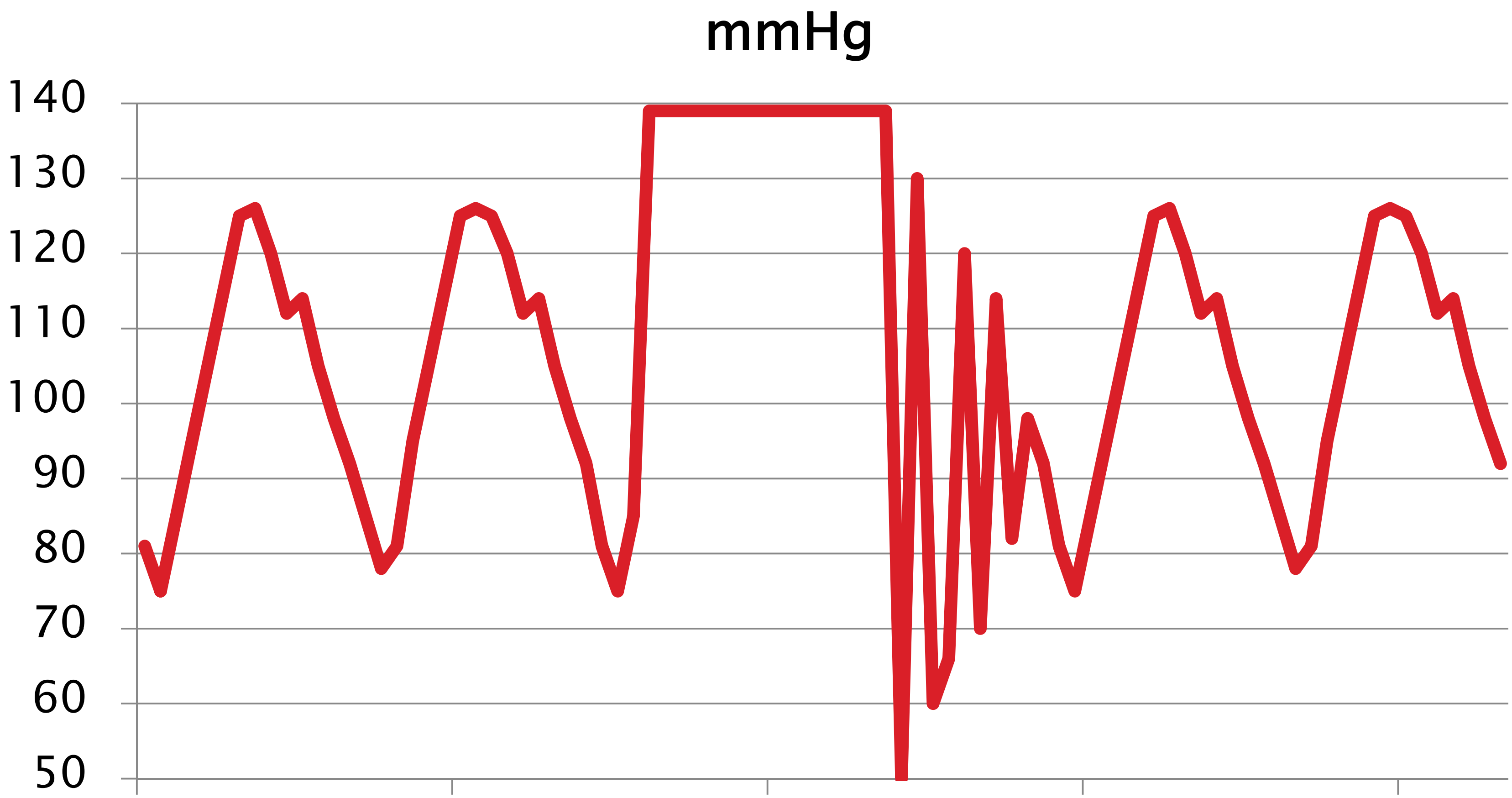


Troubleshooting

- Underdampening
  - Waveform artifact
  - Sharp, spiked appear
  - False high systolic
  - False low diastolic
- Patient: clinical conditions that may cause this?
- Equipment issues



Dynamic Response/Square Wave Test



Medications

- Potent vasoactive medications benefit from invasive monitoring
- Highly concentrated meds require central venous access for administration
- Multiple medications require compatibility checks

Vasoactive Continuous Infusions

- Nitroglycerin
- Nitroprusside
- Esmolol
- Labetelol

Decrease BP and HR

- Epinephrine
- Norepinephrine
- Milrinone
- Vasopressin
- Dopamine
- Dobutamine
- Phenylephrine

Increase BP and HR

Decrease BP: Nitrates

- Nitroglycerin: vasodilator, hits preload
  - Acute Coronary Syndrome
- Nitroprusside: vasodilator, balanced in reducing preload and afterload
  - Systemic hypertension/hypertensive crisis
  - Acute CVA
  - (not in ACS due to coronary steal: shunts coronary blood flow away myocardium)

Nitroglycerin

- ACS Standard for angina, chest pain from STEMI
- Vasodilator
  - Venous smooth muscle relaxer, decrease preload
  - Coronary vasodilation
- Glass bottle: 50mg/250ml D5W
- Dosing 5mcg/min to max of 200mcg/min
  - Hint: if at 100mcg/min, try another drug

Decrease BP: Beta blockers

- Esmolol: (Brevibloc)
  - Short acting Beta 1 selective blocker
  - Potent
  - Manage hypertensive crisis, reduced shear in dissection of aortic aneurysm
- Labetalol
  - Nonselective Beta with some Alpha 1
  - Reduce myocardial contractility
  - Vasodilation
  - Hypertensive crisis, dissection of aneurysm
  - Bolus or continuous
  - Slower onset, longer acting

Increase BP

- Epinephrine: Adrenalin
- Norepinephrine: Levophed
- Milrinone
  - Phosphodiesterase inhibitor
  - Positive Inotrope and vasodilator
  - Pulmonary Hypertension
- Vasopressin (100 units/100ml D5W
  - Vasoconstrictor
  - 0.01 to 0.04 units/min IV

Increase BP

- Dopamine:
  - Low dose: increases renal blood flow
    - less than 3mcg/kg/min
  - Medium dose: increase myocardial contractility and heart rate
    - 3 to 10mcg/kg/min
  - Higher dosing: generalized vasoconstriction
    - Greater than 10mcg/kg/min

Increase BP

- Dobutamine
  - Specific Beta1 adrenergic, increase myocardial contractility
  - Used in Acute heart failure, does not cause vasoconstriction
  - Home dobutamine used as bridge to transplant or device

Increase BP

- Phenylephrine: Neo-synephrine
  - Alpha 1
  - Systemic arterial vasoconstriction
  - Often last ditch for vascular failure in shock
  - Drug induced hypotension: beta blocker overdose

Epinephrine

- ACLS standard
  - Alpha1 and Alpha2: Vasoconstriction
  - Beta1: Cardiac stimulant, coronary vasodilation
  - Beta2: Bronchodilation
- Infusion:
  - 2mg or 4mg in 250ml D5W in central line
  - 1mg/250ml for 4mcg/ml concentration peripheral
  - Dosing: 1 to 2 mcg/min or 0.02 to 0.1mcg/kg/min

Norepinephrine

- Levophed
- Systemic vasoconstriction
  - Alpha1 (more) and Beta1 effects
- Used in shock states
  - Drug of choice for sepsis
- Infusion: 2mg in 250ml D5W
  - 8 to 12 mcg/min or 0.02 to 0.1mcg/kg/min

Conclusions

- Recognize the types and presentations of hemodynamic monitoring
  - Basic waveforms
  - Patient Types
- Understand the key safety factors in the transport of these patients
- Review basic setup of monitor systems

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