HEART PEARLS!

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Archive for category Cardiac catheterization

Cardiac catheterization– analysis of hemodynamic data

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Posted by Dr Jayachandran Thejus MD in Cardiac catheterization

- **Pressure measurements**
- **Cardiac output measurements**
- **Vascular resistance**
- **Valvular stenosis**
- **Intraventricular pressure gradient**
- **Valvular regurgitation**
- **Shunts**

Pressure measurements

Systems–

- Fluid filled–
  - Pressure is transmitted through a fluid column in a catheter to a transducer.
  - The transducer converts pressure changes into electrical signals by the principle of the Wheatstone bridge.
  - High natural frequency and optimal damping allow high frequency response.
  - Damping (loss of energy) is reduced by
    - Catheter being short, wide and non-compliant,
    - Liquid being low density and
    - Absence of air bubbles.
  - Transducer should be zeroed by positioning at the level of the atria.
  - 30 to 40 msec delay.
  - Errors–
    - Catheter whip artifact
    - End-pressure artifact (end-hole faces a jet and records high pressure)
    - Catheter impact artifact– against a wall.
    - Catheter tip obstruction– in a small vessel.

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- Micromanometer–
  - Transducer is at the tip.
  - Advantages–
    - High natural frequency.
    - Optimal damping.
    - Less whip artifact.
    - No delay.
  - Disadvantages–
    - Costly.
    - More time needed for calibration.
    - Fragile.
    - More drifting.

Normal pressures

- Pressure and volume are inversely related except in early diastolic filling where both decrease.
- Normal pressures–
  - RA–
    - A 2–7
    - V 2–7
    - M 1–5
  - RV–
    - Peak systolic (S) 15–30
    - End diastolic (ED) 1–7
  - PA–
    - S 15–30
    - ED 4–12
    - M 9–19
  - PCWP 4–12
  - LA
    - A 4–16
    - V 6–21
    - M 2–12
  - LV
    - S 90–140
    - ED 5–12
  - Ao
    - S 90–140
    - ED 60–90
    - M 70–105
- Normal resistances
  - Systemic vascular resistance– 700–1600
  - Total pulmonary resistance– 100–300
  - Pulmonary vascular resistance– 20–130

Normal waveforms

trials
- Diagnose this infant's chest X-ray
- Short RP narrow complex tachycardia
- What is the additional finding in this atrial fibrillation?
- A peculiar narrow complex tachycardia
- LBBB with an additional problem
- Aortic regurgitation

RA pressure-

- A height depends on atrial contractility and ventricular compliance.
- V height depends on atrial compliance.
- X descent depends on atrial relaxation.
- Y descent depends on tricuspid orifice and early atrial emptying into RV.
- A is more than V.
- Pressure falls during inspiration.

Left atrium

- v is higher than a because LA is constrained posteriorly by pulmonary veins.
- v height most accurately reflects LA compliance.

PCWP

- Compared to LA pressure, slightly damped and delayed.
- a and v waves present. c may not be present.
- Similar to PA diastolic pressure except in conditions with elevated pulmonary vascular resistance.

Ventricles

- LV, compared to RV, has
    - Longer systole
    - Longer isovolumic contraction
    - Shorter ejection period
    - Longer isovolumic relaxation
- Systolic gradient of 5 mmHg between RV and PA is normal.
- End diastolic pressure is measured at-
    - Best- c point- rise in pressure at onset of isovolumic contraction
    - Second best- at R of ECG

Great vessels

- Notch in downstroke is called incisura.
- When pressure recording is moved from central to periphery, systolic pressure increases while diastolic pressure decreases till mid thoracic aorta and then increases. Mean will be similar.
- Increased systolic pressure in periphery is more in young due to increased compliance.
- Transvalvular aortic gradient is measured best at coronary artery level to avoid pressure recovery (increased lateral pressure downstream).

Abnormal pressure characteristics

- **Atrial pressure**
    - m-
        - low- hypovolemia
        - high-
            - ventricular failure
            - Cardiac tamponade
            - AV valve stenosis
            - AV valve regurgitation
            - Volume overload
    - a-
        - absent-

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    - atrial fibrillation
    - atrial flutter
    - atrial standstill
  - elevated-
    - AV valve stenosis
    - Ventricular hypertrophy
    - Ventricular failure
  - cannon-
    - AV asynchrony
- v-
  - elevated-
    - AV valve regurgitation
    - ventricular failure
    - Reduced atrial compliance as in restrictive myopathy
    - For LA pressure only- VSD
- a and v equal-
  - tamponade
  - constrictive pericarditis
  - hypervolemia
- x descent-
  - prominent-
    - tamponade
    - ventricular ischemia
    - Subacute constrictive pericarditis
  - blunted-
    - atrial fibrillation
    - atrial ischemia
- y descent-
  - prominent-
    - constrictive pericarditis
    - restrictive cardiomyopathy
    - AV valve regurgitation
  - Blunted-
    - Tamponade
    - ventricular ischemia
    - AV valve stenosis
- M or W pattern-
  - constrictive pericarditis
  - ventricular ischemia
  - ventricular failure
- Ventricularisation of atrial pressure- severe AV valve regurgitation
- Sawtooth pattern- atrial flutter
- For RA pressure-

        - Kussmaul sign
            - constrictive pericarditis
            - ventricular ischemia
            - dissociation between pressure record and intracardiac ECG- Ebstein
            - RA m, RV EDP, PA diastolic P, & PCWP are within 5 mmHg range- tamponade
    - PCWP not equal to LVEDP
        - MS
        - LA myxoma
        - Decreased LV compliance
        - Cor triatriatum
        - Pulmonary venous obstruction
        - Increased pleural pressure
        - PCWP is measured in non-dependent zone of lung
- **Ventricular pressure-**
    - Systolic pressure-
        - Elevated-
            - Ventricular outflow obstruction
            - Hypertension
            - RV- ASD, VSD
        - Reduced-
            - Hypovolemia
            - Ventricular failure
            - Cardiac tamponade
    - EDP-
        - Elevated-
            - Hypervolemia
            - Ventricular failure
            - Decreased ventricular compliance
            - Cardiac tamponade
            - Constrictive pericarditis
            - Regurgitant valvular disease
        - Reduced-
            - Hypovolemia
            - AV valve stenosis
    - LV EDP > RV EDP-
        - Restrictive cardiomyopathy
    -
    - Dip and plateau in diastole
    -
        - Constrictive pericarditis
        - Restrictive cardiomyopathy
        - RV ischemia
        - Acute AV valve regurgitation
- **Aortic pressure-**
    - Increased systolic pressure- HT, AR

- Decreased systolic pressure– hypovolemia, heart failure, AS
- Wide pulse pressure– HT, AR, PDA, RSOV
- Low pulse pressure– hypovolemia, heart failure, AS, cardiac tamponade

- **PA pressure–**
  - Systolic pressure–
    - Increased–
      - LV failure
      - Restrictive cardiomyopathy
      - MS
      - MR
      - PPH
      - Pulmonary disease
      - Hypoxia
      - Pulmonary embolism
      - Significant left to right shunt
    - Decreased–
      - Hypovolemia
      - RVOT obstruction
      - TS, tricuspid atresia
      - Ebstein
  - Pulse pressure–
    - Reduced–
      - RV infarction
      - Pulmonary embolism
      - Cardiac tamponade
  - PA diastolic pressure higher than PCWP
    - Pulmonary disease
    - Pulmonary embolism
    - Tachycardia
- Bifid pulmonary artery waveform
  - MR (large left atrial v wave is transmitted backwards)

Cardiac output measurements

- Thermodilution technique
  - Bolus of cold saline or dextrose is injected via proximal port– thermistor distally– temperature plotted against time– area under curve and cardiac output are inversely related.
  - Errors in–
    - TR
    - Low output state– cardiac output is overestimated
- Fick method
  - Cardiac output (l/min)= oxygen consumption (ml/min)/ AV oxygen difference (vol %) x Hb (mg/dl) x 13.6
  - Greatest source of error is measurement of oxygen consumption.
  - Preferred over thermodilution method in low output states as accuracy is maintained.

- Angiographic method
  - Found from the end diastolic and end systolic ventricular images.
  - Preferred method in AR and MR.
- Indicator dilution method
  - Tedious- so not used.

Vascular resistance

- Resistance= pressure gradient/flow
- Units are
  - absolute unit- dyne.sec./cm^5
  - Wood unit- mmHg/l/min- also called hybrid unit- obtained by dividing absolute unit measure by 80
- Systemic vascular resistance= (mean aortic pressure- mean RA pressure)/systemic flow. Result is obtained in Wood units.
- Total peripheral resistance= mean aortic pressure/systemic flow
- Pulmonary vascular resistance= (mean PA pressure-mean LA pressure)/pulmonary flow.
- Vascular impedance is better than vascular resistance as it takes into account viscosity, pulsatility, arterial compliance and reflected waves.

Valvular stenosis

- Pressure gradients
  - If femoral pressure is used instead of ascending aortic pressure for AS, the size of the femoral sheath should be at least 1 F more than that of the catheter.
  - Peak instantaneous gradient in AS occurs in the upstroke and is more than the peak to peak gradient.
  - Mean gradient is found by planimetry of the area separating the curves. It is used for orifice area calculations.
- Area calculation
  - Gorlin's formula is used.
  - Aortic valve area= (1000 x COP)/(44.3 x SEP x HR x √mean gradient)
  - Mitral valve area= (1000 x COP)/(37.7 x DFP x HR x √mean gradient)
  - In these formulae, area is obtained in cm2 when cardiac output is input in L/min, systolic ejection period or diastolic filling period is input in msec, and mean gradient is input in mmHg.
  - SEP is the time from aortic valve opening to closure. DFP is the time from mitral opening to closure.
  - Simplified formula for aortic valve area is COP/√mean or peak to peak gradient.
  - These formulae can be calculated by echo also.
  - Normal aortic valve area is 2.6 to 3.5 cm2.
  - In low output states, Gorlin formula may be underestimating valve areas.
  - In low output states, if dobutamine increases AVA by more than 0.2 cm2 with no change in gradient, it means that baseline AS severity was an overestimation. In severe AS, gradient increases while AVA does not increase by more than 0.2 cm2.

Intraventricular pressure gradient

- Intracavitary gradient is distinguished from AS gradient by absence of gradient between distal LV and aorta.

Valvular regurgitation

- Sellers classification
  - + minimal
  - ++ moderate
  - +++ intense (equal to distal chamber)
  - ++++ very intense (more than distal chamber) & persists over the entire series.

- Regurgitant stroke volume = angiographic stroke volume – forward stroke volume. Forward stroke volume is found by Fick or thermodilution method.
- Regurgitation fraction = regurgitant stroke volume / angiographic stroke volume.
- Sellers classes correspond to regurgitant fractions of upto 20%, 21 to 40%, 41 60% and more than 60% respectively for +, ++, +++ and ++++.

Shunts

- Arterial desaturation means less than 93%.
- Venous oversaturation means more than 80%.
- SVC-PA oxygen difference should be less than 8%.
- IVC has higher oxygen as kidneys use less oxygen.
- Mixed venous saturation is best measured in pulmonary artery.
- Systemic blood flow= oxygen consumption / (systemic oxygen – mixed venous oxygen)
- Pulmonary blood flow= oxygen consumption / (pulmonary vein oxygen- pulmonary artery oxygen)
- Effective blood flow is the mixed venous blood that enters the lungs without contamination by shunt flow.
- Effective blood flow= oxygen consumption / (pulmonary vein oxygen- mixed venous oxyen)
- All oxygen **contents** in these formulae are in ml of oxygen / liter of blood.
- Flamm formula for mixed venous oxygen **content** is (3 SVC + 1 IVC) / 4.
- Left to right shunt
  - PBF – SBF if no associated right to left shunt
  - PBF – EBF if there is an associated right to left shunt

- Right to left shunt
  - SBF – EBF

- Qp/Qs
  - For left to right shunt significance.
  - Less than 1.5- small, 1.5 to 2- moderate, 2 or more- large
  - Less than 1- right to left shunt
  - Does not need oxygen consumption measurement.
  - Qp/Qs= (SaO2-MvO2) / (PvO2-PaO2), all measures being oxygen **saturations**

- Indicator – dilution method
  - Not commonly used for shunt detection.
  - More sensitive than oximetry to detect small shunts.
  - Indocyanine green dye injected- densitometer placed distally.
  - Left to right shunt-
    - Inject into PA, measure in systemic artery
    - Early recirculation in downslope of curve

- Cannot localize level of shunt.

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