Monitoring

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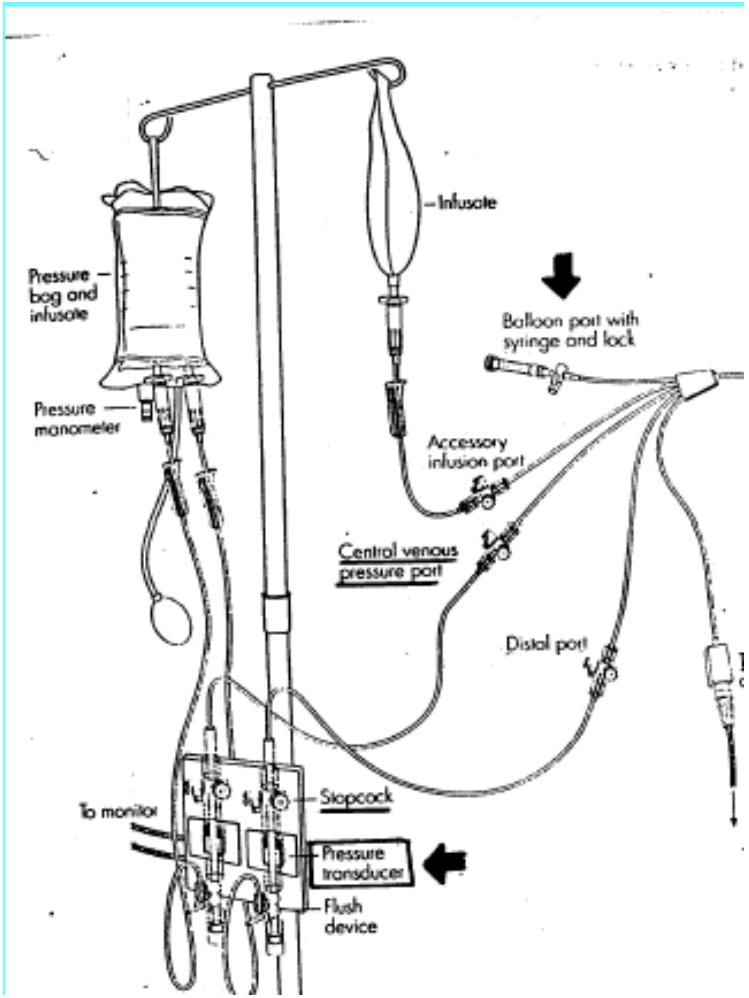
LEARNING OUTCOMES

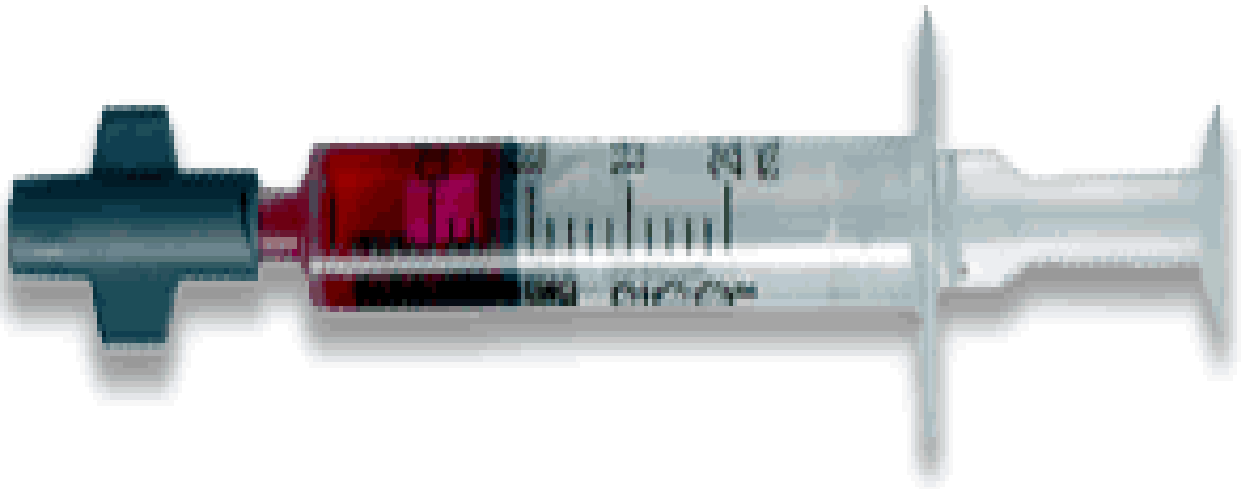
- Identify a Central Line and Arterial Line
- Discuss the indications for Central lines and Arterial Lines
- Discuss the complications associated with Central lines and Arterial lines
- Articulate the management of a patient with a Central line and/or Arterial line.

CVP and Arterial Monitoring



Direct Arterial Monitoring

- Arterial cannulation w/ continuous pressure waveform display remains the accepted standard for BP monitoring



Indications and Advantages

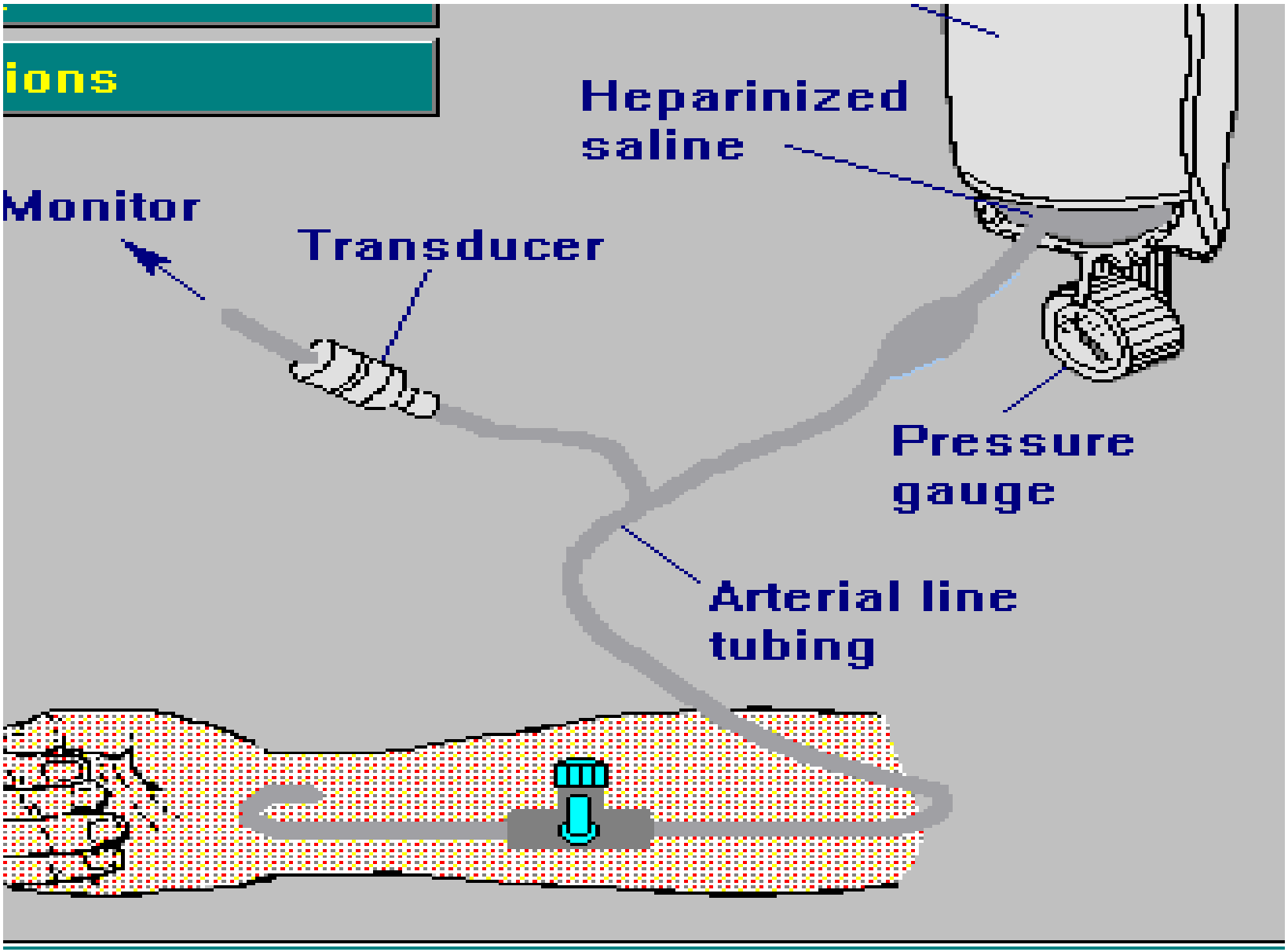
- Frequent ABG's
- Continuous real-time monitoring when rapid, moment-to-moment BP
- Changes are anticipated, i.e. CV instability, major fluid shifts or EBL
- Failure of indirect BP monitoring i.e. morbid obesity, burned extremity
- Deliberate induced hypotension
- Cardiac surgery for cardiopulmonary bypass
- Major vascular surgery
- Administration of vasoactive drug infusions

WHAT IS AN ARTERIAL LINE?

- AN ARTERIAL LINE IS A CANNULA USUALLY POSITIONED IN A PERIPHERAL ARTERY

SUCH AS:

- Radial artery
- brachial artery
- dorsalis pedis artery
- femoral artery


ions
Heparinized saline
Monitor
Transducer
Pressure gauge
Arterial line tubing

THE ARTERIAL WAVEFORM

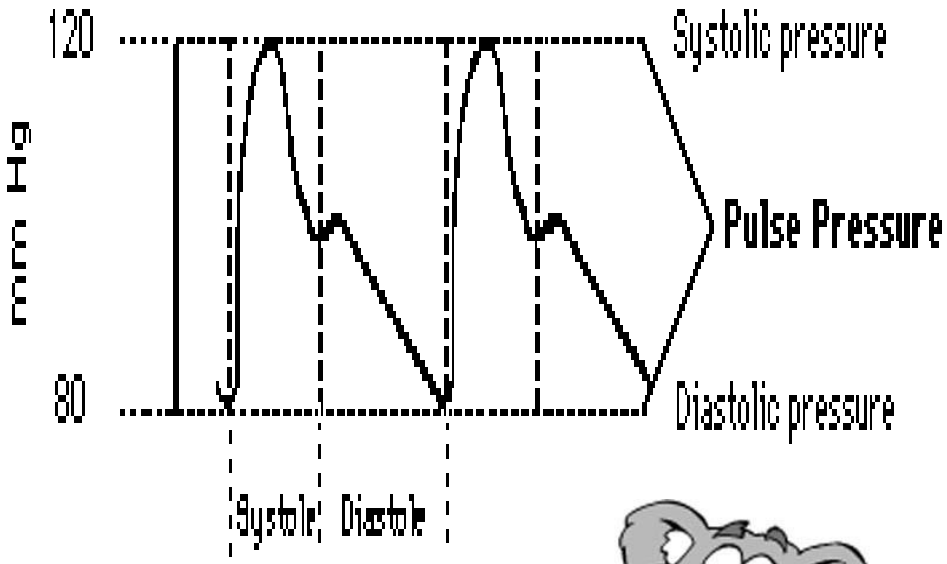
- The arterial waveform reflects the pressure generated in the arteries following ventricular contraction and can be described as having:-

  Anacrotic notch-

  Peak systolic pressure- maximum left ventricular systolic pressure

  Dicrotic notch-reflects the closure of the aortic valve caused by a rise in pressure in the aorta.

  Diastolic pressure-related to the degree of vasoconstriction in the arterial system



Natural Frequency and Damping

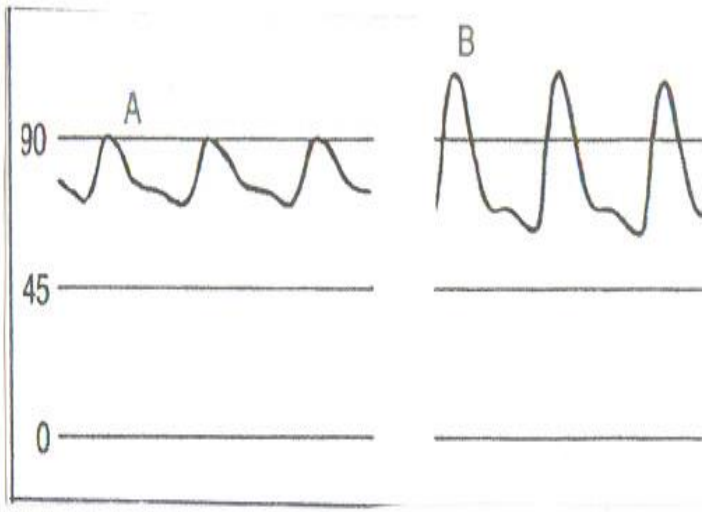
- Left ventricular ejection initiates a pressure wave that is propagated down the aorta toward the periphery
- The arterial BP waveform is a periodic complex wave, reproduced by Fourier analysis : a technique that recreates the original pressure wave by summing a series of simple sine waves of various amplitudes and frequencies
- The original pressure wave has a characteristic periodicity that is called the ***Fundamental Frequency***, which is equal to the pulse rate
- Each measuring system has a natural frequency about which it can oscillate

Natural Frequency and Damping

- If the frequency of the monitored pressure waveform approaches the natural frequency of the measuring system, the system will resonate and pressure waveforms recorded on the monitor will appear exaggerated (Resonance or Ringing)
- **Damping** prevents a system from overshooting after responding to a change, particularly at frequencies close to the natural frequency of the system

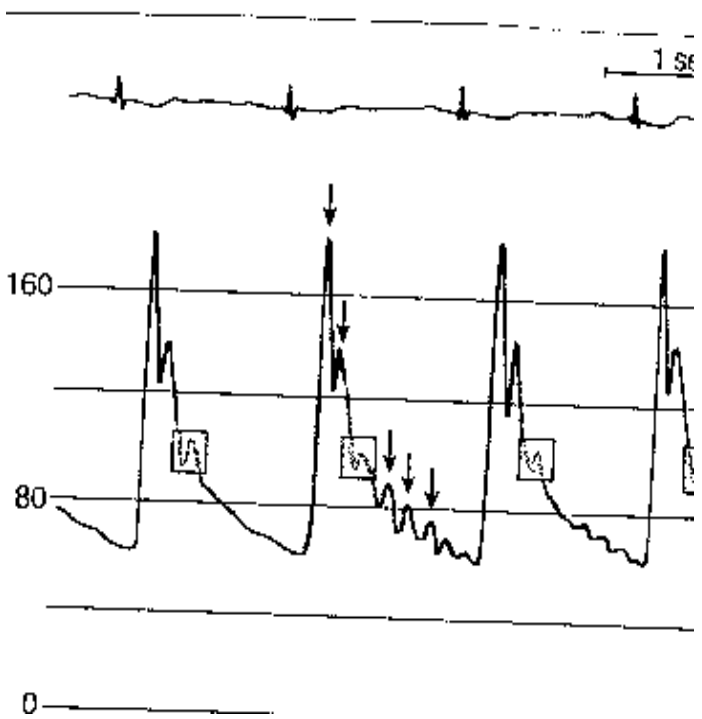
Overdamping

- **Overdamping** causes slurred upstroke, absent dicrotic notch, and loss of fine detail
- Causes include blood clots, air bubbles in the tubing, and kinked catheters



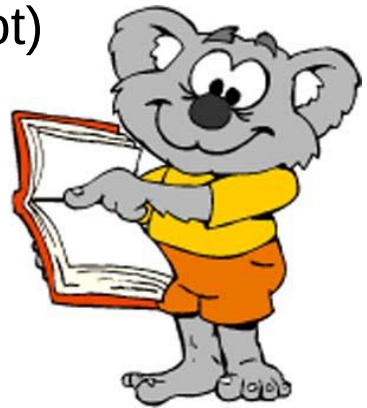
Underdamping

- **Underdamping** produces exaggerated peaks and troughs in the waveform
- It can cause falsely high systolic pressures and low diastolic pressures
- Causes include long connecting lines (>1.4 mm), small tubing (<1.5 mm internal diameter), or when the catheter occlude the vessel



Transducer Leveling and Zeroing

- The pressure transducer is exposed to atmospheric pressure to establish the zero pressure reference value against which all intravascular pressures are measured
- In the supine patient, pressure transducers are leveled most often to the midchest position in the midaxillary line
- In other than supine positions (head injuries, CHF etc.), the transducer should be placed at the level of the aortic root (Chest 2001;120:1322-1326)
- The principle behind this is that the proper level for a transducer to negate the effects of hydrostatic pressure is always at the top of the fluid column in the system being analyzed (ie. Aortic root)

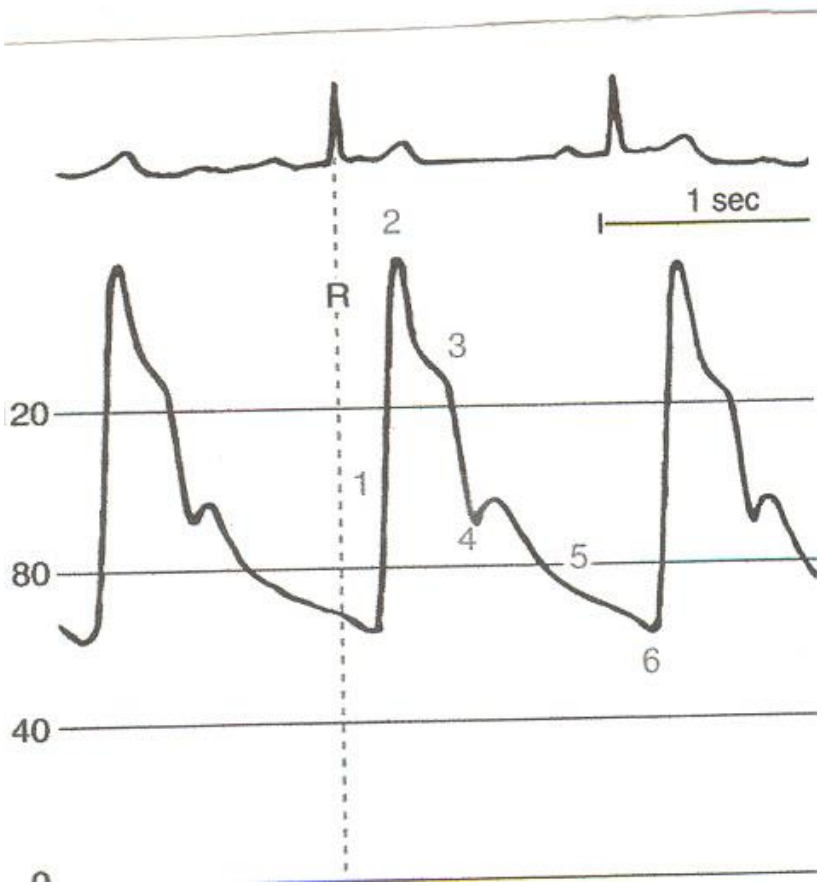


continued

- The central MAP and particularly the aortic mean is the key component in coronary and cerebral perfusion as well as the pressure that is sensed by baroreceptor mechanisms
- This is the pressure that is indirectly measured using standard noninvasive BP techniques

The Arterial Waveform in relation to the EKG

1. Systolic Upstroke
2. Systolic Peak Pressure
3. Systolic Decline
4. Dicrotic Notch
5. Diastolic Runoff
6. End-diastolic Pressure



Comparative Analysis of Different Sites

	Brachial	Radial	Axillary	Femoral
Ease of cannulation	No data obtained	Less difficult in normotension, although hypotension and vasoconstriction may render cannulation difficult	Technically difficult, although pulsation and pressure are maintained even with peripheral vascular collapse	Less difficult, can be cannulated, even during profound hypotension
Collateral circulation	Lacks the anatomic benefit of collateral circulation	Dual circulation in most of the population	Extensive collateral circulation	Collateral circulation exists via a number of anastomoses
Inadvertent neural or adjacent structure injury	Damage to the median nerve may result in appreciable long-term disability	Carpal tunnel or sympathetic-mediated pain syndrome from median or radial nerve pressure or from blood extravasation into palmar sheath	Axillary sheath rapidly fills with blood; nerve damage and neuropathy secondary to brachial plexus compression	Potential for extraperitoneal hemorrhage from too high an entry site; vascular injury from femoral common branch entry; hematoma formation
Thrombogenicity	High risk; thrombotic sequelae may be profound	High risk, smaller arterial lumen associated with increased risk of thrombosis	Less risk; catheter at this site poses little risk if thrombosis occurs	Less risk; large intraluminal diameter and high rate of flow discourage thrombus formation
Accuracy of waveform	Substantial difference in contour and amplitude of ascending aortic and brachial waveform	Substantial difference in contour and amplitude of ascending aortic and radial waveforms	Proximity to aortic arch allows a reliable waveform, even during profound vasoconstriction	Morphologically reliable waveform
Accuracy of physiological data	Subject to inaccuracy inherent in distal location; overestimates systolic blood pressure; may be more accurate than radial approach	Subject to inaccuracy inherent in distal location; overestimates systolic blood pressure; underestimates central aortic pressure	More accurately reflects systolic blood pressure	More accurately reflects systolic blood pressure

Complications

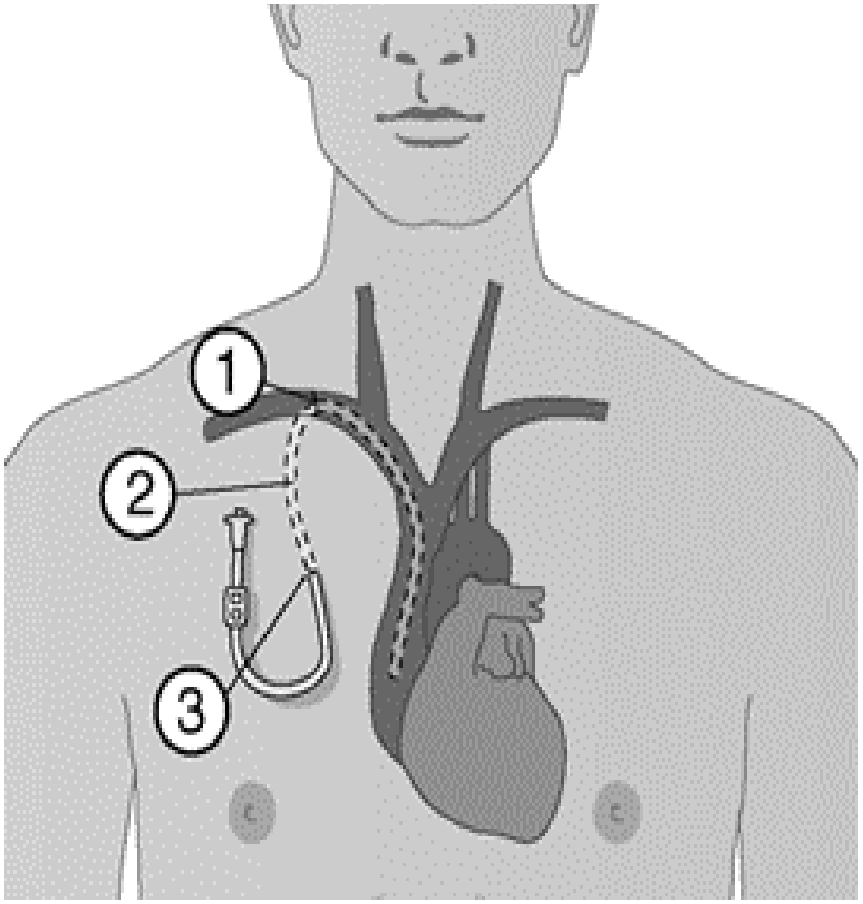
- Ischemia
- Hemorrhage
- Thrombosis
- Embolism
- Cerebral air embolism (retrograde flow assoc. w/ flushing)
- Aneurysm formation
- Arteriovenous Fistula formation
- Skin necrosis
- Infection (Stopcocks are an important source)

REMOVAL OF ARTERIAL LINE

- THIS IS AN ASEPTIC PROCEDURE
- REMEMBER UNIVERSAL PRECAUTIONS
- THE PROCEDURE SHOULD BE EXPLAINED TO THE PATIENT
- TAKE DRESSING OFF LINE
- REMOVE ARTERIAL LINE ENSURING THAT THE ENTRY SITE IS COVERED WITH GAUZE
- APPLY DIGITAL PRESSURE FOR AT LEAST 5 MINUTES TO ENSURE HAEMOSTASIS
- DRESS SITE WITH GAUZE AND MICROPORE
- ASSESS THE PERIPHERAL CIRCULATION AS THROMBOSIS CAN OCCUR AFTER REMOVAL

WHAT IS A CENTRAL LINE

- It is a catheter that provides venous access via the superior vena cava or right atrium



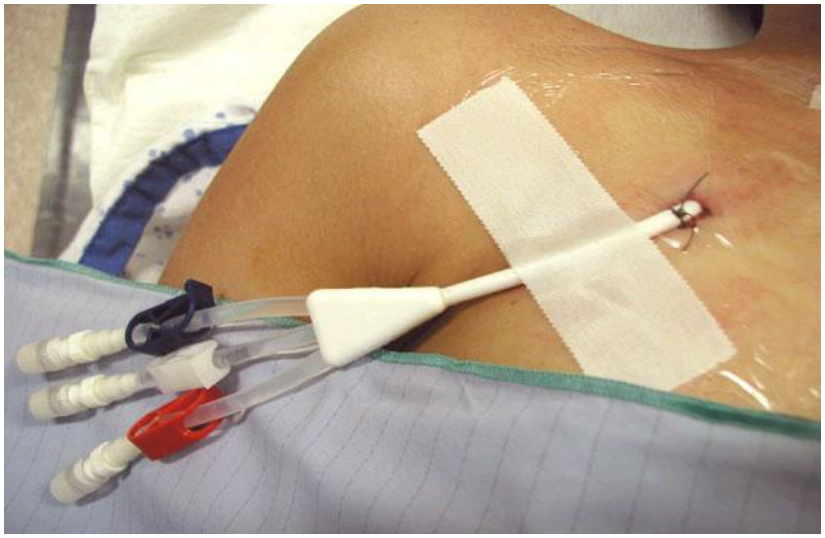
COMMON CENTRAL LINE INSERTION SITES

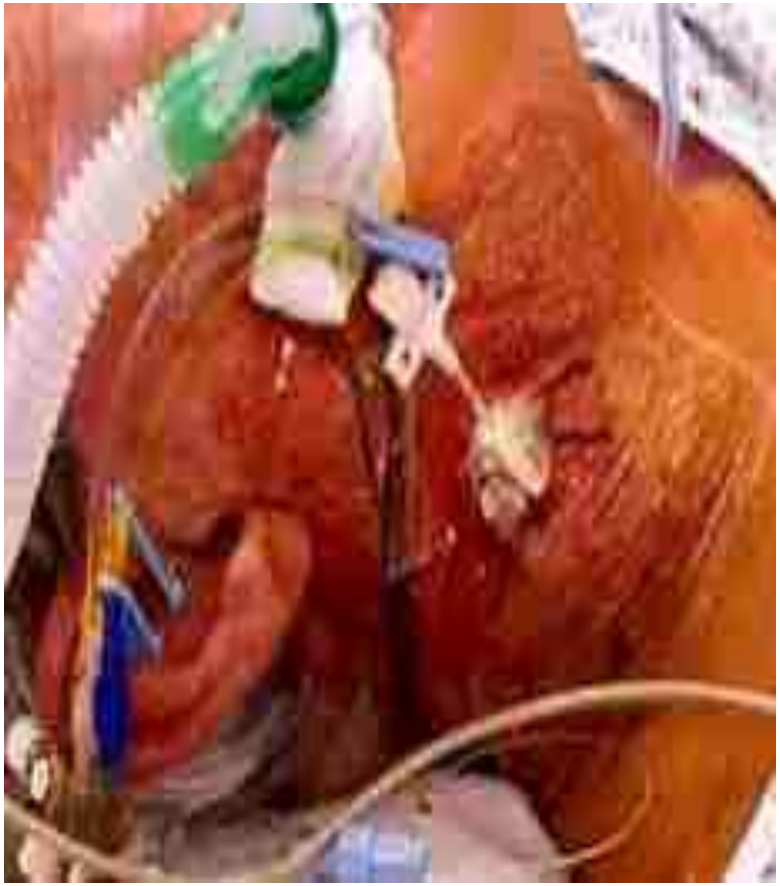
- Right internal jugular
- left internal jugular
- right subclavian
- left subclavian
- femoral (as a last resort)

- Or peripherally inserted central catheters (PICC) which are inserted via the antecubital veins (basilic vein is the best) in the arm and is advanced into the central veins

TYPES OF CENTRAL LINE

- SINGLE LUMEN
- TRIPLE LUMEN
- QUADRUPLE LUMEN
- QUINTUPLE LUMEN





COMPLICATIONS FOLLOWING CVP LINE INSERTION

- Malposition of the catheter
- haematoma
- arterial puncture
- pneumothorax
- haemorrhage
- sepsis
- air emboli
- Catheter embolism
- Thrombosis
- Haemothorax
- Cardiac tamponade
- Cardiac arrhythmias

WHAT IS CENTRAL VENOUS PRESSURE

- IS THE PRESSURE WITHIN THE SUPERIOR VENA CAVA OR THE RIGHT ATRIUM

CVP READINGS ARE USED:-

- TO SERVE AS A GUIDE TO FLUID BALANCE IN CRITICALLY ILL PATIENTS
- TO ESTIMATE THE CIRCULATING BLOOD VOLUME
- TO ASSIST IN MONITORING CIRCULATORY FAILURE

Indications for CVP

- Central Venous Pressure Monitoring
- Pulmonary artery catheterization and monitoring
- Transvenous cardiac pacing
- Temporary hemodialysis
- Drug administration:
  - Concentrated vasoactive drugs
  - Hyperalimentation
  - Chemotherapy
  - Agents irritating to peripheral veins
- Rapid infusion of large volumes : Trauma and Major surgery
- Aspiration of Air Emboli
- Inadequate peripheral IV access
- Sampling site for repeated blood testing

CENTRAL VENOUS PRESSURE MONITORING

- THIS IS A HELPFUL TOOL IN THE ASSESSMENT OF CARDIAC FUNCTION, CIRCULATING BLOOD VOLUME, VASCULAR TONE AND THE PATIENT'S RESPONSE TO TREATMENT
- HOWEVER, CVP SHOULD NOT BE INTERPRETED SOLELY BUT IN CONJUNCTION WITH OTHER SYSTEMIC MEASUREMENTS, AS ISOLATED CVP MEASUREMENTS CAN BE MISLEADING

METHODS OF CVP MONITORING

- There are two methods of CVP monitoring
  - *manometer system:* enables intermittent readings and is less accurate than the transducer system
  - *transducer system:*enables continuous readings which are displayed on a monitor.

MONITORING WITH TRANSDUCERS

- Transducers enable the pressure readings from invasive monitoring to be displayed on a monitor
- To maintain patency of the cannula a bag of normal saline or heparinised saline should be connected to the transducer tubing and kept under continuous pressure of 300mmHg thus facilitating a continuous flush of 3mls/hr

PROCEDURE FOR CVP MEASUREMENT USING A TRANSDUCER

- EXPLAIN THE PROCEDURE TO THE PATIENT
- ENSURE THE LINE IS PATENT
- POSITION THE PATIENT SUPINE (IF POSSIBLE) AND ALIGN THE TRANSDUCER WITH THE MID AXILLA (LEVEL WITH THE RIGHT ATRIUM)
- ZERO THE MONITOR
- OBSERVE THE CVP TRACE
- DOCUMENT THE READING AND REPORT ANY CHANGES OR ABNORMALITIES

MONITORING WITH TRANSDUCERS

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What does this number mean?

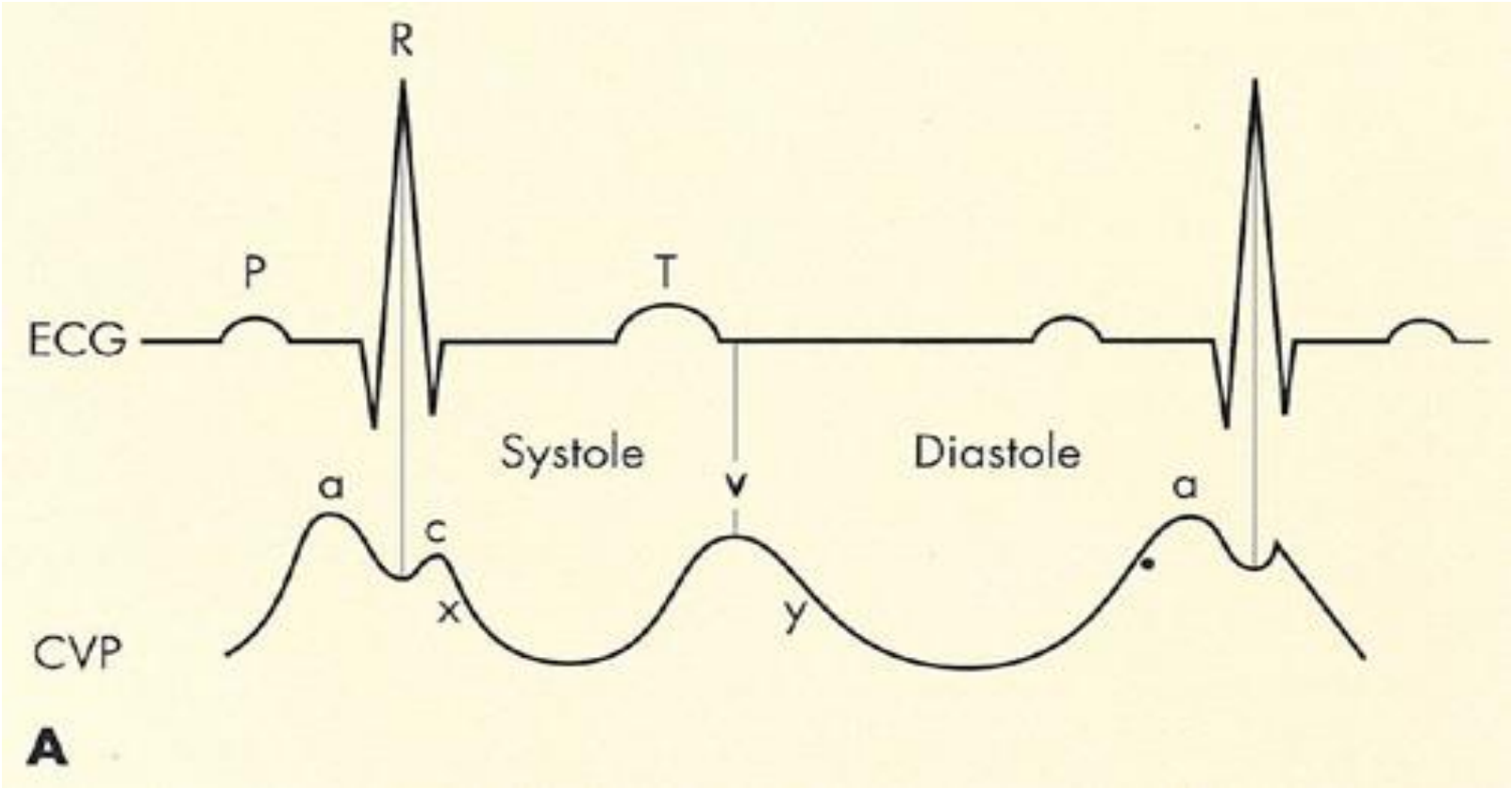
- CVP is a measure of the pressure in the right atrium, which reflects changes in right ventricular end-diastolic pressure
- Estimates cardiac function and blood volume. It does not measure either of these directly - it must be interpreted!
- Determined by the function of the right heart and the pressure of venous blood in the vena cava

CVP and Left Heart Pressures

- In a normal patient the CVP closely resembles the left atrial pressure and can be used to estimate it
- This depends on the assumption that there is no right ventricular disease and normal pulmonary vascular resistance

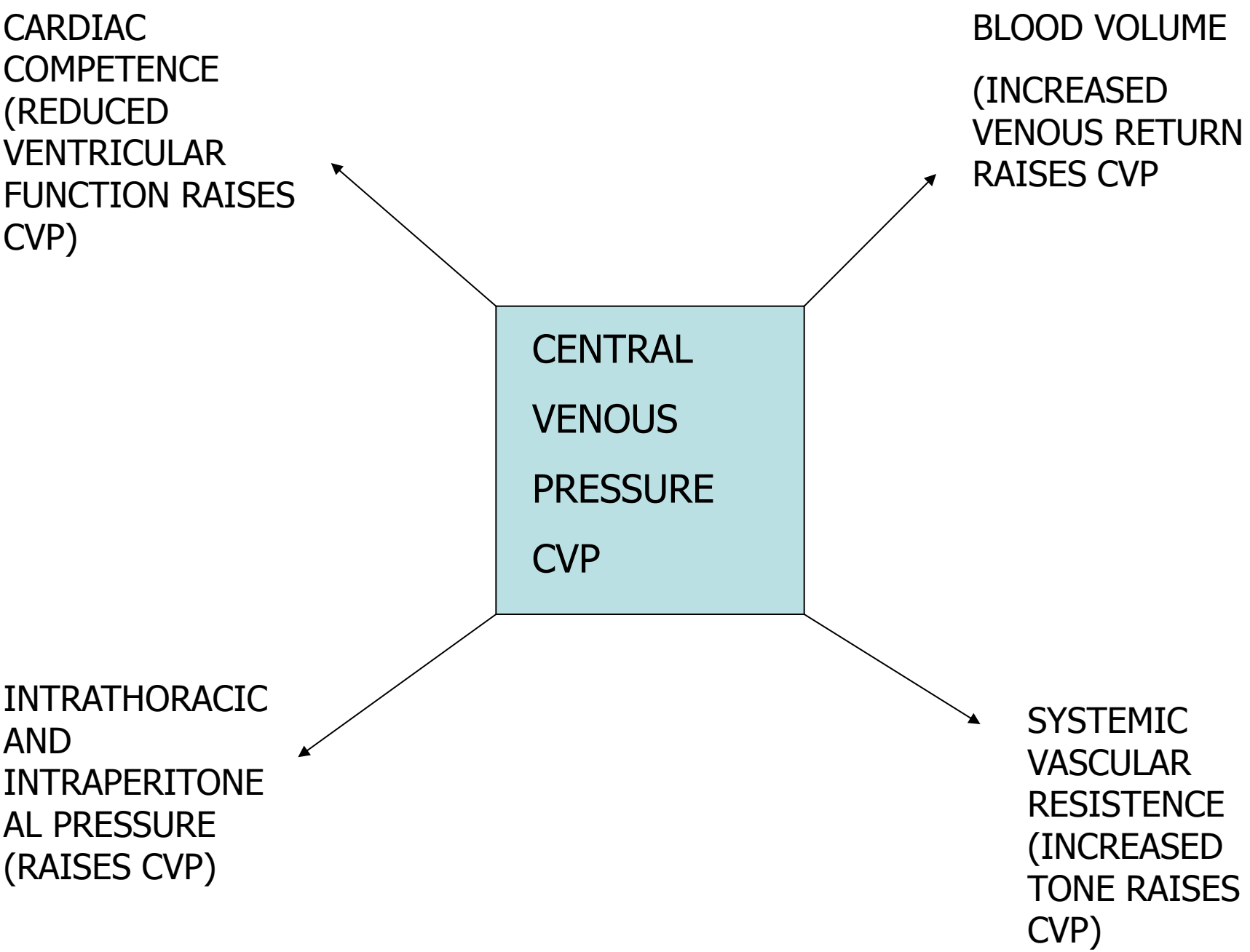
THE CVP WAVEFORM

- The CVP waveform reflects changes in right atrial pressure during the cardiac cycle



NORMAL CVP MEASUREMENTS

- Central venous presure monitoring should normally show measurements as follows:
- Mid Axilla: 0 - 8 mmHg (Woodrow 2000)
- An isolated CVP reading is of limited value; a trend of readings is much more significant and should be viewed in conjuncton with other parameters e.g. BP and urine output.


CARDIAC COMPETENCE (REDUCED VENTRICULAR FUNCTION RAISES CVP)
BLOOD VOLUME
(INCREASED VENOUS RETURN RAISES CVP
CENTRAL VENOUS PRESSURE CVP
INTRATHORACIC AND INTRAPERITONEAL PRESSURE (RAISES CVP)
SYSTEMIC VASCULAR RESISTENCE (INCREASED TONE RAISES CVP)

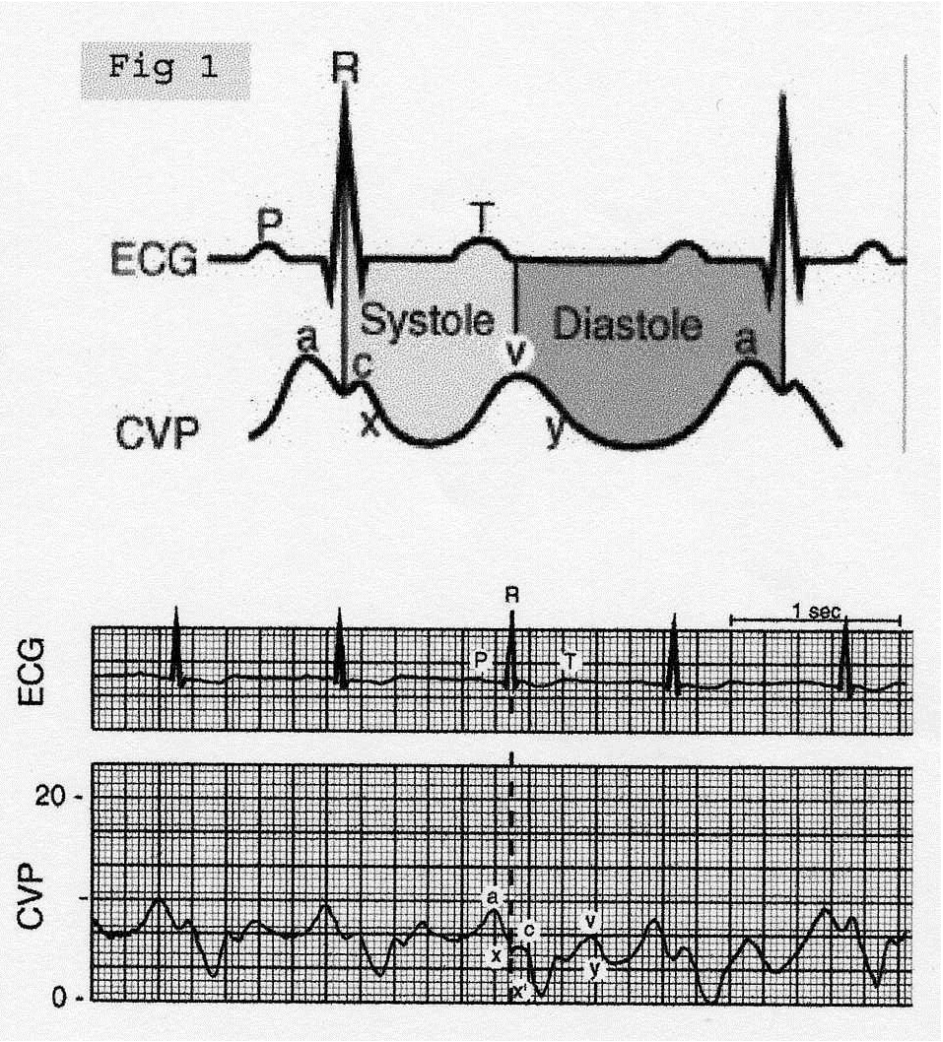
MANAGEMENT OF A PATIENT WITH A CVP LINE

- Monitor the patient for signs of complications
- Label CVP lines with drugs/fluids etc. being infused in order to minimise the risk of accidental bolus injection
- If not in use, flush the cannula regularly to help prevent thrombosis. A 500ml bag of 0.9% normal saline should be maintained at a pressure of 300mmHg.

- Ensure all connections are secure to prevent exsanguination, introduction of infection and air emboli
- Observe the insertion site frequently for signs of infection.
- The length of the indwelling catheter should be recorded and regularly monitored.
- CVP lines should be removed when clinically indicated

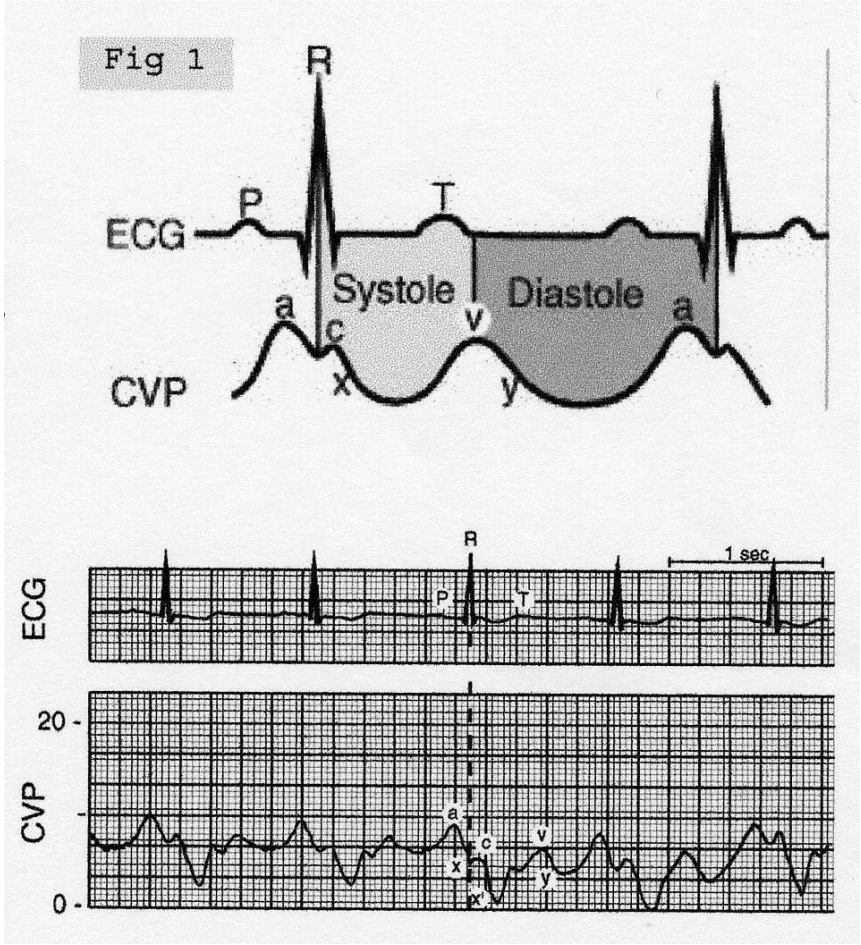
CVP Waveform

- Three Peaks (a, c, v)
- Two Descents (x, y)



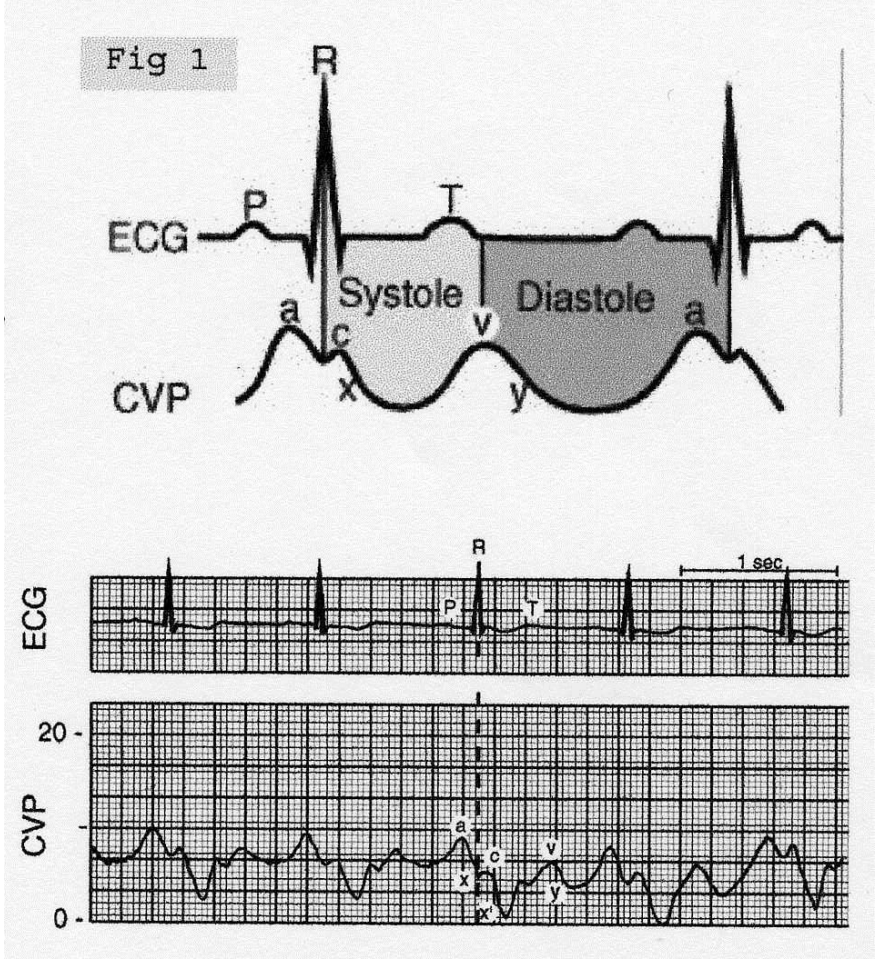
“a” wave

- Caused by atrial contraction (follows the P-wave on EKG)
- End diastole
- Corresponds with “atrial kick” which causes filling of the right ventricle

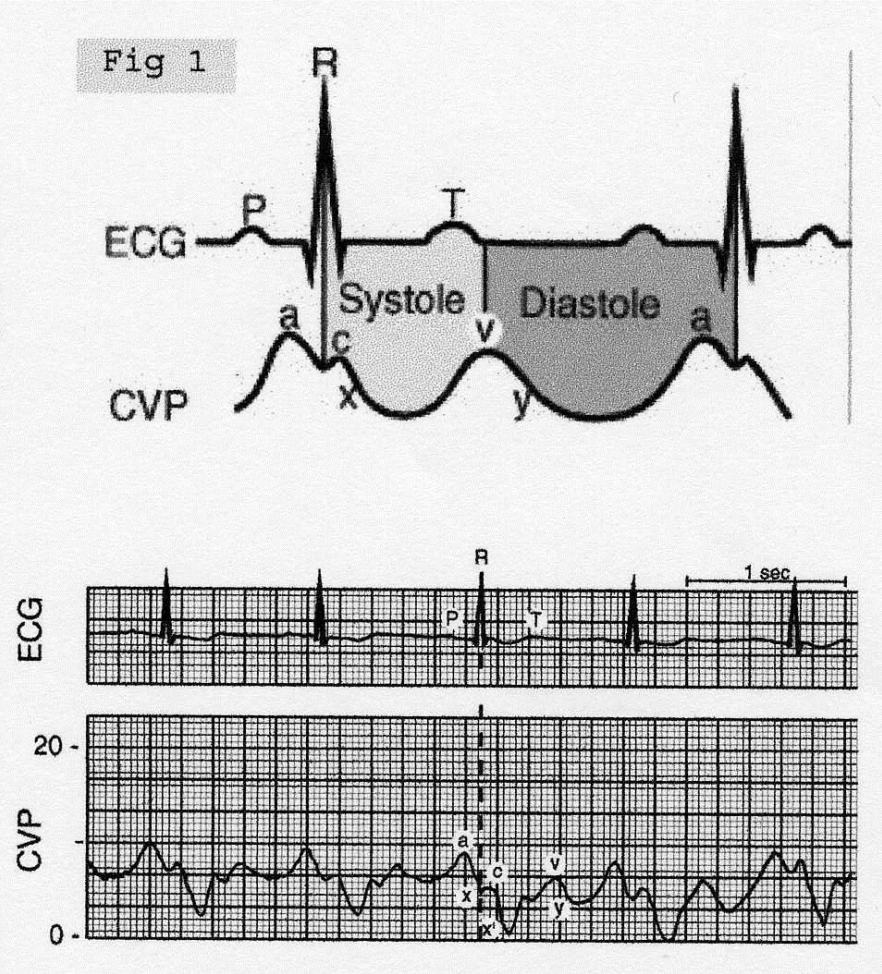


“c” wave

- Atrial pressure decreases after the “a” wave as a result of atrial relaxation
- The “c” wave is due to isovolemic right ventricular contraction; closes the tricuspid valve and causes it to bow back into the right atrium
- Occurs in early systole (after the QRS on EKG)



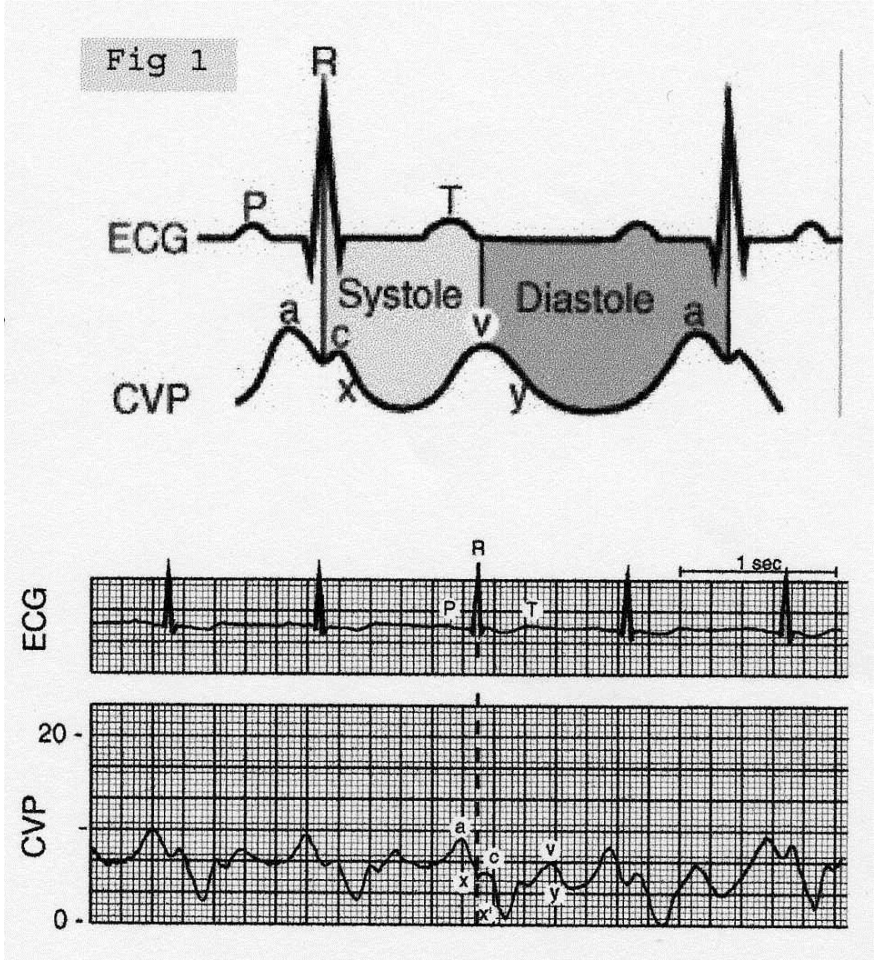
“x” descent



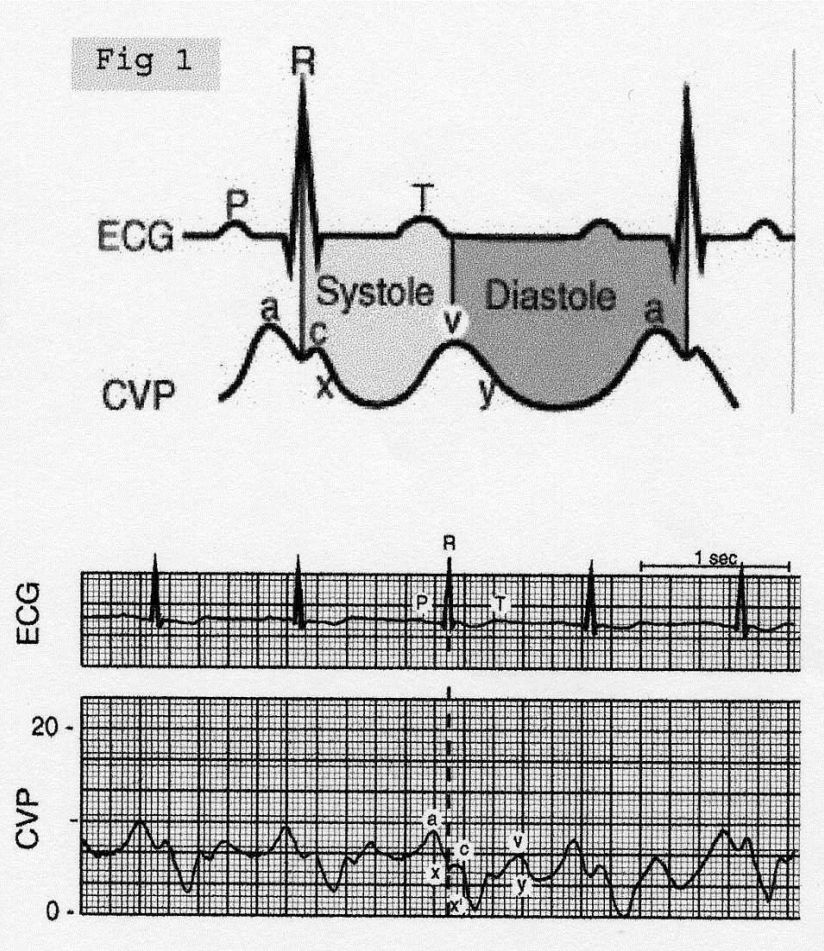
- Atrial pressure continues to decline due to atrial relaxation and changes in geometry caused by ventricular contraction
- Mid-systolic event
- “Systolic collapse in atrial pressure”

“v” wave

- The last atrial pressure increase is caused by filling of the atrium with blood from the vena cava
- Occurs in late systole with the tricuspid still closed
- Occurs just after the T-wave on EKG



“y” descent



- Decrease in atrial pressure as the tricuspid opens and blood flows from atrium to ventricle
- “Diastolic collapse in atrial pressure”

Measuring CVP

- The peak of the “a” wave coincides with the point of maximal filling of the right ventricle
- Therefore, this is the value which should be used for measurement of RVEDP
- Machines just “average” the measurement
- Should be measured at end-expiration

Respiratory Effects

- During spontaneous ventilation, a decrease in pleural and pericardial pressures occurs during inspiration - these are pressures that are transmitted to the right atrium
- This causes a decrease in the measured CVP (but transmural pressure may actually INCREASE)
- Mechanical ventilation causes the opposite effect during an forced inspiratory breath

Respiratory Effects (cont.)

- Pleural and pericardial pressures are almost equal to atmospheric pressure at end-expiration
- This is true with both spontaneous and mechanical ventilation
- This point in time provides the best estimate for transmural pressure and cardiac preload

Things to remember…

- There are three parts of the waveform that are systolic events (c, x, v)
- There are two parts of the waveform that are diastolic events (a, y)
- The EKG is used as a reference to properly identify the parts of the waveform
- The terms systole and diastole refer to VENTRICULAR events only

Things to remember…

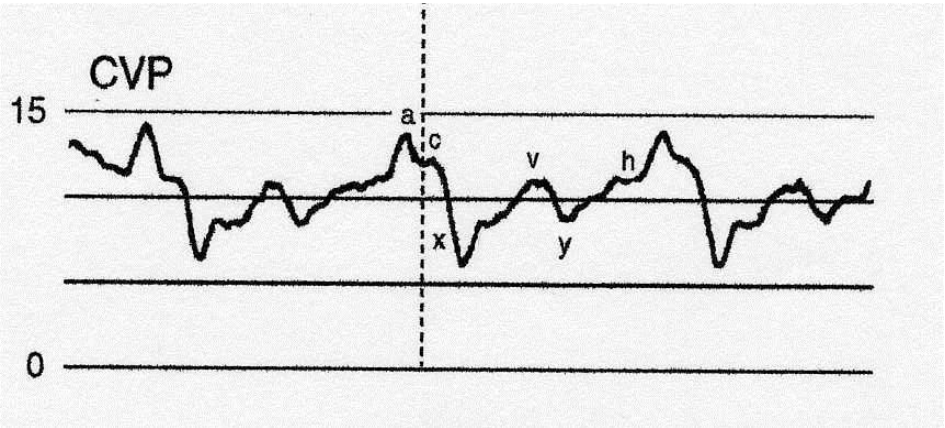
- The CVP wave represents changes in pressure, not changes in volume
- Mnemonic for the CVP wave
  - "a" wave due to atrial contraction
  - "c" wave due to tricuspid closure and ventricular contraction
  - "v" wave due to venous filling of atrium

Tachycardia and CVP

- A short PR interval can cause the “a” and “c” waves to fuse
- Tachycardia reduces the time spent in diastole, causing a short “y” descent
- This can make the “v” and “a” waves appear to merge

Bradycardia and CVP

- Causes each wave to become more distinct
- “h” wave may become evident - plateau wave in mid- or late diastole
- The “h” wave has very little clinical significance



Clinical Examples

- Atrial Fibrillation
- Junctional Rhythm
- Ventricular Pacing
- Tricuspid Regurgitation/Stenosis
- Pericardial Constriction
- Cardiac Tamponade

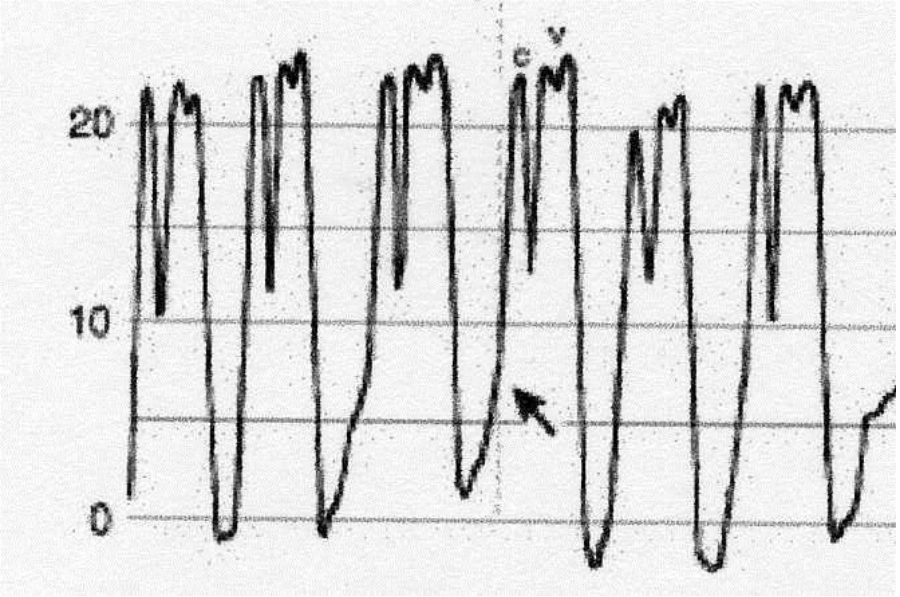
Atrial Fibrillation

- The “a” wave disappears (no atrial contraction or “kick”)
- The “c” wave becomes more prominent (atrial volume is higher at beginning of systole because the atrium did not empty)

Junctional Rhythm

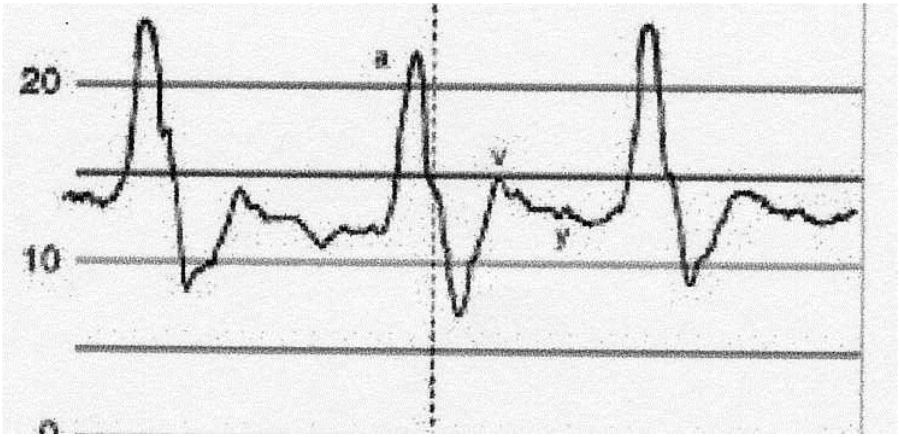
- Atrial contraction occurs during systole (when the tricuspid valve is closed)
- The blood has no place to go so the pressure goes up much more than usual, resulting in a large “a” wave
- Cannon “a” wave
- Also seen with A-V dissociation, ventricular pacing, etc.

Tricuspid Regurgitation



- The right atrium gains volume during systole - so the “c” and “v” wave is much higher
- The right atrium “sees” right ventricular pressures and the pressure curve becomes “ventricularized”

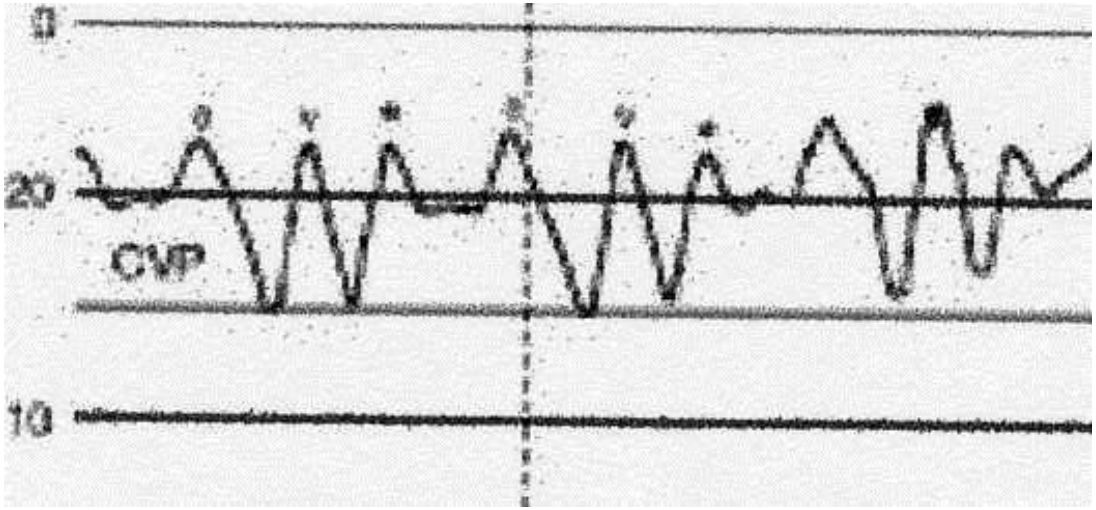
Tricuspid Stenosis



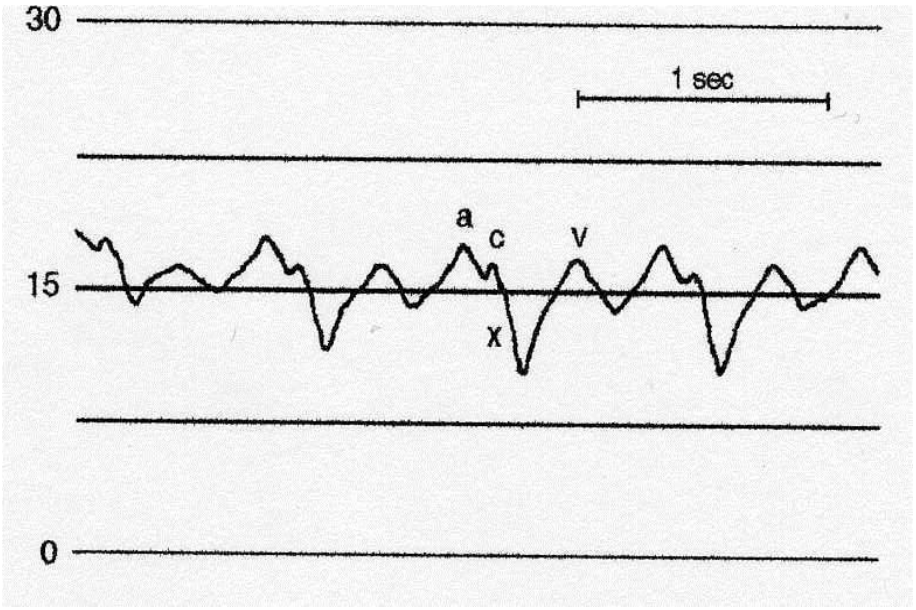
- Problem with atrial emptying and a barrier to ventricular filling on the right side of the heart
- Mean CVP is elevated
- “a” wave is usually prominent as it tries to overcome the barrier to emptying
- “y” descent muted as a result of decreased outflow from atrium to ventricle

Pericardial Constriction

- Limited venous return to heart, elevated CVP, end-diastolic pressure equalization in all cardiac chambers
- Prominent “a” and “v” waves, steep “x” and “y” descents
- Characteristic M or W pattern, dip and plateau (square root sign)



Cardiac Tamponade

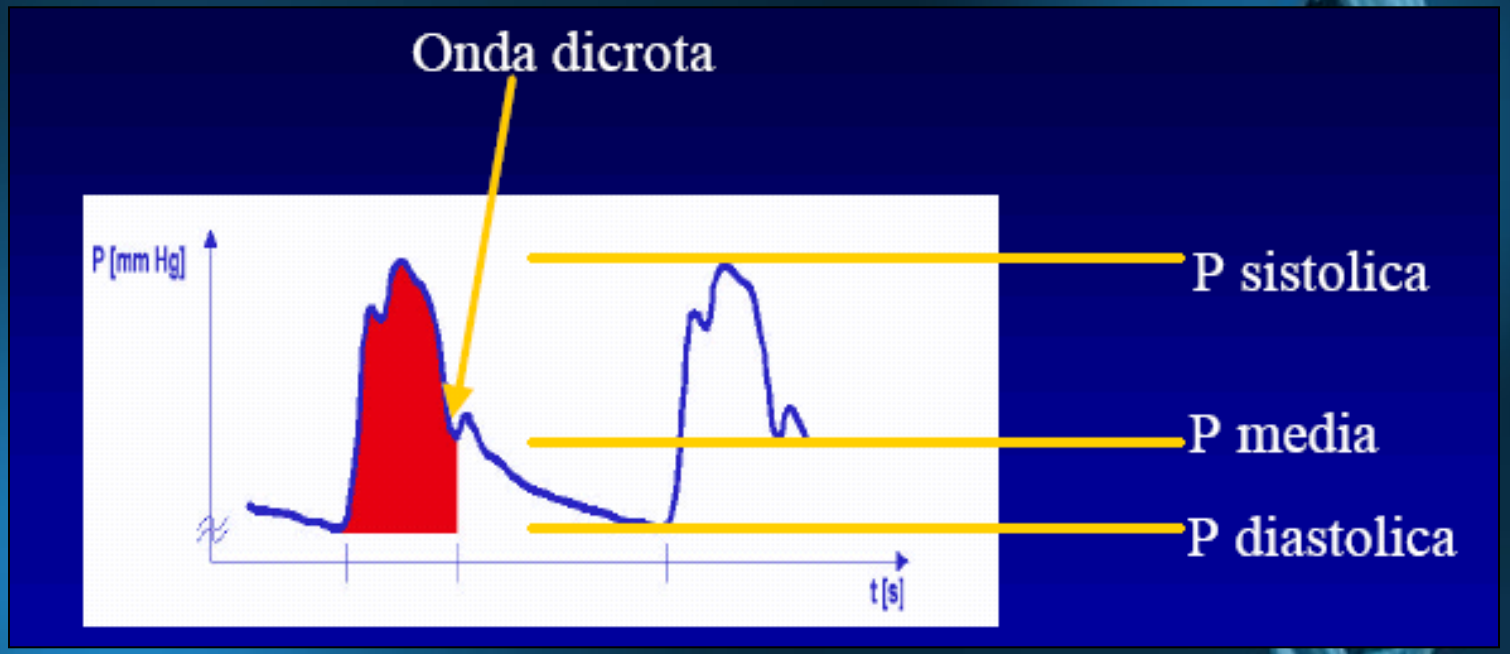


- Changes in atrial and ventricular volumes are coupled, so total cardiac volume does not change when blood goes from atrium to ventricle
- CVP becomes monophasic with a single, prominent “x” descent with a muted “y” descent
- Similar to pericardial constriction but not exactly the same

Central Line Complications

Complications	Total	Fatalities
Cardiac Tamponade	11	10
Wire or catheter embolism	12	0
Vascular injuries (non-pulmonary artery)	13	5
Hemothorax	6	4
Hydrothorax	3	1
Carotid artery injury	3	0
Subclavian a. aneurysm	1	0
Pulmonary artery rupture	2	2
Pneumothorax	7	1
Air embolism	1	0
Fluid extravasation	1	0
Total	48	20

- (Central Line complications from ASA Closed Claims Project. ASA Newsletter 1996;60:222-5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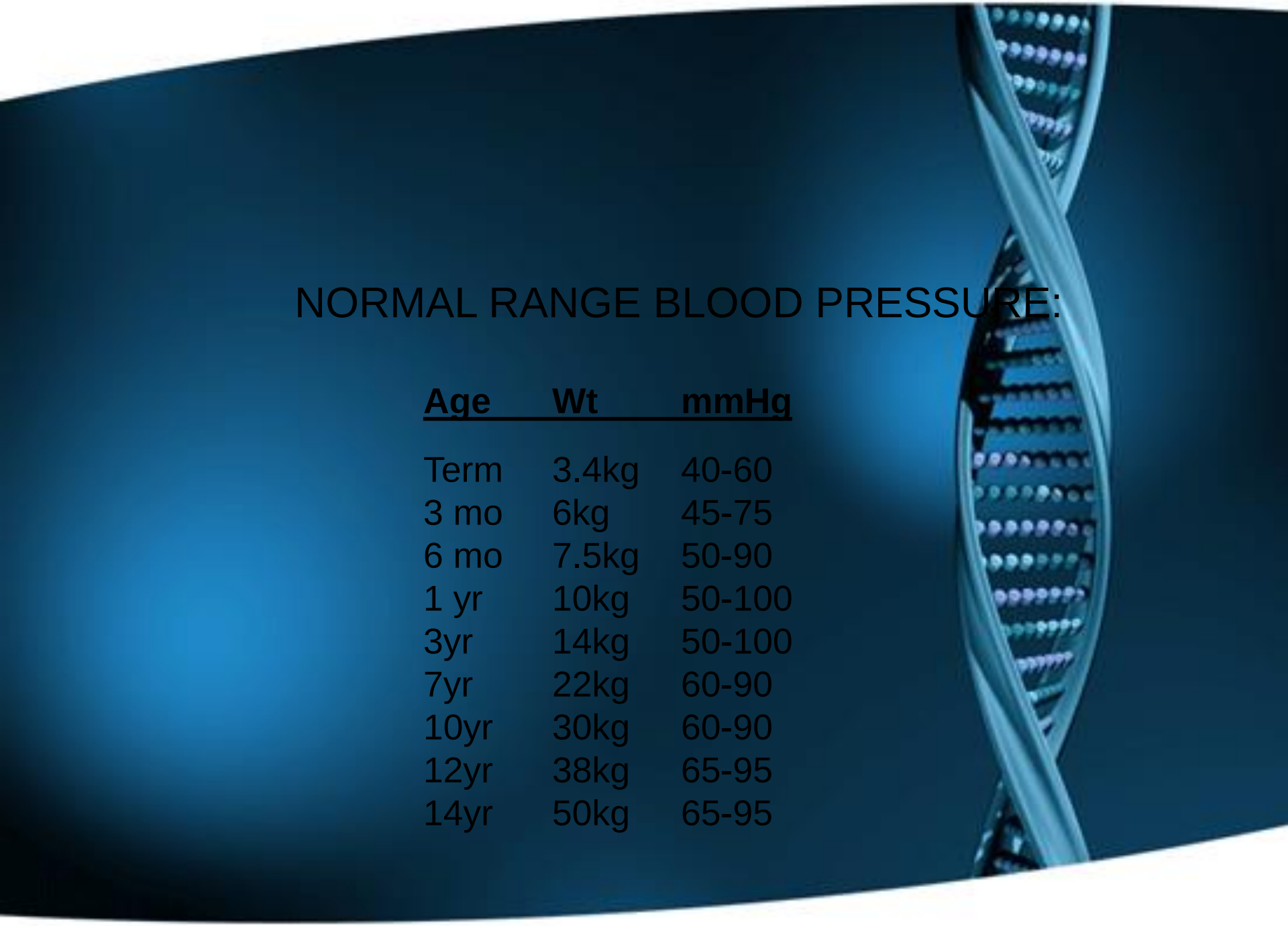
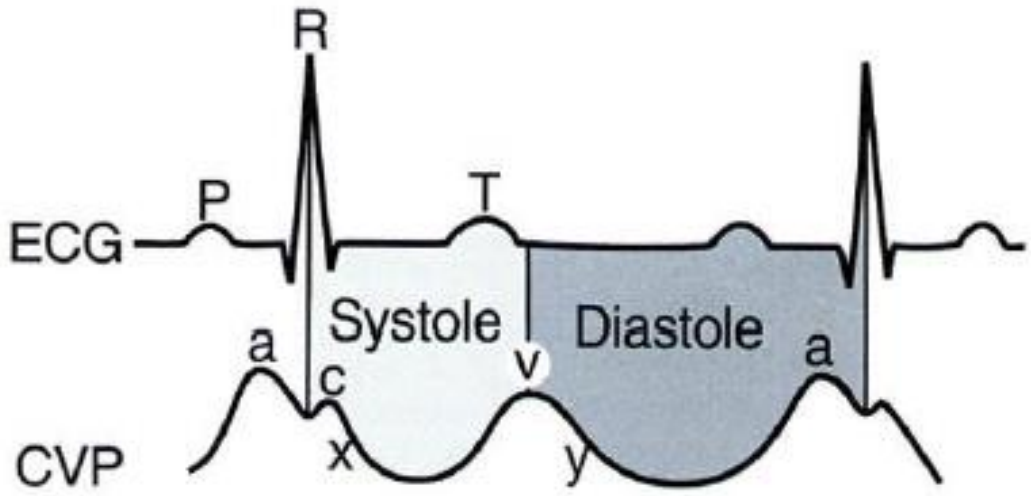


NORMAL RANGE BLOOD PRESSURE:

Age	Wt	mmHg
Term	3.4kg	40-60
3 mo	6kg	45-75
6 mo	7.5kg	50-90
1 yr	10kg	50-100
3yr	14kg	50-100
7yr	22kg	60-90
10yr	30kg	60-90
12yr	38kg	65-95
14yr	50kg	65-95

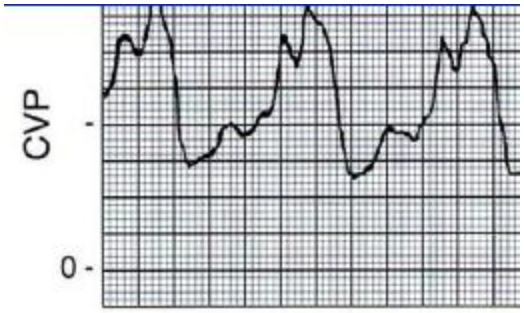


- A wave → Atrium Sistole
- C wave → Tricuspid valve closure
- X wave → Atrial relaxation
- V wave → Atrial filling with tricuspid valve closed
- Y wave → Ventricular filling after ticuspid valve opening

INTRAVASCULAR PRESSURE MONITORING

CVP – Central Venous Pressure / Right Atrium waveform

- **TRICUSPID REGURGITATION:**



- **CARDIAC TAMPONADE:**