



Intro to Critical Care Series Part 1 of 3

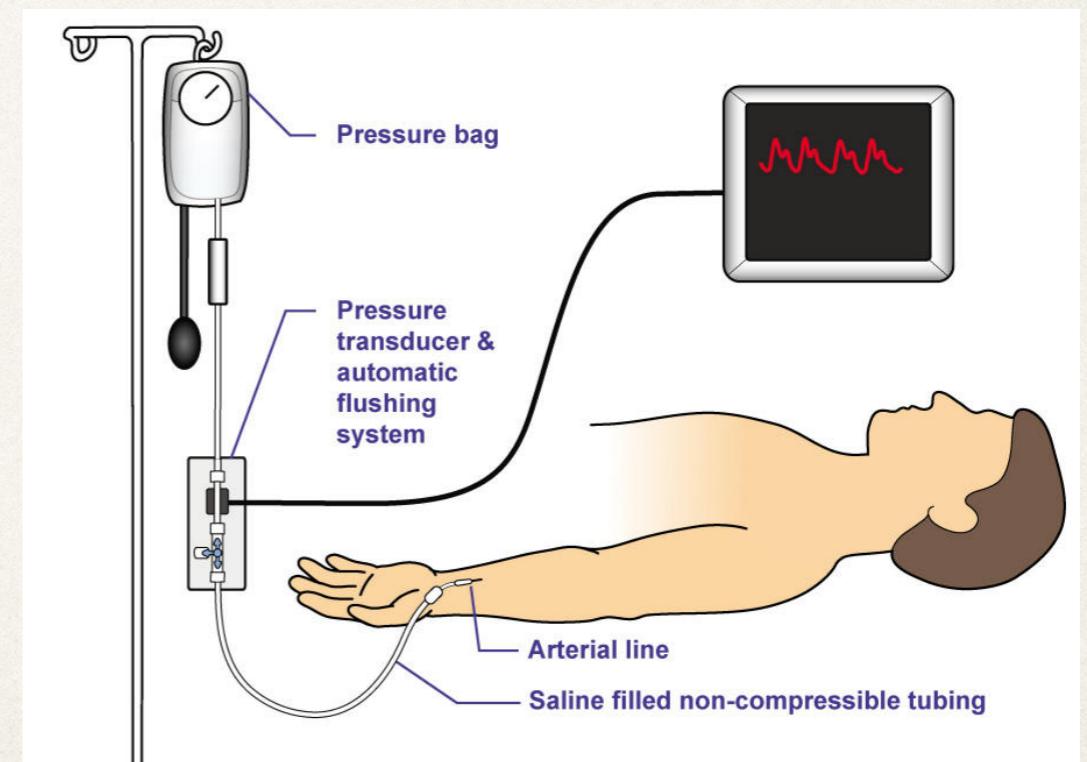
Invasive Monitoring Equipment

By Maria Cecilia ZS Rebaño, PT

Monitoring Equipment

Primarily address concerns involving cardiovascular, pulmonary, and neurological systems. Consists of:

- ❖ Device to detect physiological event of interest
- ❖ Amplifier to increase magnitude signal from sensor
- ❖ Recorder or meter to display the resultant signal



Hemodynamics (Hæmodynamics)

Fluid dynamics of blood flow

The goal of hemodynamic monitoring is to **maintain adequate tissue perfusion.**

Classical hemodynamic monitoring is based on the invasive measurement of systemic, pulmonary arterial and venous pressures, and of cardiac output.

Ex: Since organ blood flow cannot be directly measured in clinical practice, arterial blood pressure is used, as estimate of adequacy of tissue perfusion.

Who: All therapists, all disciplines

What: Recognize reasons and presence of medical equipment
Interpret settings and readouts
Assimilate information and correlate with clinical picture

When: Alarms go off on the equipment (identify cause before silencing)
Abnormal readouts occur
Patients may be presenting with worsening states

Where: Working in ICU, or with patients on monitoring equipment

Why: To provide safe interventions in the critical care setting
To determine medical emergencies requiring immediate treatment

Lines Management 101

Just to start us off.



Pre-Treatment

- ✿ **Review** the chart for lines, drains, equipment, devices
- ✿ **Learn** specific parameters & precautions that protect the Pt, therapist, or both
- ✿ **Discuss** planned interventions with RN

Treatment Protocols

- ✿ Observe + Inventory: Pt's position, appearance
- ✿ Systematically verify presence of documented lines (left to right, top to bottom, survey environment - everything is to be considered in the plan for mobilization)
- ✿ Note all the readings on monitors, before, during, after tx
- ✿ Anticipate how interventions will affect VS, how they will look on the monitor, and what can artificially change based on position change response

Treatment Protocols

- ✿ Discuss with RN any lines that can be temporarily disconnected
- ✿ Gently trace (tactile) each line from Pt to source
- ✿ Always ask for assistance to untangle or free any lines that may be under the Pt
- ✿ Ensure there is **no tension** on any line prior to moving the Pt.

DO NOT attempt to free a line you cannot completely visualize! Always ask for assistance in mobilizing Pts.

Noninvasive

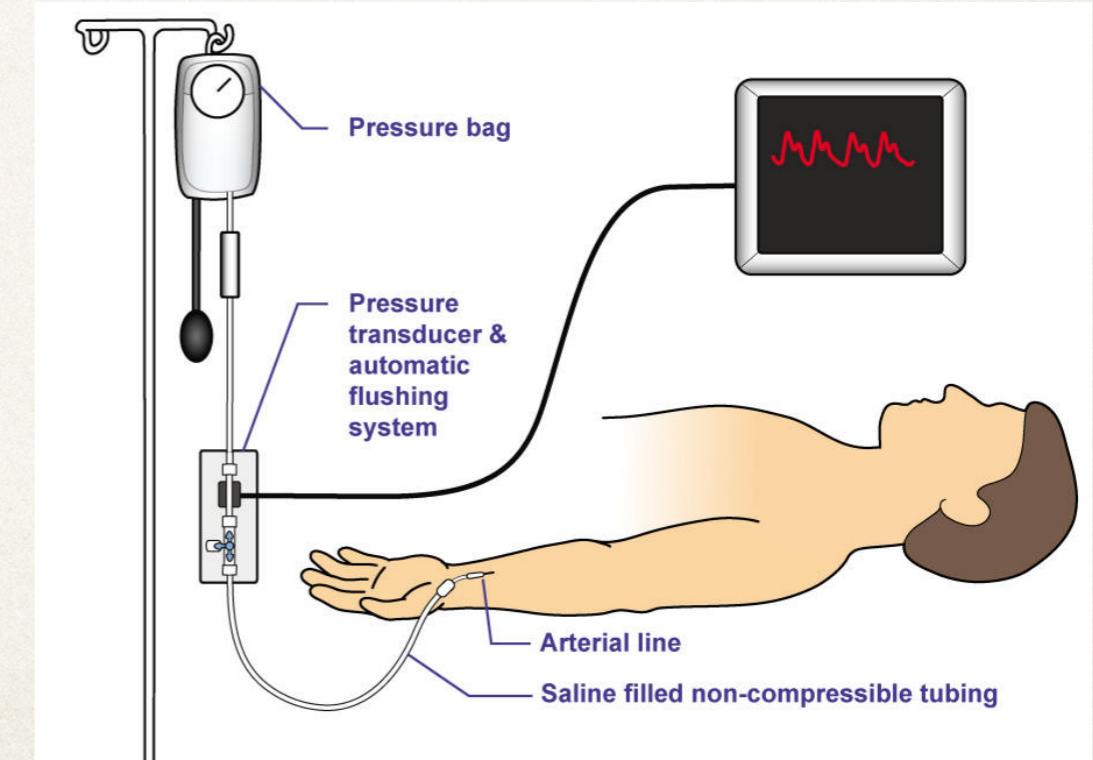
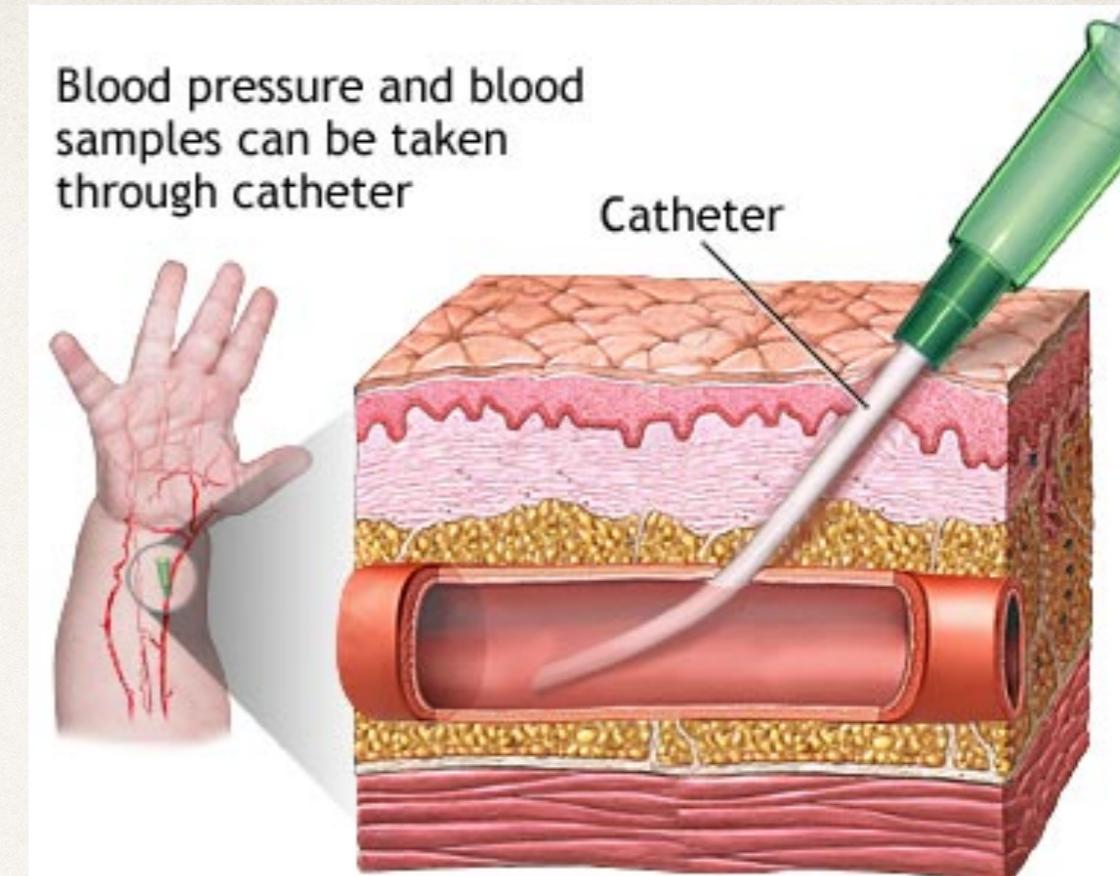
VS

Invasive

-
- ❖ Electrocardiogram
 - ❖ Pulse Oximetry (Sp02)
 - ❖ Blood Pressure Monitoring (NIBP) - sphygmomanometry
 - ❖ Respiratory Rate
 - ❖ Level of Consciousness (Bispectral Index Sensor)
 - ❖ End Tidal CO₂ (^{et}CO₂ or ETCO₂)
 - ❖ Arterial Line
 - ❖ Central Line
 - ❖ PAC (Pulmonary Artery Catheter / Swan-Ganz Catheter)
 - ❖ Chest Tube(s)
 - ❖ Temperature monitoring
 - ❖ ICP (Intracranial Pressure monitoring)

Arterial Line

- ✿ "art-line" or "a-line"
- ✿ thin catheter inserted into an artery to monitor blood pressure directly, in "real-time"
- ✿ obtain arterial blood gas (ABG)
- ✿ most common: radial, femoral
- ✿ less common: brachial, axillary, ulnar, dorsalis pedis



Arterial Line

- ✿ Pt on inotropic drugs
- ✿ Pt on vasoactive drugs
- ✿ Pt requires frequent arterial blood gas sampling, provides ease of access, reduce "sticks"
- ✿ continuous monitoring (SBP, DBP, MAP)



Which Pressure?

Which pressure should be monitored depends on the clinical situation.

- systolic pressure is important when there is a **high risk of bleeding**
- diastolic pressure is important in determining **coronary perfusion** pressure and therefore is particularly important in patients with coronary disease
- mean arterial pressure is a major determinant of **perfusion pressure of other organs**

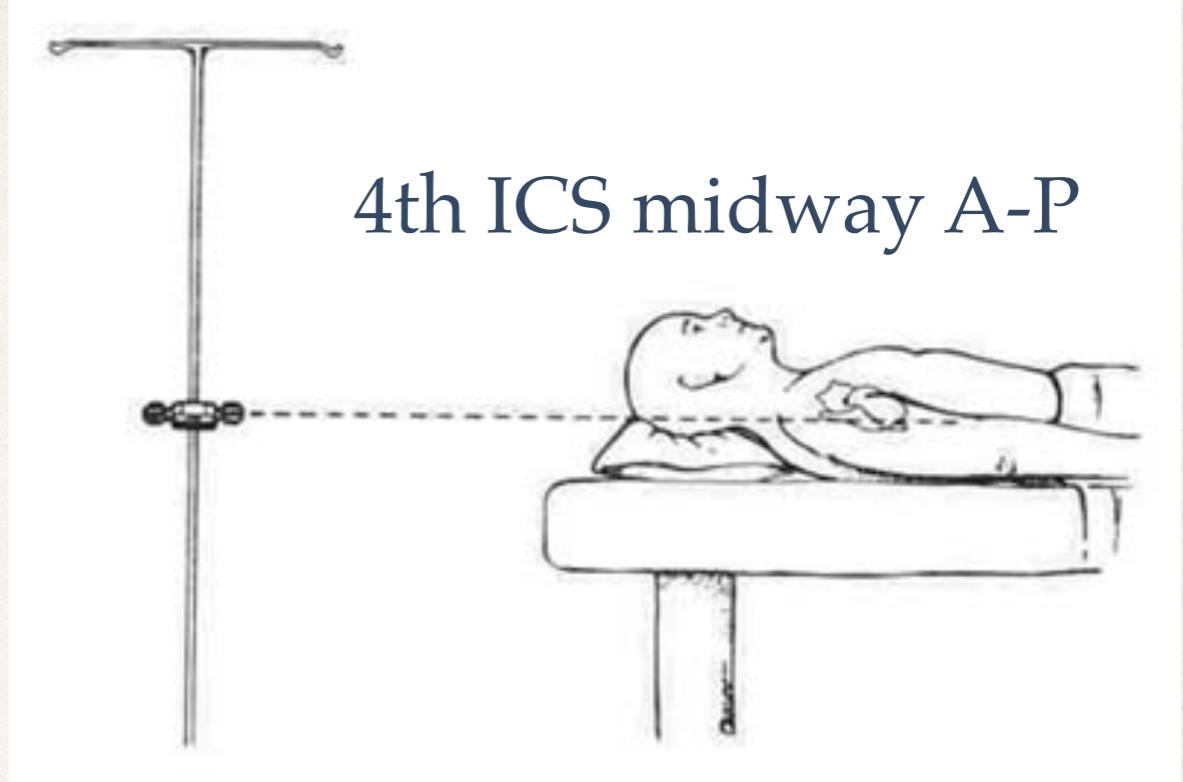
Arterial Line

- ✿ Transducer at level of RA

Too low = Higher BP (over reading)

Too high = Lower BP (under reading)

IF an arterial line is dislodged accidentally, apply pressure immediately (and up to 5 mins) and notify nursing staff.



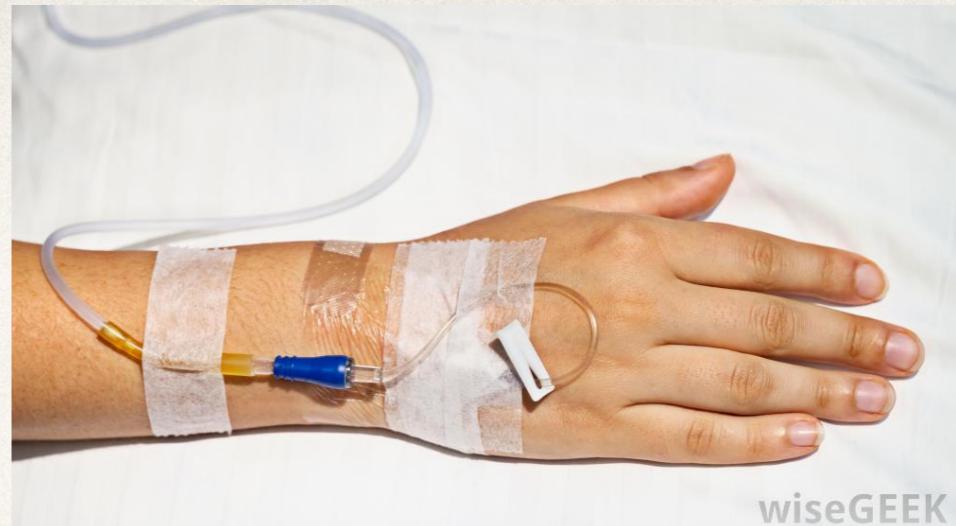
Arterial Line

- ✿ MAP: Mean Arterial Pressure

$$\frac{\text{DBP} + \text{DBP} + \text{SBP}}{3} \quad \text{i.e. } 110/70 (83)$$

- ✿ Tissue Perfusion Pressure
- ✿ The same in all parts of the CV system when supine
- ✿ Does not vary significantly with motion artifact

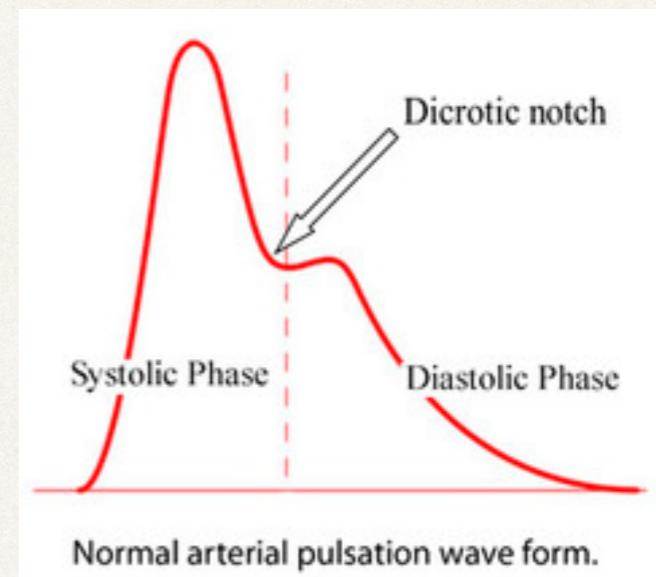
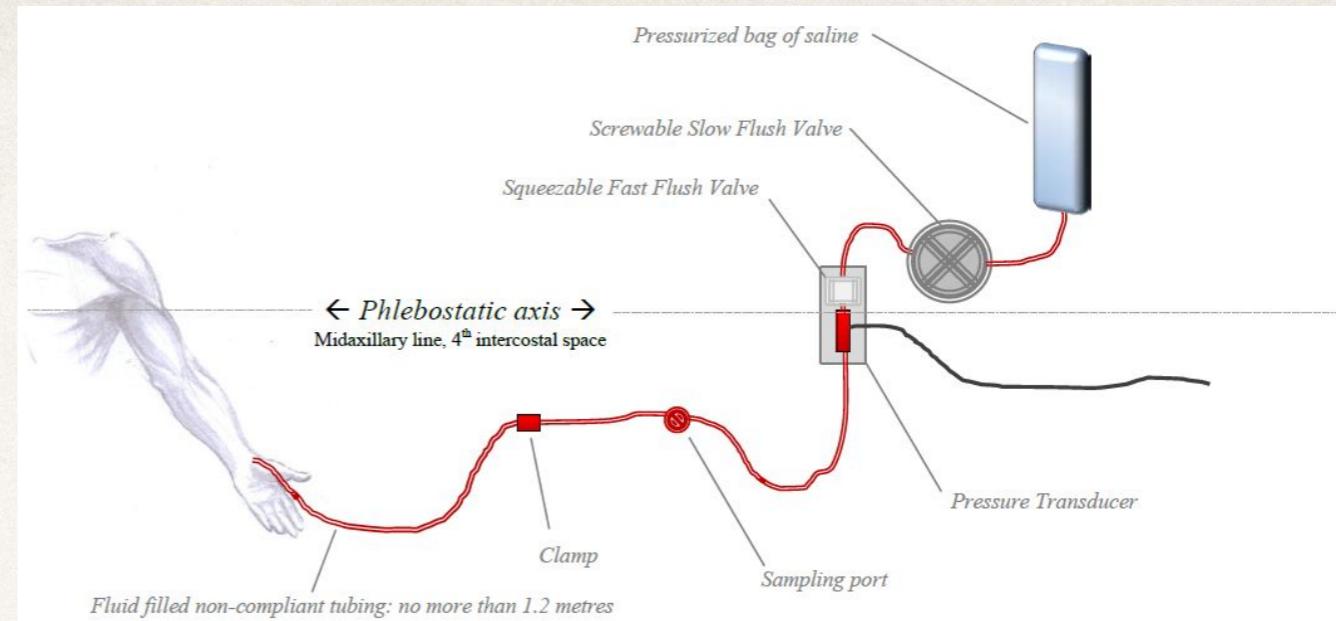
✿ **70-110** **<60**
danger of lack of
tissue perfusion



Arterial Line

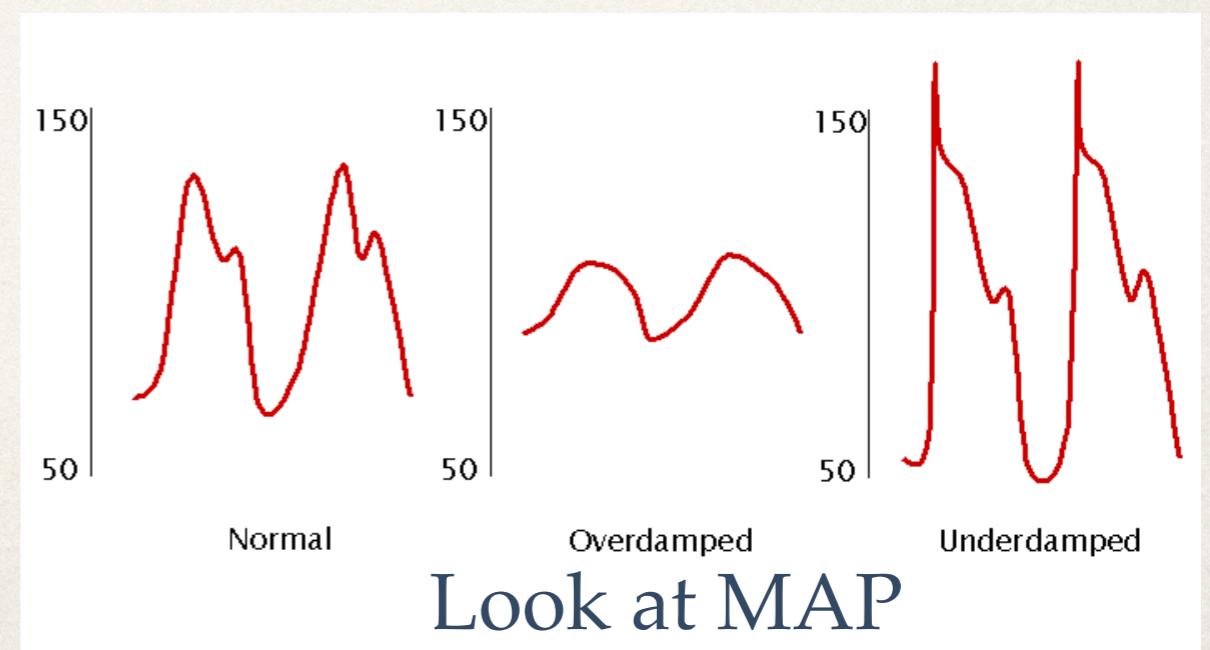
❖ Waveform

Waveform quality must be assessed prior to acceptance of a displayed pressure value. Pressures are derived from the detected waveform; poor quality waveforms will produce inaccurate pressure readings.

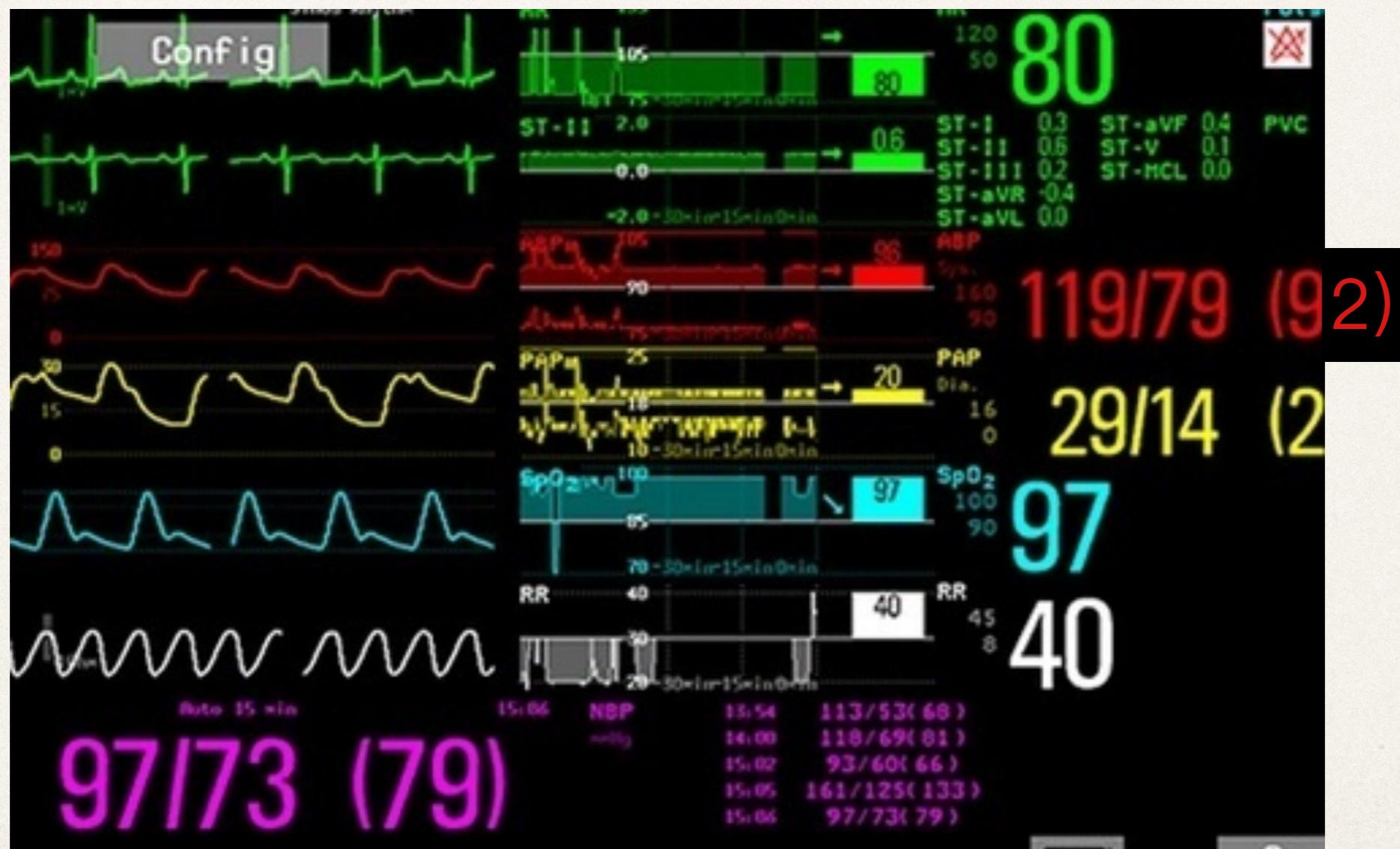


❖ Abnormal Readings

Waveform changes may occur during alteration of intrathoracic or intrapericardial pressures. They may indicate presence of cardiac tamponade, pericarditis, aortic insufficiency.



Arterial Line



Mobilizing with Arterial Lines

- ✿ If not on high dose (2+ meds and/or $>/= 40 \text{ mcg}$) pressors, ok to mobilize
- ✿ Femoral line - dangling ok, standing possible if asymptomatic and all other vitals signs stable
- ✿ Generally NO Ambulation

EVIDENCE-BASED PRACTICE ???



Perme C, Lettin C, Throckmorton TA, et al.

Early Mobility and Walking for Patients with Femoral Arterial Catheters in Intensive Care Unit: a Case Series.

J. Acute Care Phys Ther 2011; Vol 2, Number 1-pg 30-34

Perme C, Masud F.

Mobilizing Patients with Femoral Arterial Catheters during Physical Therapy Interventions Did Not Lead to Catheter Related Complications

Am. J. Respir. Crit. Care Med. 2009 179: A1586

Complications

Hemorrhage - from disconnection, or around the line

Distal Ischemia - color and sensation changes, loss of function

Arterial thrombosis or embolism (may manifest as "splinter hemorrhages")

Accidental drug injection

Damage to artery, e.g. Aneurysm, retrograde air embolism

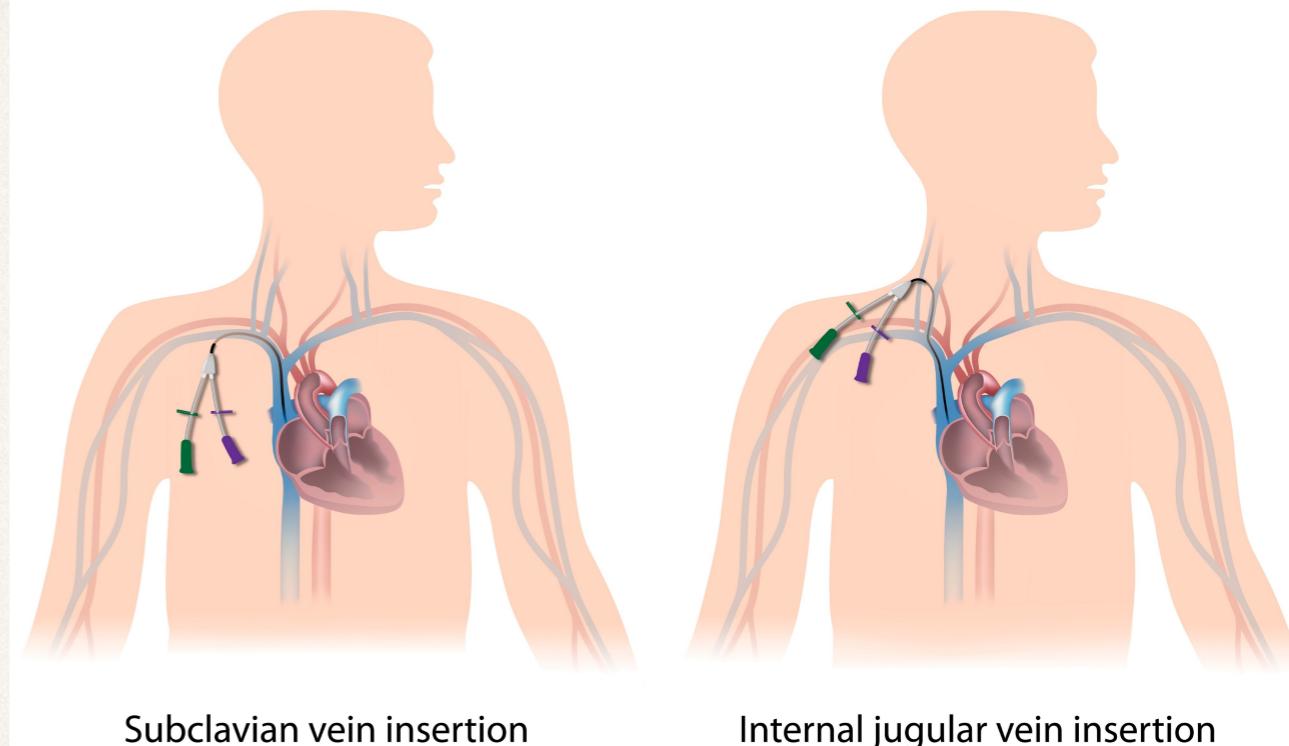


Look for signs and symptoms of pain, pallor, cyanosis, diaphoresis, significant changes in vital signs

Central Line

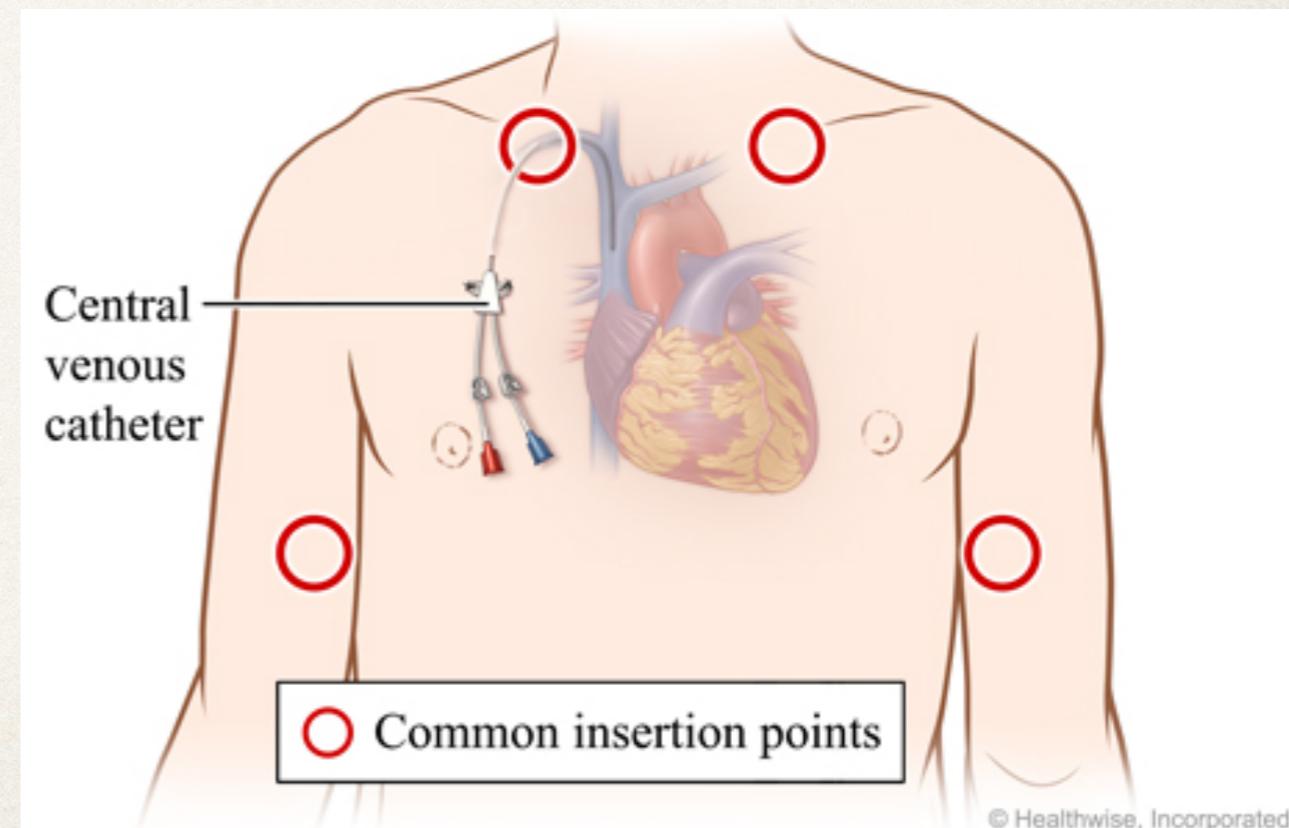
- ❖ "central venous catheter", "central venous line", "central venous access catheter"
- ❖ placed by a physician, under US guidance, with follow-up CXR to confirm placement & ensure no pneumothorax was caused
- ❖ most common: int. jugular (neck), subclavian or axillary (chest), rests in proximal SVC
- ❖ less common: femoral v. (groin), or through arms (PICC)

Central Venous Catheter



Subclavian vein insertion

Internal jugular vein insertion



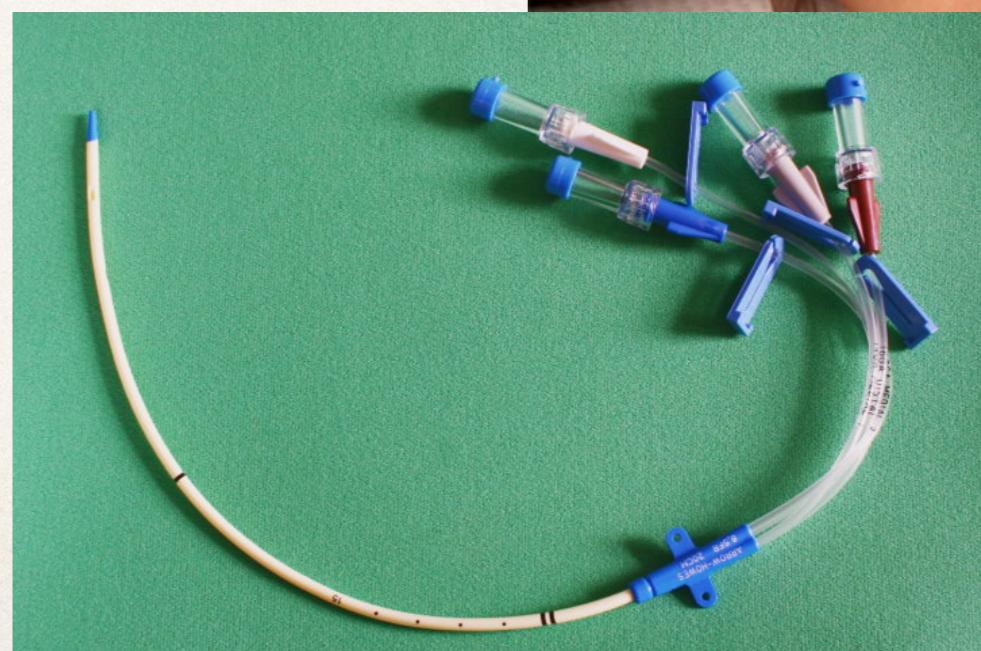
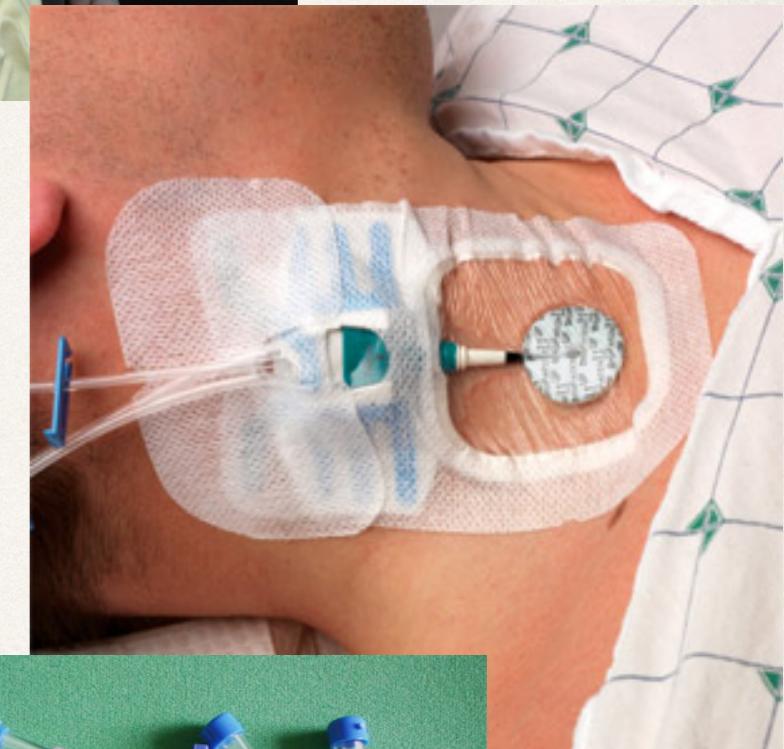
Central
venous
catheter

○ Common insertion points

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Central Line

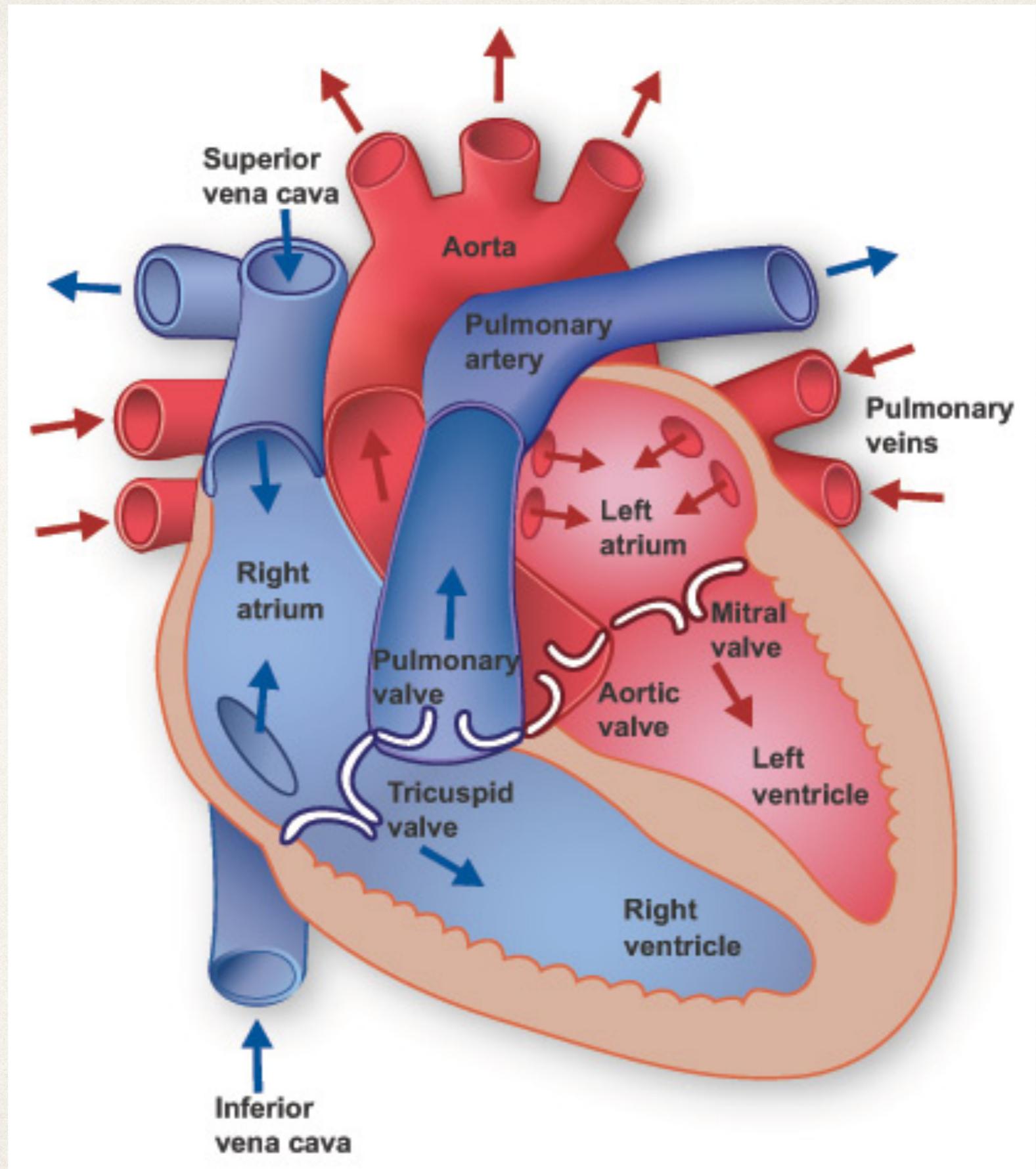
- ✿ allows IV access for meds& other procedures, blood sampling
- ✿ route for emergency placement of a temporary pacemaker
- ✿ use for **Total Parenteral Nutrition**
- ✿ continuous monitoring of **central venous pressure (CVP)** or **right atrial pressure (RAP)**



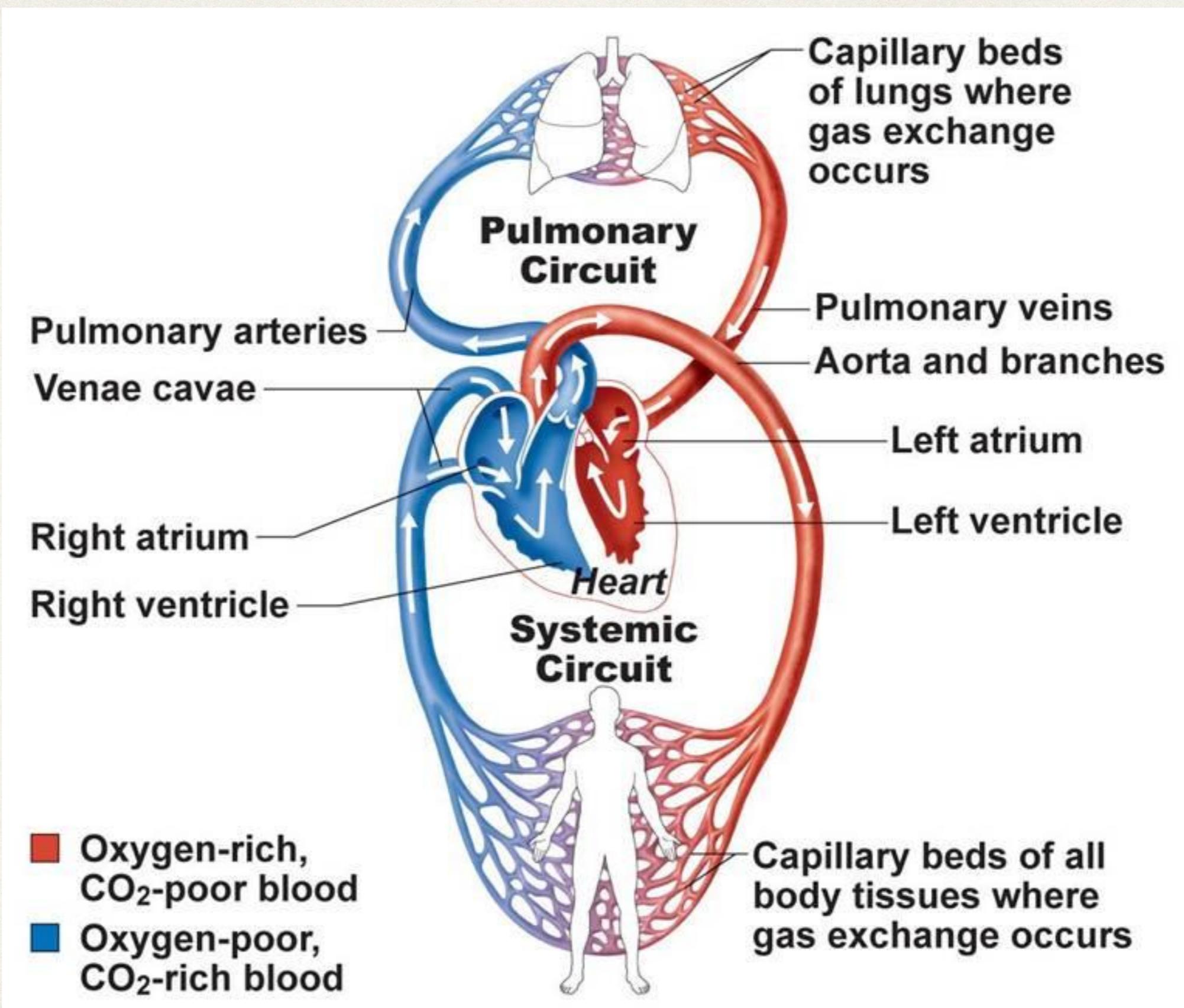
Central Line

- ✿ administer blood products, plasmapheresis
- ✿ dialysis, central temp monitoring
- ✿ frequent blood draws, medications
- ✿ measures **ScvO₂ (mixed venous oxygen saturation)** reflects the amount of oxygen "left over" after the tissues remove what they need
- ✿ Some **caustic** agents which may make peripheral veins prone to phlebitis include:
 - Calcium chloride
 - Chemotherapy
 - Hypertonic saline
 - Potassium chloride (KCl)
 - Amiodarone
 - Vasopressors (epi, norepi)

Anatomy of the Heart



Pulmonary & Systemic Circulation



Central Line

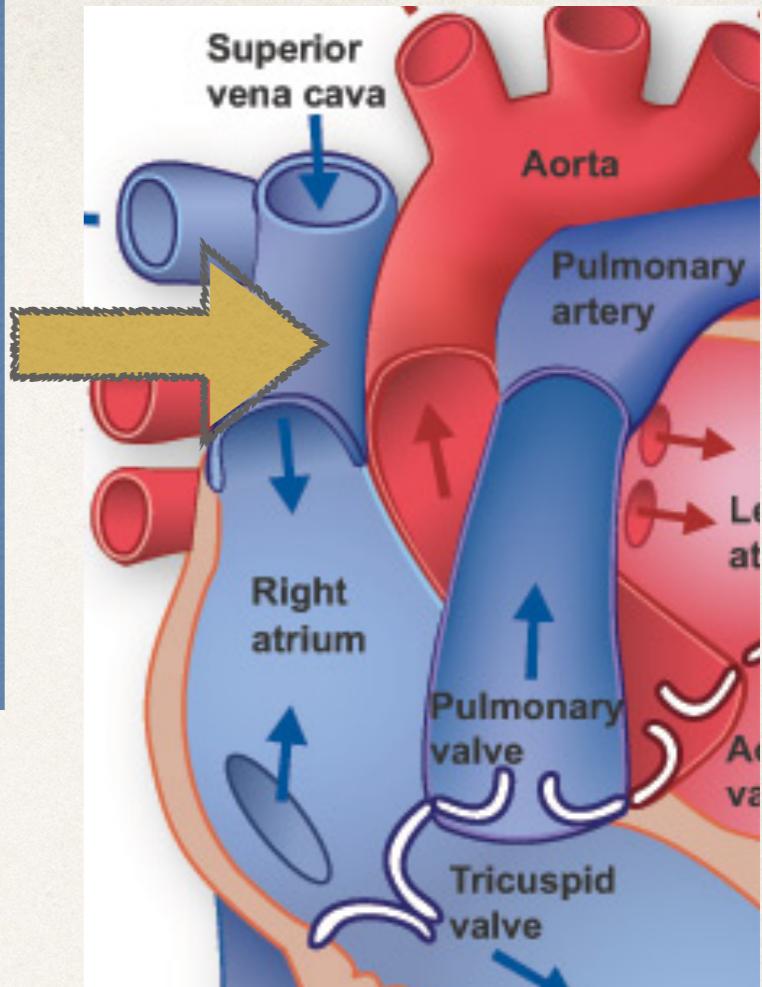
- ✿ Central Venous Pressure (CVP)
 - pressure in vena cava, approx. of R. Atrial Pressure (RAP)

CVP 3-8 | RAP 0-8

<hypovolemia, shock

>fluid overload, high PEEP,
RV failure, pericardial effusion,
tricuspid insufficiency

CVP reflects the amount of blood returning to the heart and the ability of the heart to pump the blood back into the arterial system.



CVP WAVEFORM

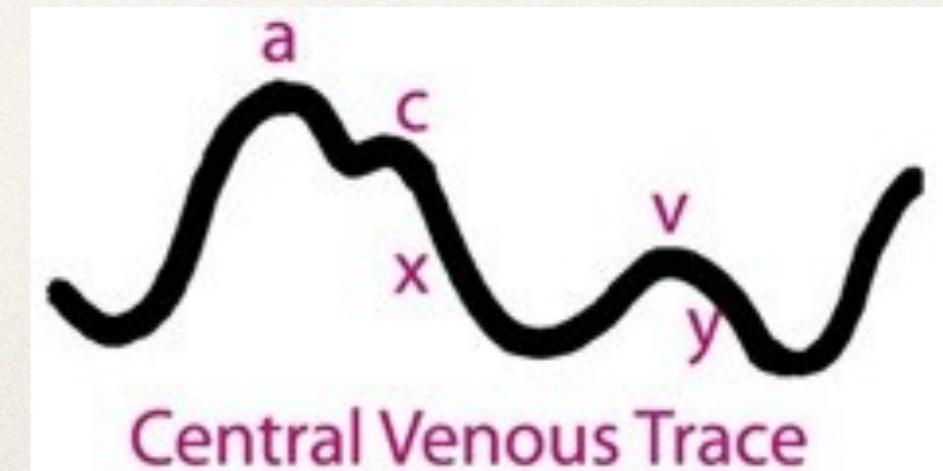
a = atrial contraction

c = closing and bulging of the tricuspid valve

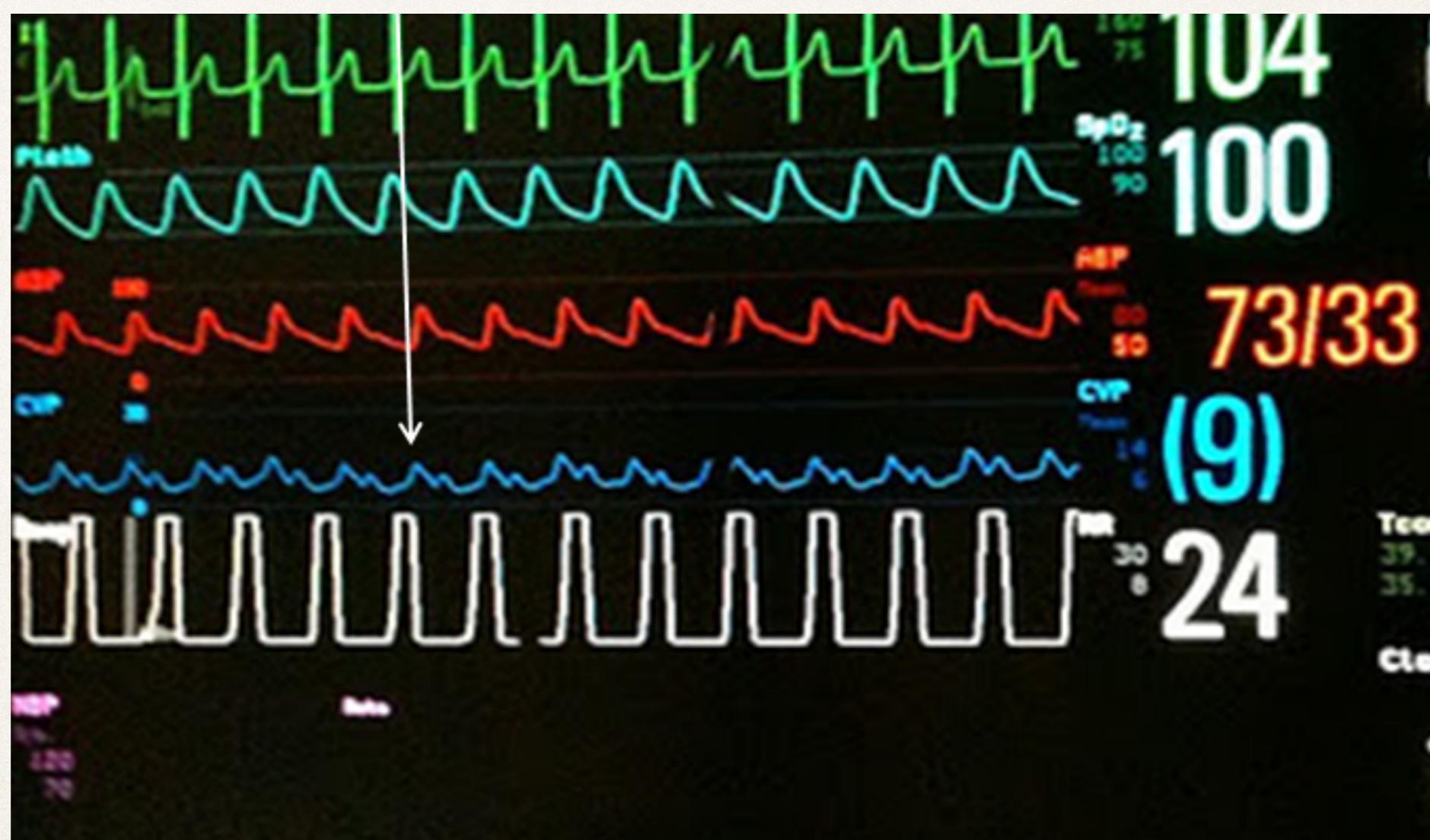
x = atrial relaxation

v = passive filling of atrium

y = opening of the tricuspid valve



Central (Venous) Line



Mobilizing with Central Lines

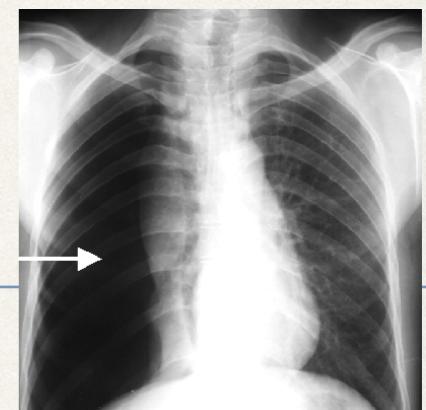
- ✿ If not on high dose pressors, ok to mobilize
- ✿ Femoral line - dangling ok, standing possible if Pt is asymptomatic and all other vitals signs stable
- ✿ Follow protocols on hip angle and restrictions if available (70-80 degrees - not prolonged positioning)
- ✿ Generally OK to disconnect line for brief ambulation

Complications

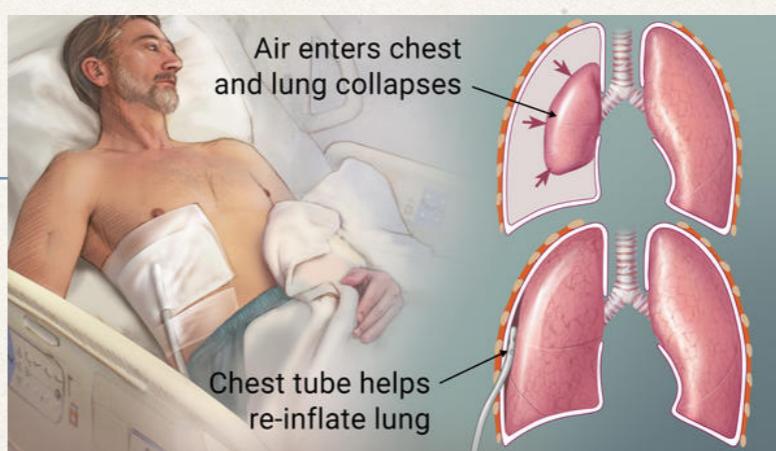
Infection, sepsis - fevers, chills, hypotension, tachycardia, confusion



Pneumo/Hemothorax - dyspnea, hypoxia, tachycardia, restlessness, cyanosis, chest pain, dec. lung sounds



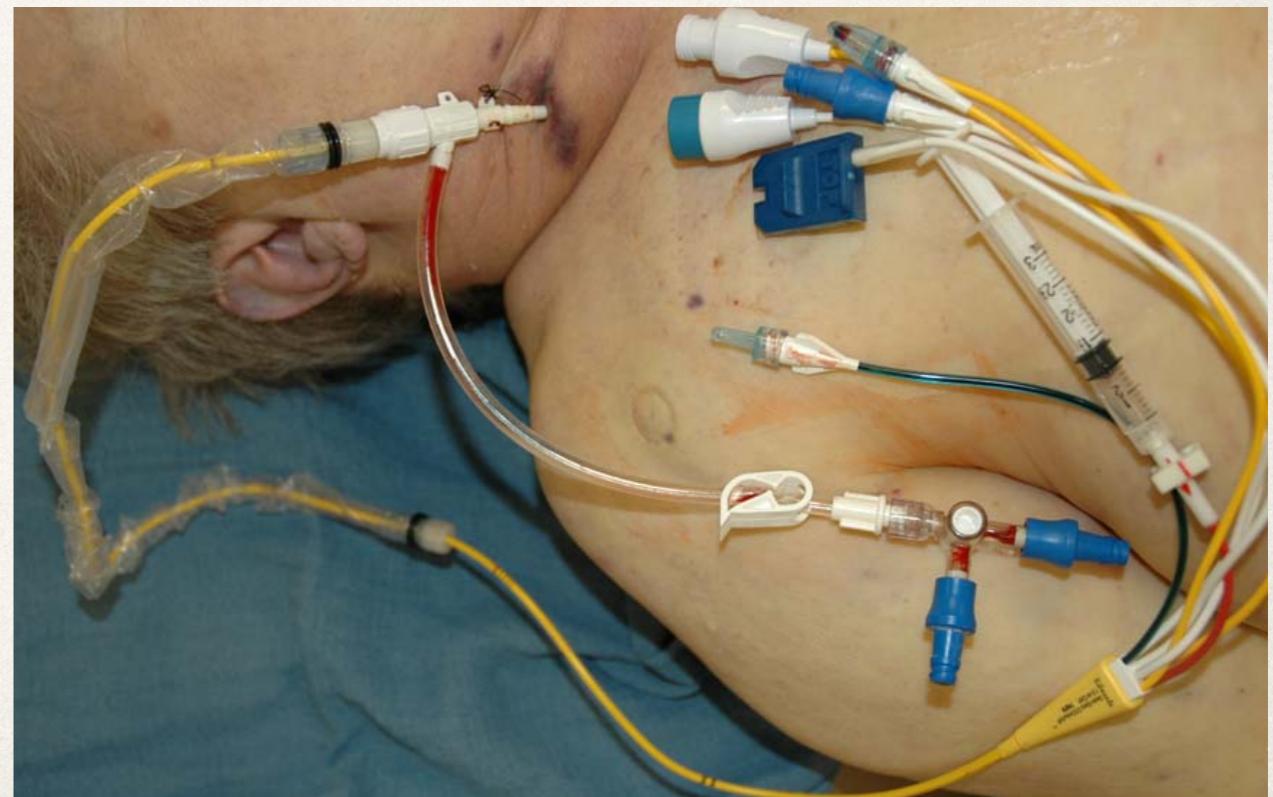
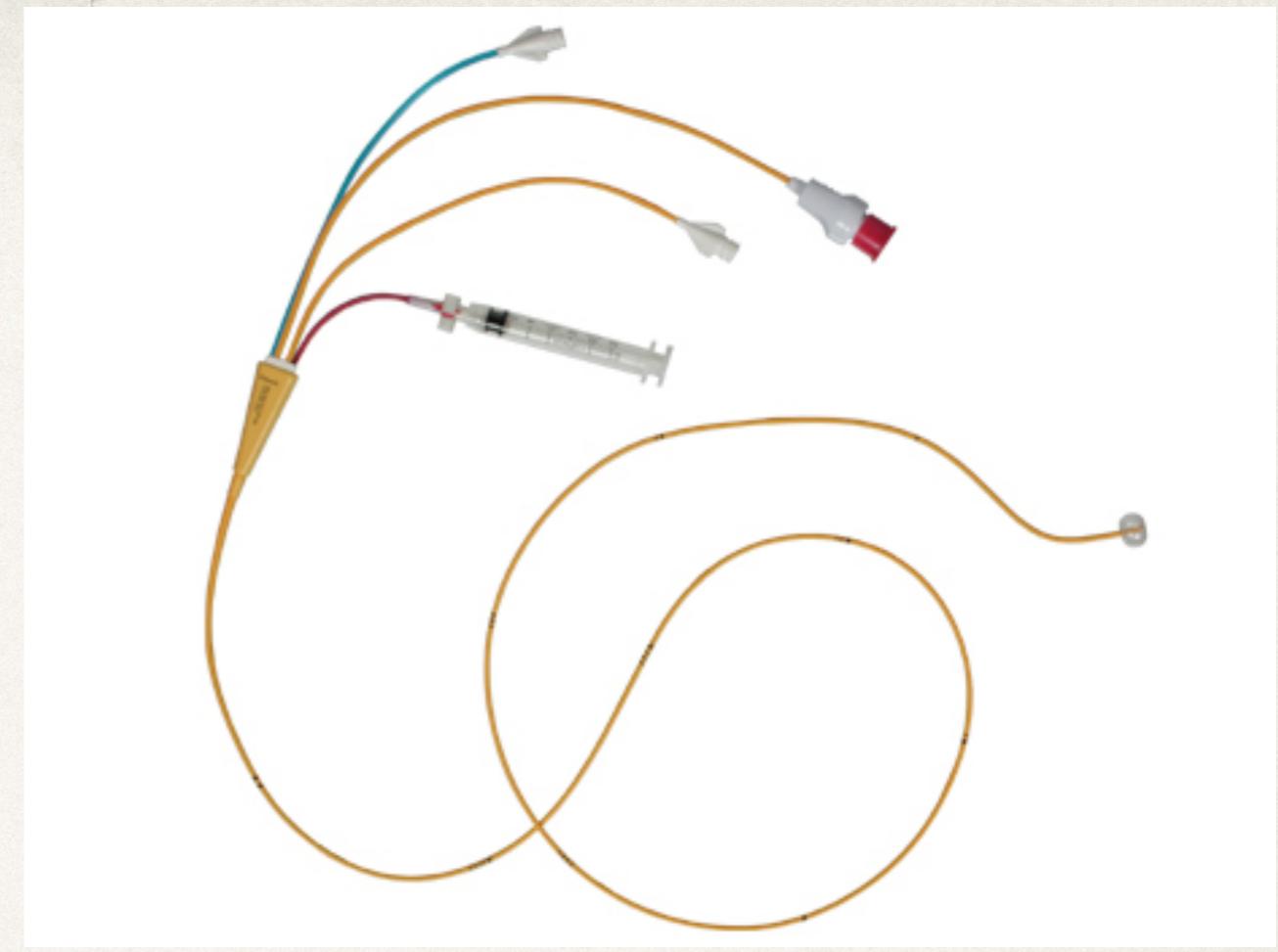
Air Embolism - dyspnea, chest pain, tachycardia, hypotension, anxiety, nausea, dizziness, and confusion.



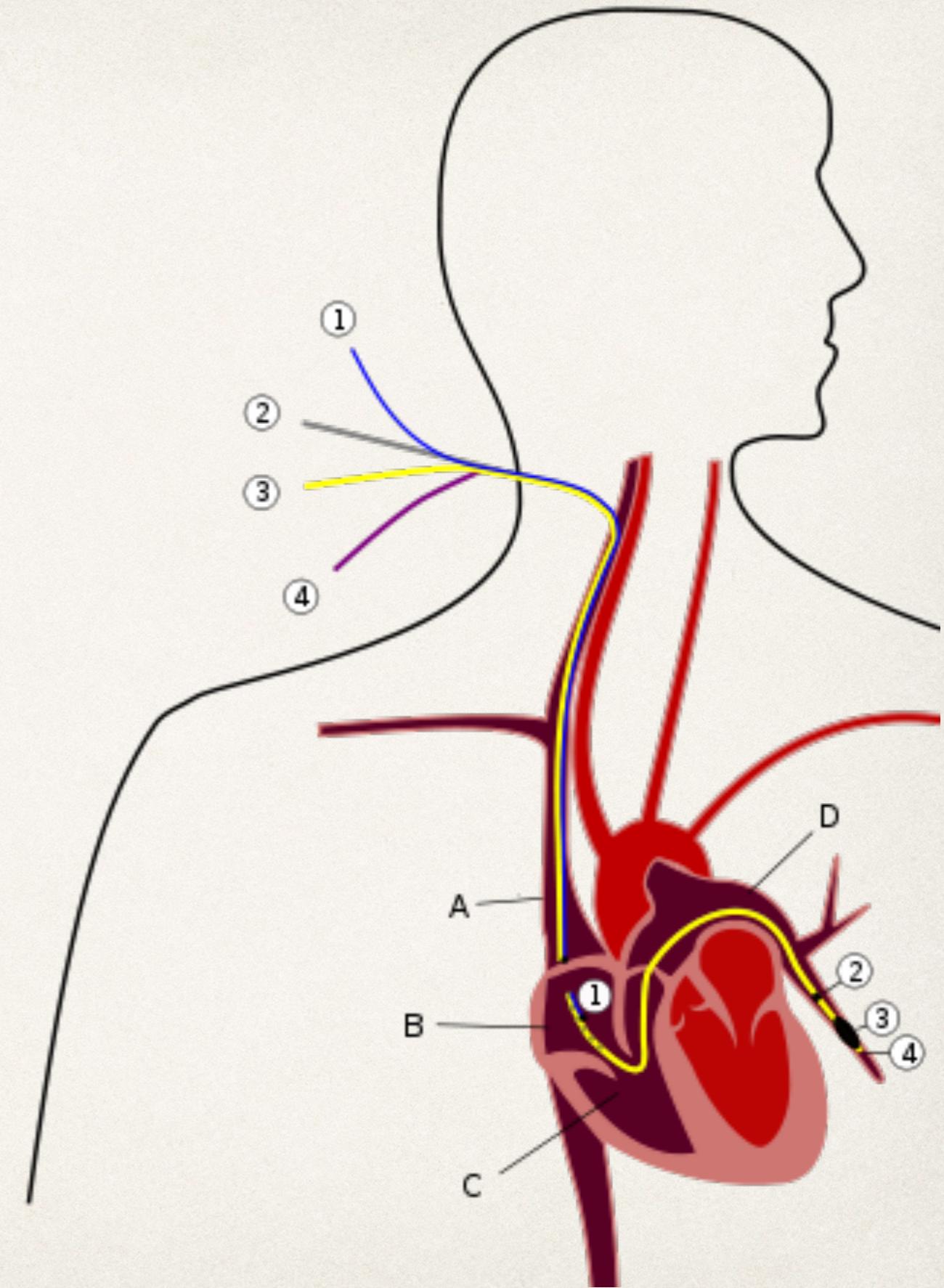
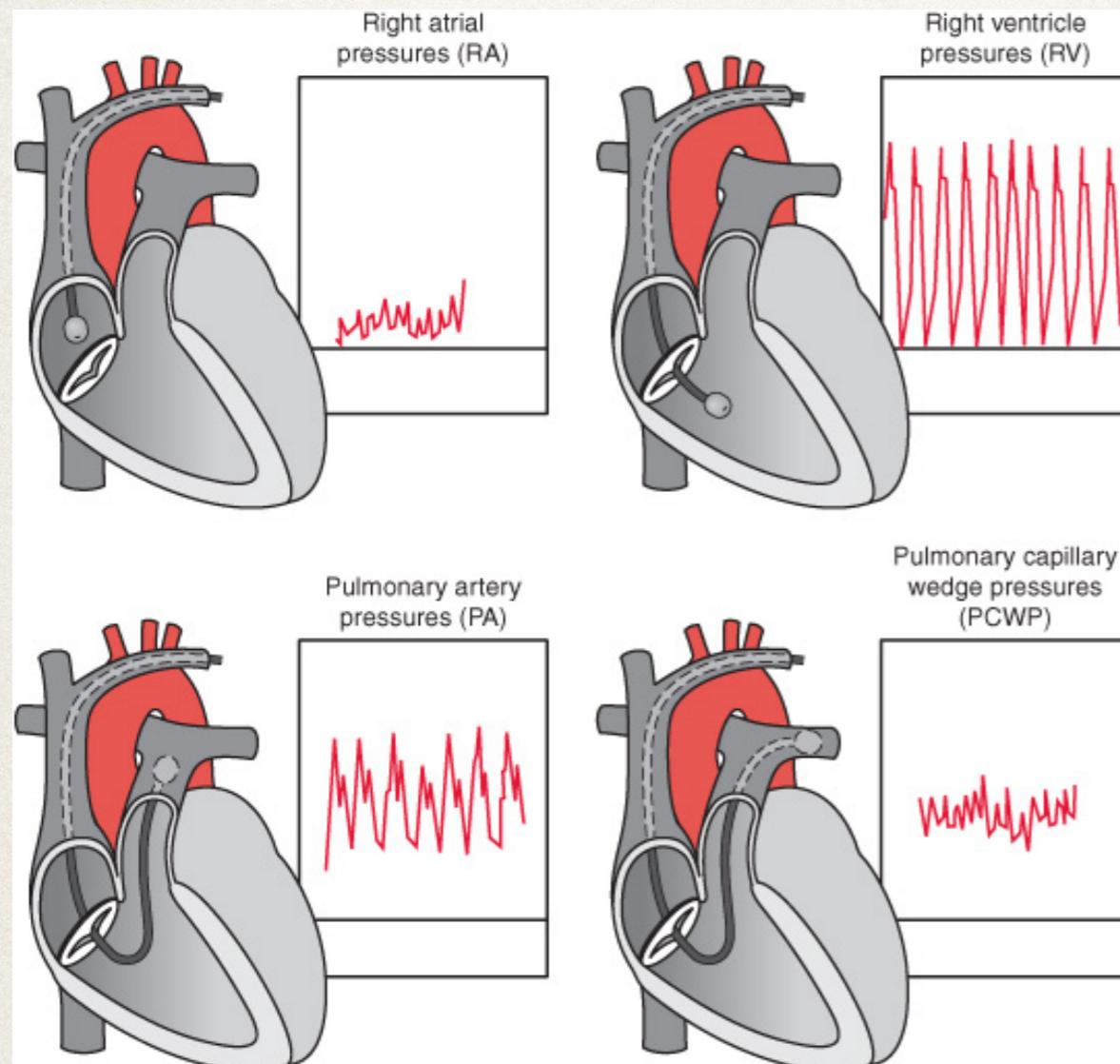
Arrhythmias, bleeding, hematomas

Pulmonary Artery Catheter

- ✿ "Swan-Ganz", PAC, "yellow snake" (inf.)
- ✿ directly measures RAP, PAP, PCWP; indirectly LAP
- ✿ **PAP 8-20 (mean) or 15-30/5-15 (Pas/Pad)**
- ✿ measures SvO_2 and Cardiac Output
- ✿ permits pacing of atria & ventricles
- ✿ **diagnostic**; it is used to detect heart failure or sepsis, monitor therapy, and evaluate the effects of drugs (therapeutic)

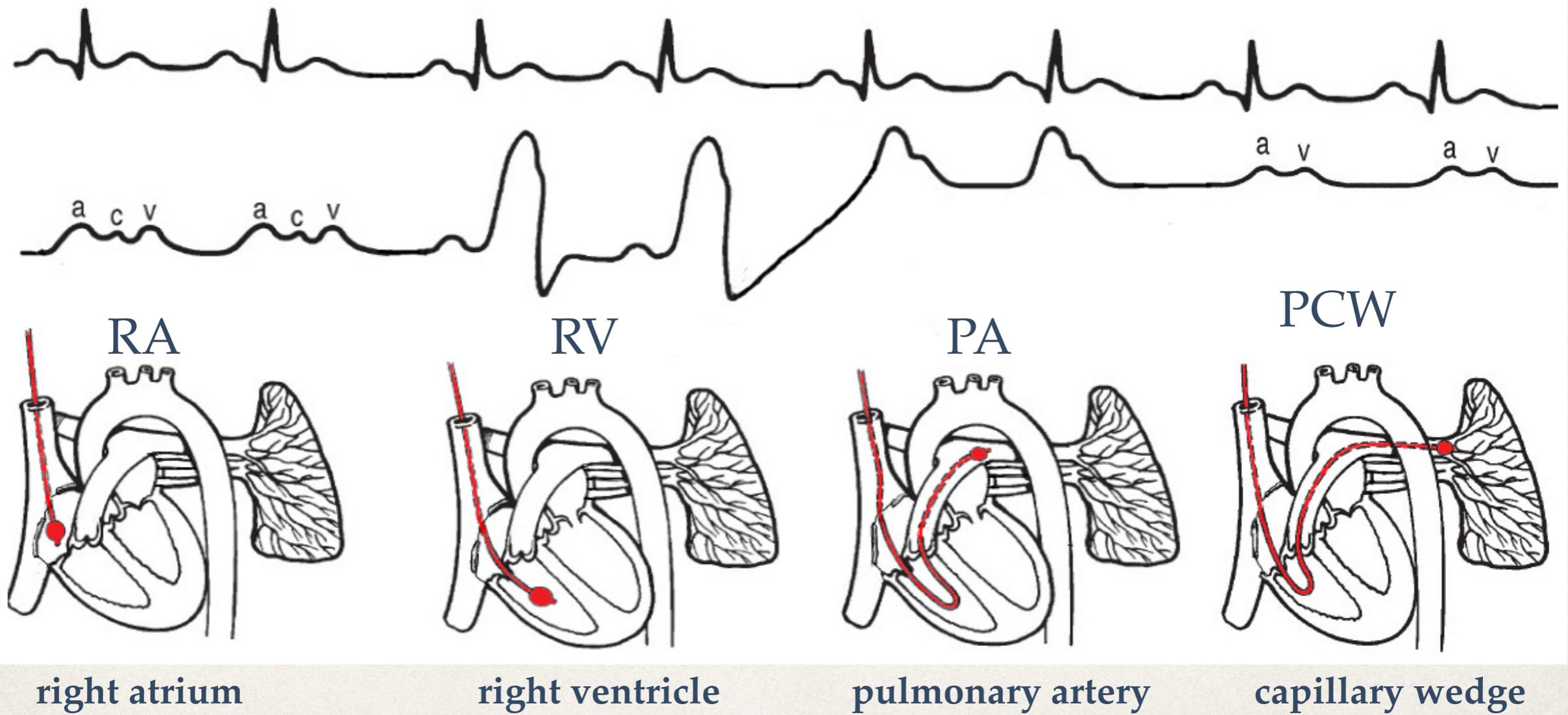


Pulmonary Artery Catheter



Pulmonary Artery Catheter

Pressure tracings of the right side of the heart (waveforms)



right atrium

right ventricle

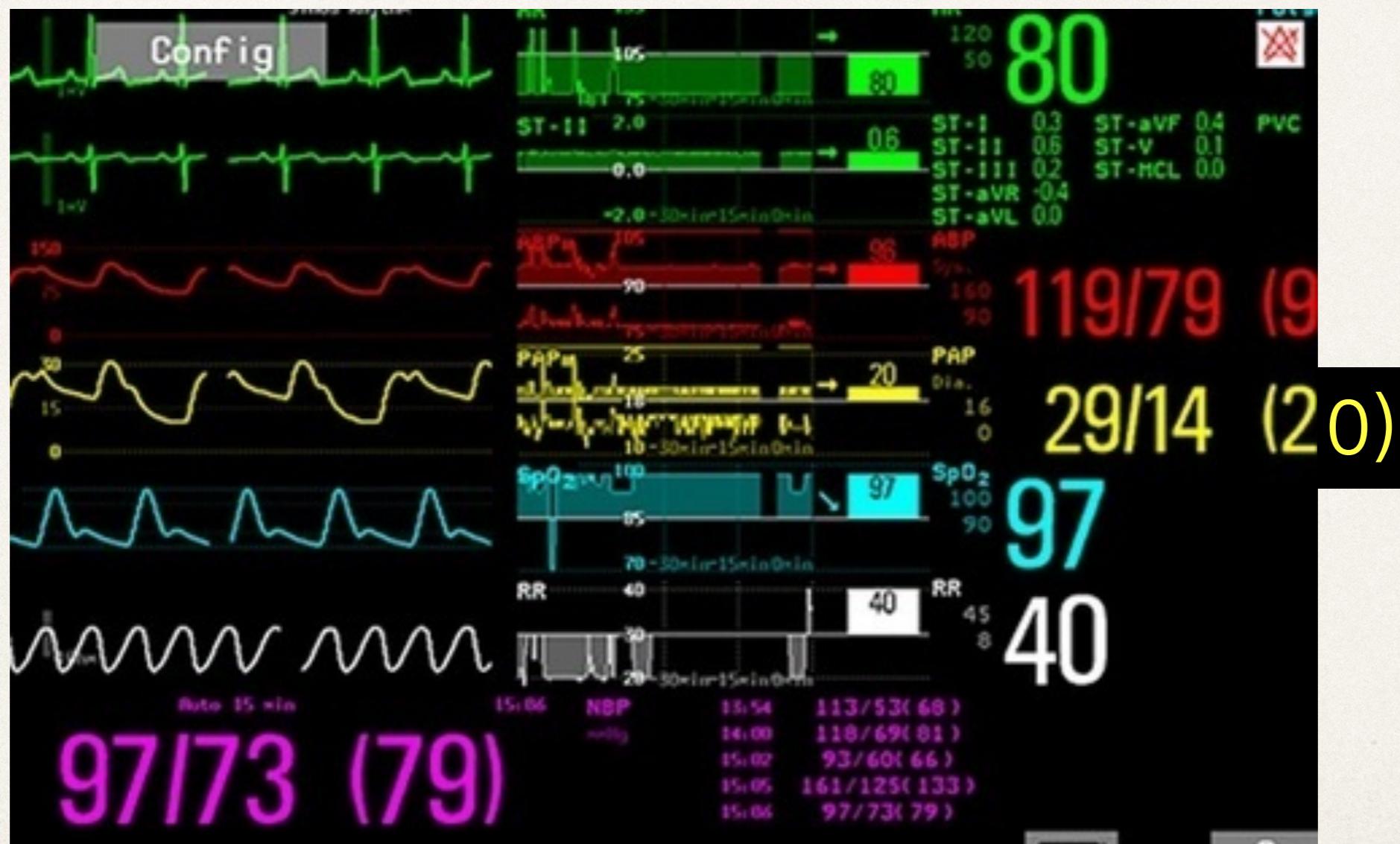
pulmonary artery

capillary wedge

Pulmonary Artery Catheter

- * Pt potentially hemodynamically unstable (often on bed rest) due to:
 - right ventricular failure
 - pulmonary hypertension
 - weaning failure of cardiac origin
 - post-cardiac surgery
 - pending heart transplants
- * Usually placed / used for few days, sometimes longer like when:
- * Pt needs continuous invasive monitoring, transplant-awaiting i.e. 1-2 wks (ok seated Thera-ex, bed to chair, rarely closely supervised on stationary bike)

Pulmonary Artery Catheter



Mobilizing with PAC

- ✿ When this line is present, mobilization, if necessary, must be undertaken by an experienced clinician after it has been determined that Pt is hemodynamically stable.
- ✿ PA line must be locked to prevent catheter tip from advancing
- ✿ Avoid ROM & therapeutic exercise to the ipsilateral shoulder. Movement of the PA line may cause arrhythmias, intravascular ulnar injury, or the line becomes dislodged
- ✿ Monitor the waveforms & Pt clinical response / appearance

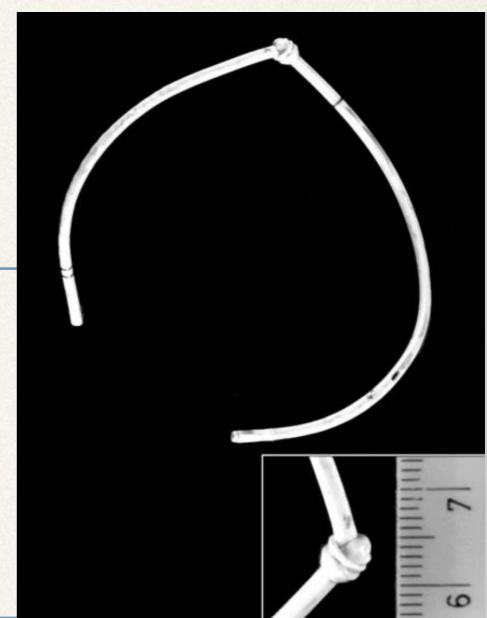
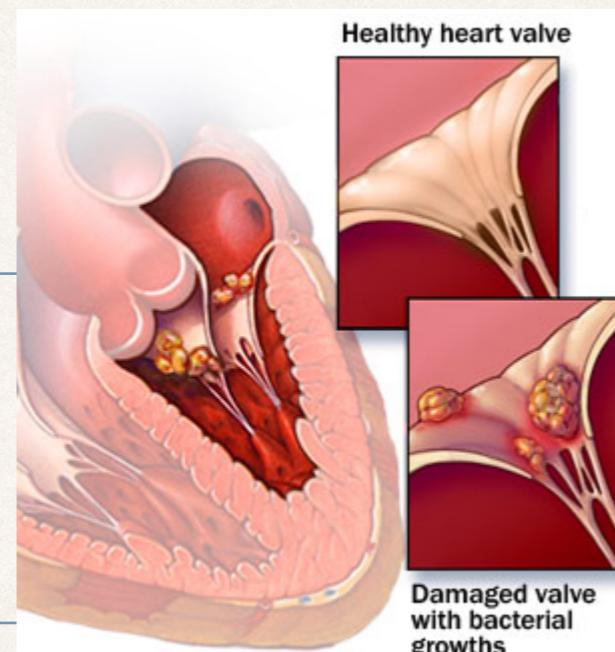
Complications

Vessel rupture - catheter tip advances into pulmonary artery

lethal arrhythmias if SA node stimulated, valve damage

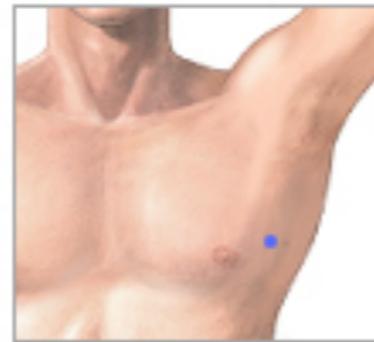
Air embolism, hypotension, hypoxia, pulmonary infarction

(Late) Knotting, endocarditis

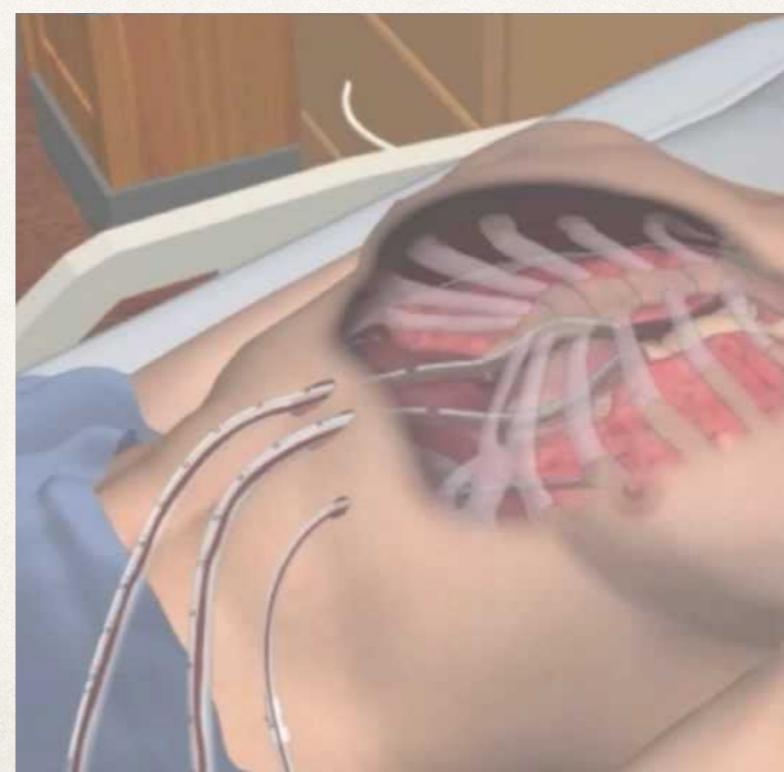
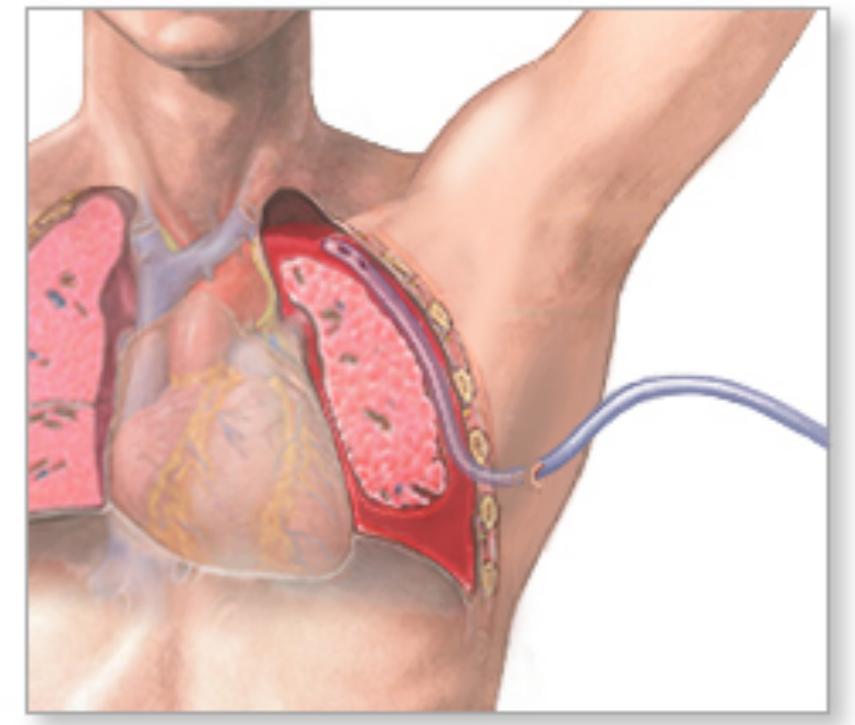


Chest Tubes

- ❖ large catheters placed in the thoracic cavity
- ❖ connected to a graduated collection reservoir at bedside
- ❖ used to prevent reentry or remove air or fluid from pleural or mediastinal space, and provide negative intrapleural pressure



Chest tube
drains blood
from the lungs



- Bleeding is common after cardiac surgery
- Chest tubes are necessary to evacuate the blood until coagulation is restored
- Adequate evacuation capacity is imperative to prevent retained blood in the pleural and pericardial spaces postoperatively

Chest Tubes

- ❖ Pneumothorax : Open or closed; simple or tension
- ❖ Hemothorax
- ❖ Hemopneumothorax
- ❖ Hydrothorax
- ❖ Chylothorax
- ❖ Empyema
- ❖ Pleural effusion
- ❖ Patients with penetrating chest wall injury who are intubated or about to be intubated.



Chest Tubes

Cardiac



- ✿ After thoracic surgery, chest tubes placed in mediastinum to drain the pericardium
- ✿ Expect 50-200 ml after surgery, and about 500 ml over the first 24 hours. **Report anything that exceeds 70 ml/hr** after that
- ✿ When mobilizing, ensure that the Pt is premedicated for pain. Don't be afraid to move the patient unless otherwise ordered, as **position changes are essential to facilitate drainage, help avoid complications, and help make Pt more comfortable**

Chest Tubes

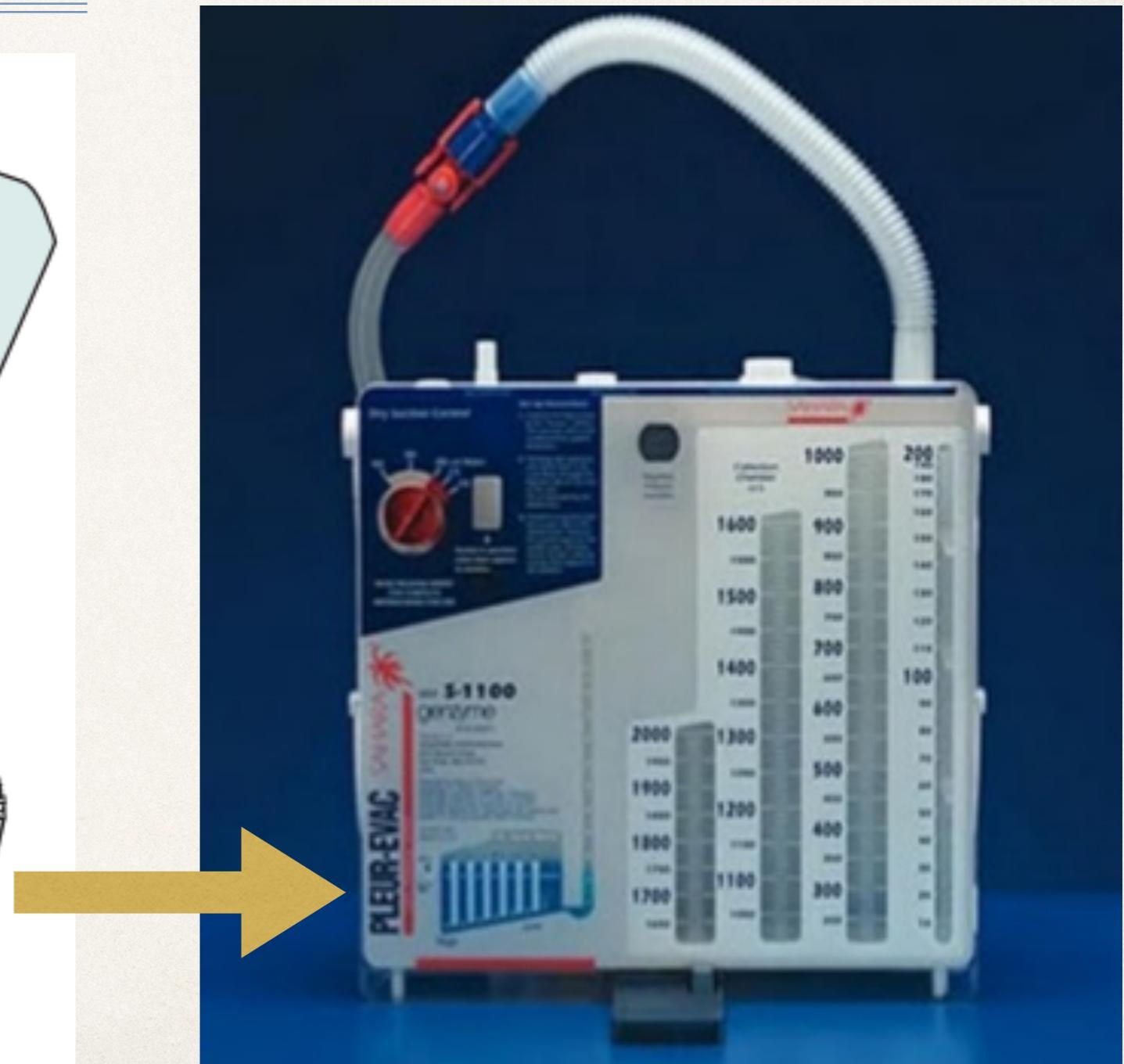
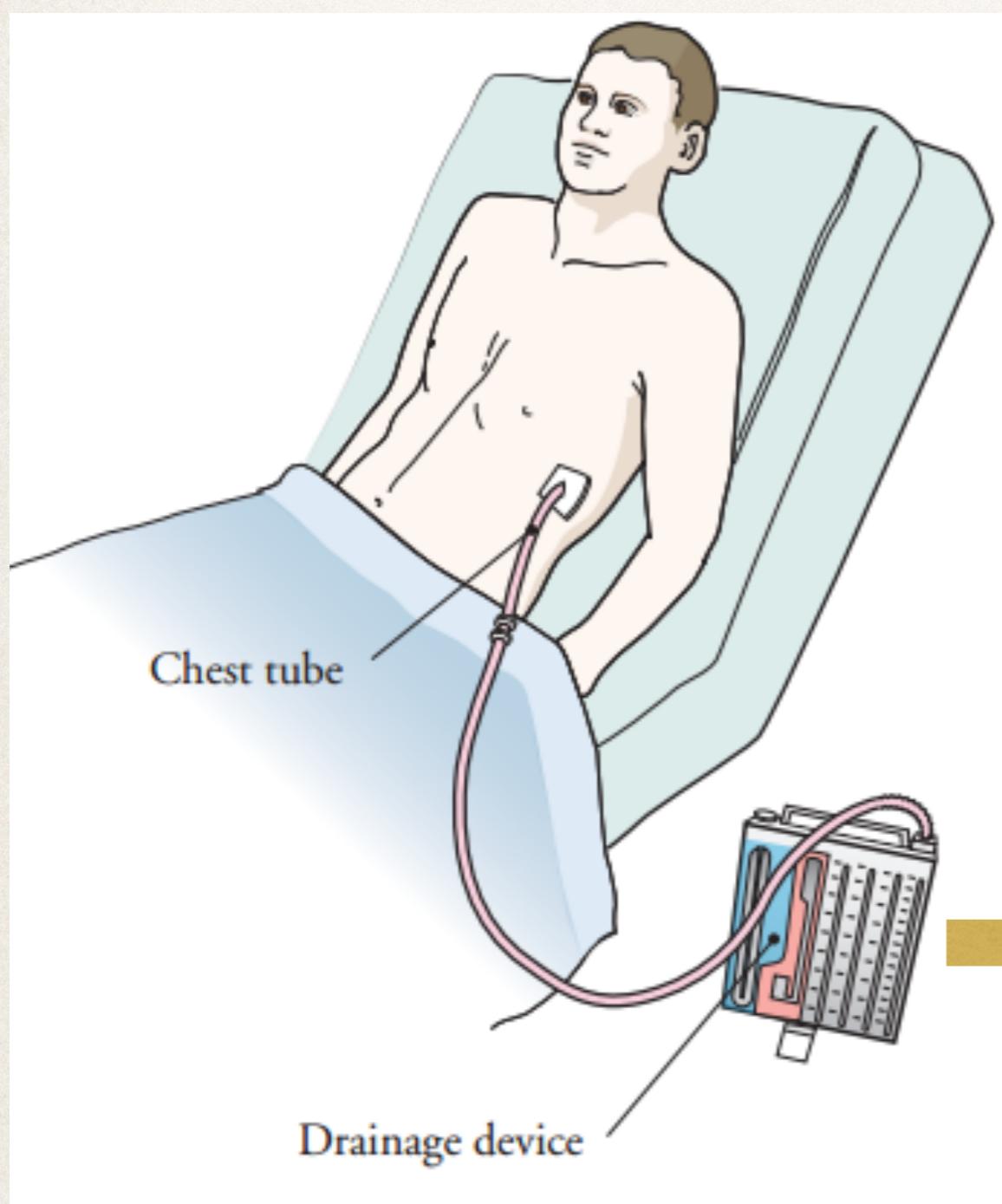
Pleural



- ✿ In non-surgical situations, commonly inserted in 6th ICS in mid, or posterior axillary line
- ✿ Apical chest tubes generally drain air
- ✿ Expect 100-300 ml during first 3 hrs after pleural insertion. It declines after 2 hrs, amounting to 500-1000 ml in first 24 hrs
- ✿ Crackling or "rice crispies" palpation near dressing or insertion site is a sign of subcutaneous emphysema. This is air that gets trapped beneath the skin. A possible cause of this is a poor seal at the chest-tube insertion site.



Chest Tubes



Mobilizing with Chest Tubes

- ✿ Ensure Pt is premedicated for pain
- ✿ Always keep chest tube drainage system below the chest level / incision, and ensure it is upright at all times, don't let it tip!
- ✿ Check for air leaks (air bubbles will be present in the underwater seal)
- ✿ Always discuss with MD or RN prior to disconnecting suction (i.e., wall vs water seal, clamping)
- ✿ After CT removed, HOLD therapy until radiograph rules out PTX.

Complications

Infection, sepsis - fevers, chills, hypotension, tachycardia, confusion

Pneumo/Hemothorax - dyspnea, hypoxia, tachycardia, restlessness, cyanosis, chest pain, dec. lung sounds, abrupt drop in Sp02 from BL / < 80%

Poor Tube placement - too far in, damaging other organs (lung, diaphragm, stomach), or too far out that it falls off

Arrhythmias, bleeding, hematomas

Indications of Respiratory Distress

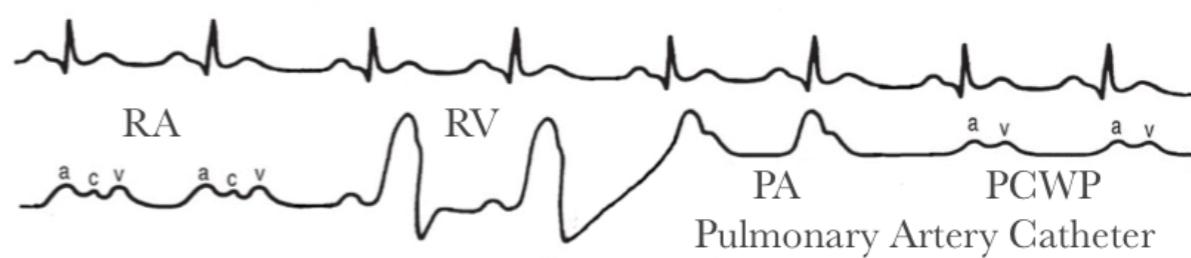
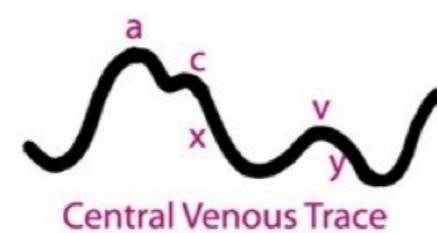
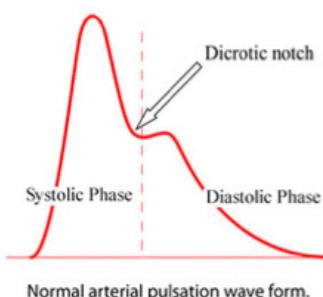
- ✿ Increased RR
- ✿ Nasal flaring
- ✿ Intercostal & sternal retractions
- ✿ Visible expression of distress
- ✿ Increased use of neck accessories
- ✿ Paradoxical breathing

Common Hemodynamic Parameters

<u>Parameter</u>	<u>Acronym</u>	<u>Normal Values</u>	<u>Clinical Significance</u>
Arterial Blood Pressures	BP, NBP, ABP	(mmHg)	too high: art. damage / rupture, cause aneurysms, over stretch heart too low: cause fainting (lack of blood to brain), can signify shock or anaphylaxis
Systolic BP	SBP	90-140	
Diastolic BP	DBP	60-80	
Right Atrial Pressure	RAP/CVP	0-8	> can indicate tamponade, tension pneumothorax, pleural effusion, PE, forced exhalation < can indicate hypovolemia, distributive shock, deep inhalation
Right Vent Systolic Pressure	RVs	15-30	> caused by left sided heart failure (from Mitral or Aortic regurg, CHF), PE < usually due to cardiomyopathy from failure, dilation, ischemia (MI)
Pulmonary Artery Pressures	PAP	8-20 (mean)	> SOB, fatigue, arrhythmias, weakness, dizziness (rest >25 or exs >30 = PAH)
Pulm Art Wedge Pressure (LV function estimation)	PWP, PCWP	4- 15 (mean)	> Left ventricle failure, mitral valve pathology, cardiac insufficiency, cardiac compression
Mean Arterial Pressure	MAP	70-110	> heart stressed, works harder, cause fatty deposits, lead to heart failure < lack of perfusion/blood flow causing shock, organ failure

Monitoring Equipment

	Indications	Mobilizing Precautions	Normal Values	Complications	Errors/Artifact
ECG	HR and rhythms	Keep leads and wires intact, observe for arrhythmias	sinus rhythm or Pt baseline between 60-100		movement & breathing rates
PULSE OXIMETRY	SpO2 (saturation of peripheral oxygen)	Keep sensors in contact with skin	>90%		poor pulse or waveforms, cold extremities, dark nail polish
ETCO2	respiratory depression monitoring	Capnography pattern, position of device so	35-45		correlate with RR or vent settings
Arterial Line	continuous, real time BP monitoring, blood gas monitoring	avoid mobilizing if on high dose pressors, no ambulation	SBP 90-140/DBP 60-80, (MAP 70-110)	hemorrhage, ischemia, thrombosis, embolism, vessel rupture	transducers too high/low (dampened tracings), bubbles/kinks in line
Central Line	IV access for meds/blood/TPN/dialysis, other procedures, continuous CVP/RAP (fluid status)	check for pressor dose, femoral lines ok to dangle/stand bedside, no ambulation	CVP 3-8, RAP 0-8	PTX, HTX, arrhythmias, infections, hemorrhage	
Pulmonary Artery Catheter	continuous direct measurement of RAP-PAP-PCWP (heart status), SvO2, allows AV pacing	Locked PA line, avoid ROM/Exs to ipsi shoulder, determine hemodynamic stability	PAs 15-30/PAd 5-15, mean PAP (8-20)	vessel rupture, lethal arrhythmias, valve damage, air embolism	
Chest Tubes	PTX, HTX, Empyema, pericardial/pleural effusion	drainage system below incision/chest level, HOLD therapies after removal until PTX r/o	check parameters/output ranges in chart	PTX, HTX, bleeding, infection	



Evidence-Based Practice

Mobilizing patients in ICU is safe, feasible and improves physical function, and continue improvement post-discharge. It can also reduce length of hospital stay and costs.

- ✿ Bailey P . Crit Care Med. 2007 Jan;35(1):139-45
- ✿ Morris PE. Crit Care Med. 2008 Aug;36(8):2238-43
- ✿ Schweickert WD. Lancet. 2009 May ; 373:1874-1882

Take-Away!

Use monitoring to identify cardio-pulmo dysfunction that may contribute to hypoxemia (instability) when mobilizing.

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