cardiac output measurement

partial CO2 rebreathing method

General:
- with this method, cardiac output is measured every 3 minutes
- a segment of dead space (150ml) is introduced into the breathing circuit of a ventilated patient for 30-50s (it is assumed that although pulmonary end-capillary, arterial and end-tidal PCO2 rise promptly, mixed venous PCO2 does not change during this brief period of rebreathing)
- CO = deltaCO2 elimination / (S x delta end-tidal CO2) where S is the slope of the blood CO2 dissociation curve
- a correction for venous admixture is added based on FiO2 and SaO2

Problems:
(i) unsuitable for non-intubated patients
(ii) CO2 elimination may not reach steady state in the time available (esp in chronic lung disease)
(iii) the value of S varies with Hb concentration
(iv) venous admixture cannot be calculated reliably from FiO2 and SaO2 when there is significant V/Q scatter (eg chronic lung disease)
(v) overall lack of validation in chronic lung disease

doppler ultrasound

- when doppler ultrasound with a frequency of 1-10MHz is directed along the long axis of the ascending aorta from a transducer in the suprasteral notch, the sound is reflected back with a frequency shift proportional to the velocity of blood flow.
- the blood flow velocity curve is integrated to give the average velocity over time & the troke volume is the calculated by multiplying the average velocity during each heart beat by the cross-sectional area of the aorta

- both continuous and pulsed doppler systems are in use.
- the continuous system can measure high velocities but averages the frequency shifts along the whole length of the ascending aorta so that the exact point at which the velocity is measured is unknown. It is therefore difficult to know where to measure the diameter of the aorta.
- the pulsed Doppler again uses the same transducer to generate and receive ultrasound but this produces shorter pulses instead of continuous ultrasound. The advantage is that the beam can be focussed so that measurement is being made

disadvantages of ultrasound measurement of cardiac output include:
(i) need for accurate measurement of aortic diameter (since area is pi R2)
(ii) fact aorta expands by up to 12% during systole
(iii) site of diameter measurement may not correspond to position velocity is measured
(iv) shape of the velocity profile means that if beam is not aligned along the aortic axis the measured velocity will be measured falsely low

thoracic electrical bioimpedence

- electrical impendence of tissues fluctuates according to the blood volume contained therein. Changes in impedence occur due to cardiac & respiratory activity
- thoracic electrical bioimpedence underestimates cardiac output in septic shock & aortic regurgitation & is inaccurate when there are intracardiac shunts or arrhythmias

inaccuracies arise from:
(i) motion artefact
(ii) electrical interference
(iii) tachycardia
(iv) dysrhythmias
(v) conduction defects
(vi) variations in functional residual capacity
(vii) chest deformities
(viii) pneumonectomy
(ix) pleural and pericardial effusion
(x) pulmonary oedema
(xi) chest tubes
(xii) pregnancy
(xiii) metal prostheses
(xiv) intracardiac shunts

general

- the standard is the Fick technique whereby CO = VO2/(CaO2 - CvO2) ; however, this requires sampling of the mixed venous blood & measurement of VO2 by indirect calorimetry under steady state conditions
- measurements of equal accuracy can be obtained by indicator or thermal dilution methods

measurement of cardiac output can be by several means:
1. invasive methods:
(i) indicator dilution
(ii) thermal indicator dilution
(iii) PICCO
(iv) LiDCO
(v) oesophageal doppler
(vi) TOE
2. non-invasive methods:
(i) doppler ultrasound
(ii) thoracic electrical bioimpedence
(iii) TTE

indicator dilution

- a bolus of indicator is injected into the vena cava, right heart or preferably the pulmonary artery
- the concentration of indicator reaching the systemic circulation is plotted against time and cardiac output is thereby calculated:
CO L/min = 60 x indicator dose [mg] / (average concentration [mg/L] x time [s])

- one of the problems with this technique is that recirculation of the indicator occurs before the downslope is complete

- of the dyes used for this technique, indocyanide is the most popular. It is non-toxic and has a relatively short half-life allowing repeated measurement to be made; indicator dilution has also be described using radioactive tracers such as human serum albumin or chromium labelled red cells

thermal indicator dilution

- thermal indicator dilution is used routinely in the intensive care unit
- the principle is the same as for indicator dilution but the injection & sampling are performed on the right side of the heart

-thermal dilution techniques have a number of advantages:
(i) the indicator is cheap and non-toxic
(ii) arterial puncture and blood withdrawal is not necessary
(iii) absence of recirculation (particularly important at low output states where recirculation makes dye dilution inaccurate)

- disadvantages of thermal dilution include:
(i) requires passage and placement of a special catheter
(ii) mixing with venous blood may be incomplete
(iii) pulmonary arterial blood flow varies greatly with respiration