Major Elective-
BMS-EC-10
Cardiovascular Biology

CARDIAC OUTPUT

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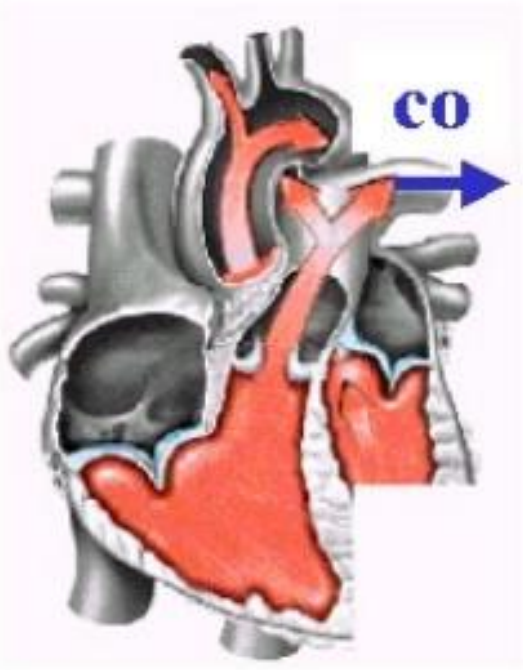
Factors on Cardiac Output

5) *Preload*:

2) *Afterload*:

3) *Contractility*:

4) *Heart Rate*:



CARDIAC OUTPUT (CO)

- A measure of cardiac performance

- The volume of blood pumped out of the ventricle per unit time indicates the blood (oxygen) is available to flow into tissues.

Cardiac Output

- Defn: vol of blood pumped by the heart per min
- CO = stroke volume (SV) x heart rate (HR)
- Normally ~ 5 lit/min
- Cardiac index – corrected for body surface area
- Affected by :
  - Met. Rate – pregnancy, hyperthyroid, septic
  - Preload / contractility / afterload

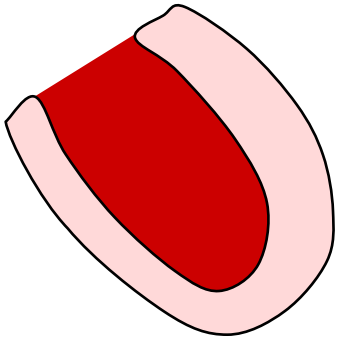
Cardiac Output: Example

- CO (ml/min) = HR (75 beats/min) x SV (70 ml/beat)
- CO = 5250 ml/min (5.25 L/min)

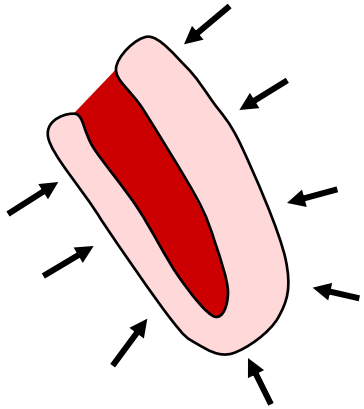
- SV = EDV -ESV
- SV = end diastolic volume (EDV also called preload) minus end systolic volume (ESV)

Left Ventricular Volumes - Definitions

End Diastolic Volume (EDV)
Volume at the end of diastole (end of ventricular filling). In a healthy heart this is directly proportional to venous return



End Systolic Volume (ESV)
Volume at the end of systole (end of ventricular contraction)



NOTE: Resting Ejection Fraction (EF) is the best indicator of both heart performance and heart disease prognosis

Stroke Volume (SV) = EDV - ESV

Ejection Fraction (EF) = $\frac{SV}{EDV}$

Left ventricular norm for EF at Rest: approximately 62%

Left Ventricular norms for Max Exercise: approximately 80%

Left Ventricular Volumes - Definitions

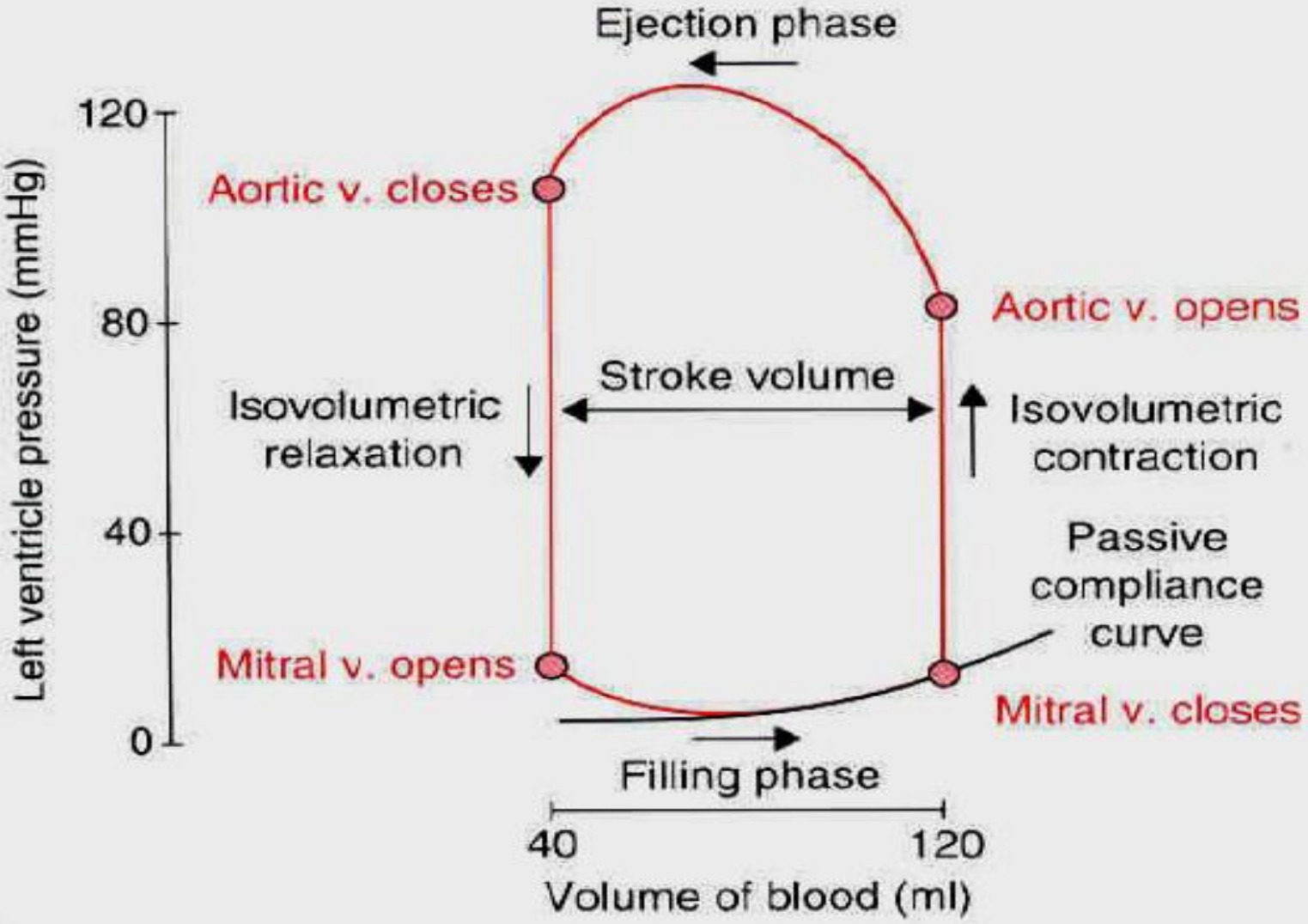


Figure 2.6 Pressure–volume cycle of human left ventricle.

Methods of measurement of CO

- Two methods are there for human
  1. Direct Fick Method
  2. Indicator dilution method

1. Fick principle
   - Amount of the substance taken up by an organ per unit of time is equal to arterial level of substance minus venous level X blood flow.

Cardiac Output Measurement

- Methods:
  - Fick method
  - Dilution techniques – dye / thermal / lithium
  - Pulse contour analysis- LiDCO & PiCCO

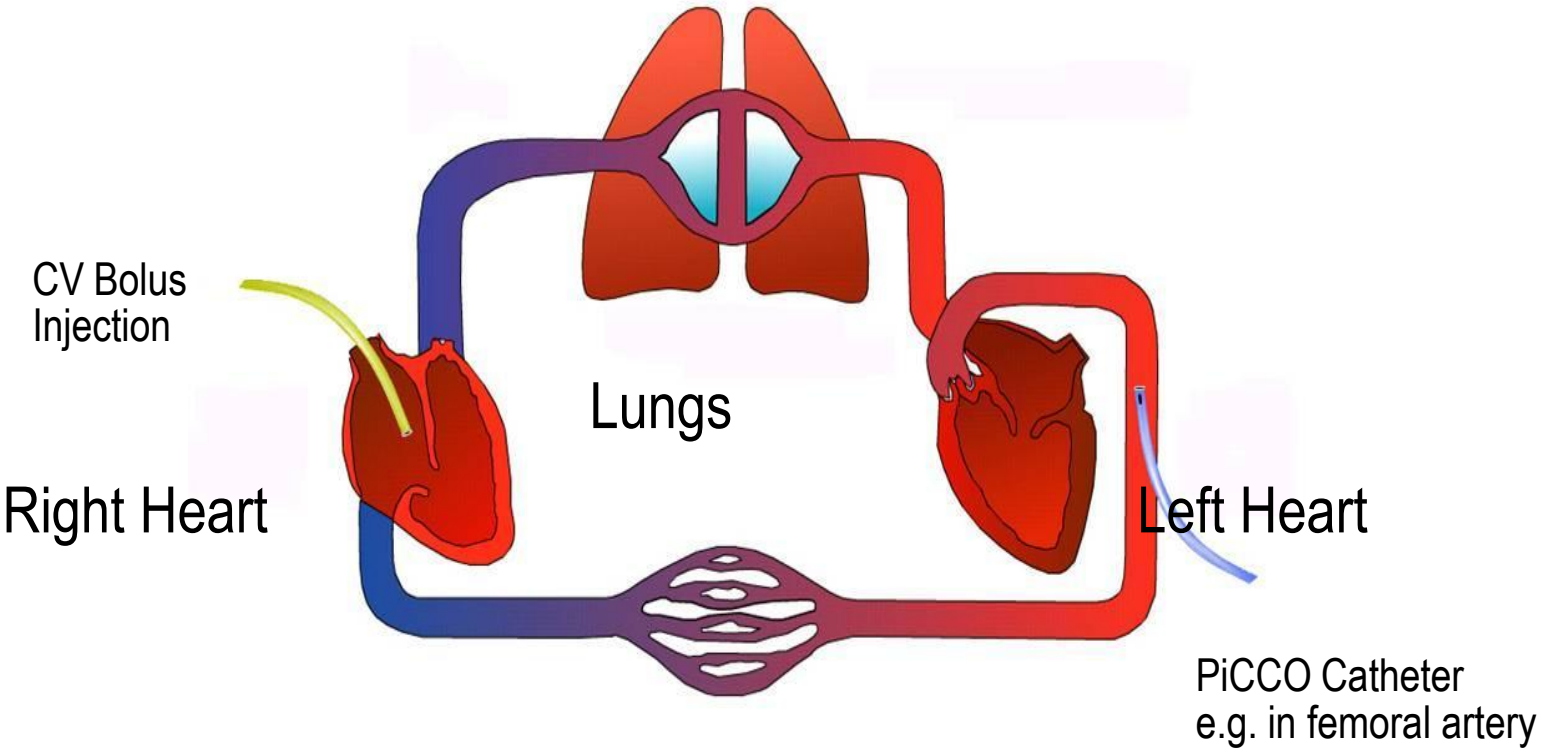
(PiCCO is a device made by Phillips that enables continuous hemodynamic monitoring using a femoral or axillary thermodilution a-line (proprietary) and a central venous line

Made by the LiDCO group in London)

  - Oesophageal doppler (Trans oesophageal Echograph)
  - Transthoracic impedance plethysmography
  - Inert gas through flow
  - Non-invasive cardiac output measurement

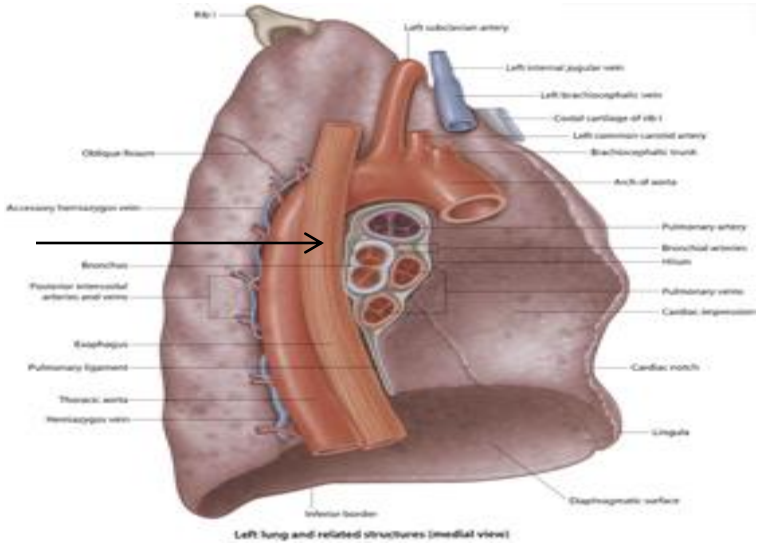
Cardiac Output Measurement

- Transpulmonary thermodilution measurement simply requires the central venous injection of a cold (< 8°C) or room-tempered (< 24°C) saline bolus…



Cardiac Output Measurement

Esophagus

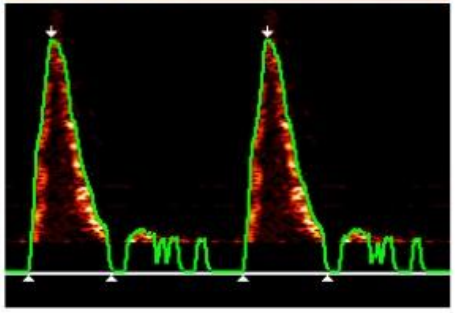


Left lung and related structures (medial view)

the technology

Oesophageal Doppler Monitor

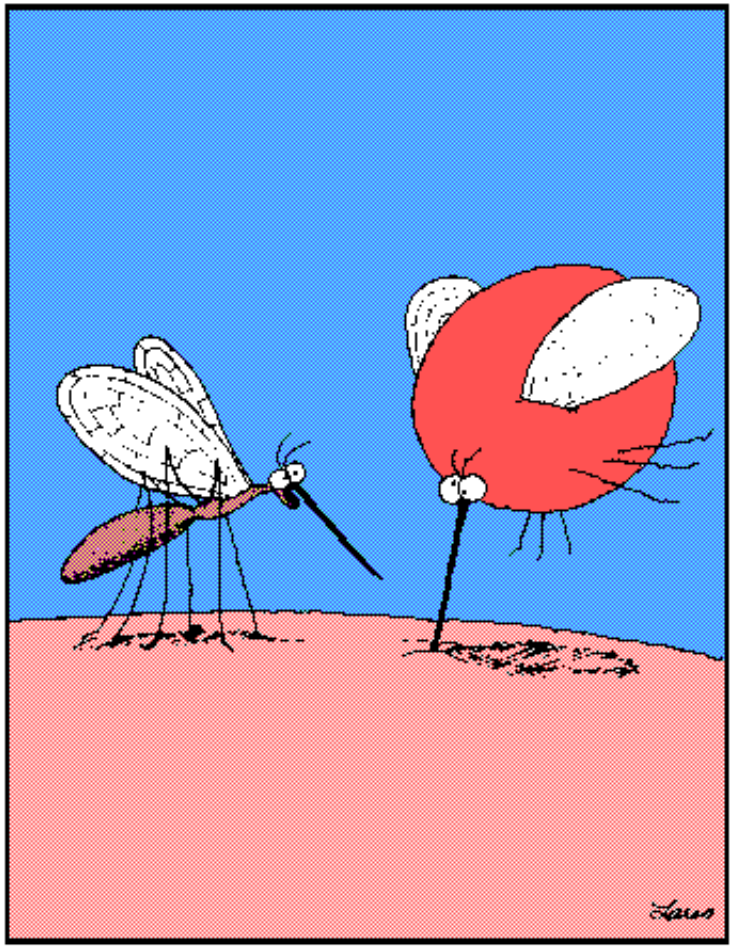
DELTEX MEDICAL



$$V = \frac{\Delta f \; c}{2 f_t \cos\theta}$$

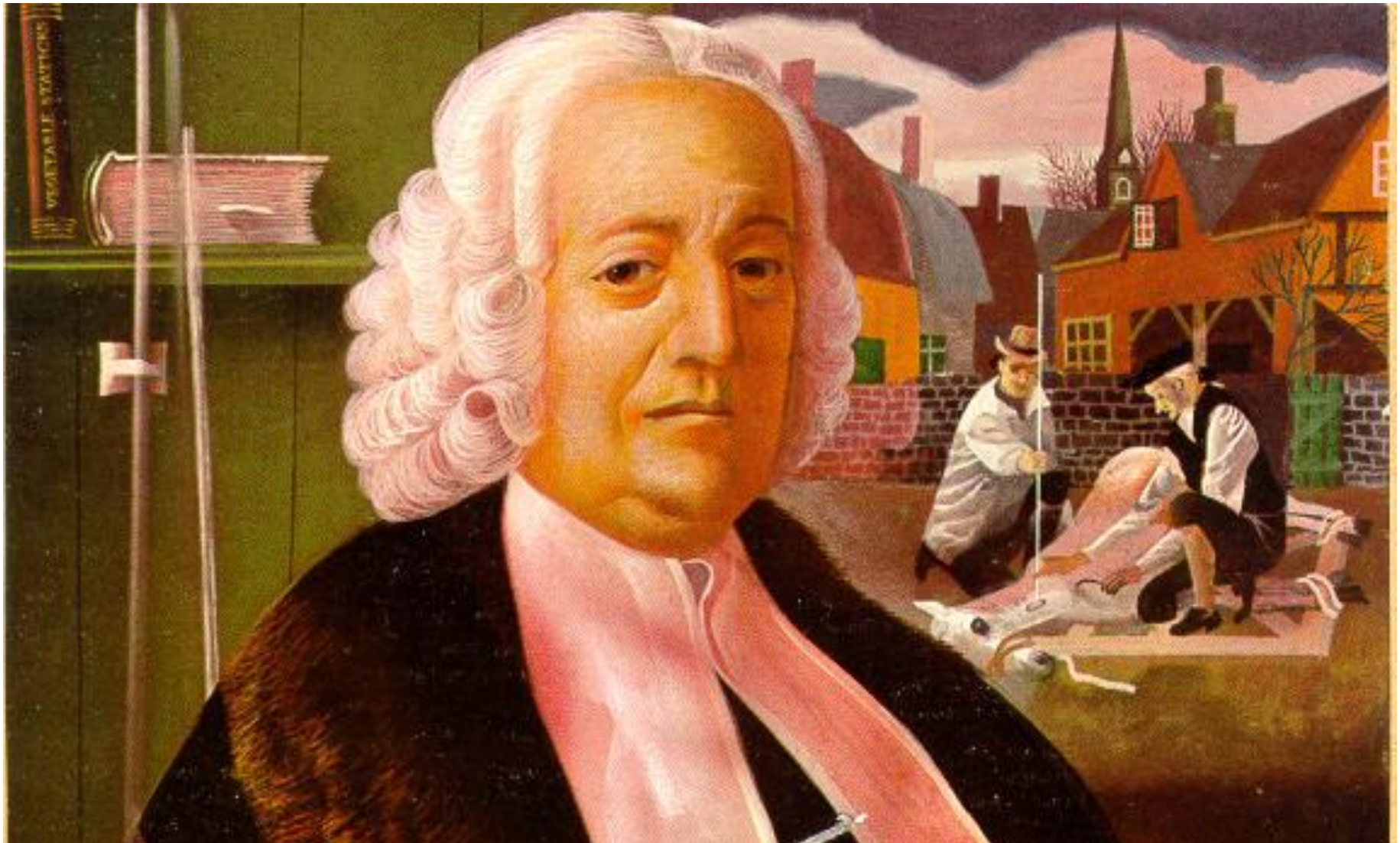
ST VINCENT'S HOSPITAL MELBOURNE

Pressure in the CVS



Pull out, Betty! Pull out! . . . You've hit an artery!

Pressure in the CVS



Cardiac Output Measurement

- Clinical indicators of CO imprecise
- Affected by anaesthetic agents used in everyday practice
- Provides estimate of:
  - whole body perfusion
  - oxygen delivery
  - left ventricular function
- Persistently low CO assoc. with poor outcome

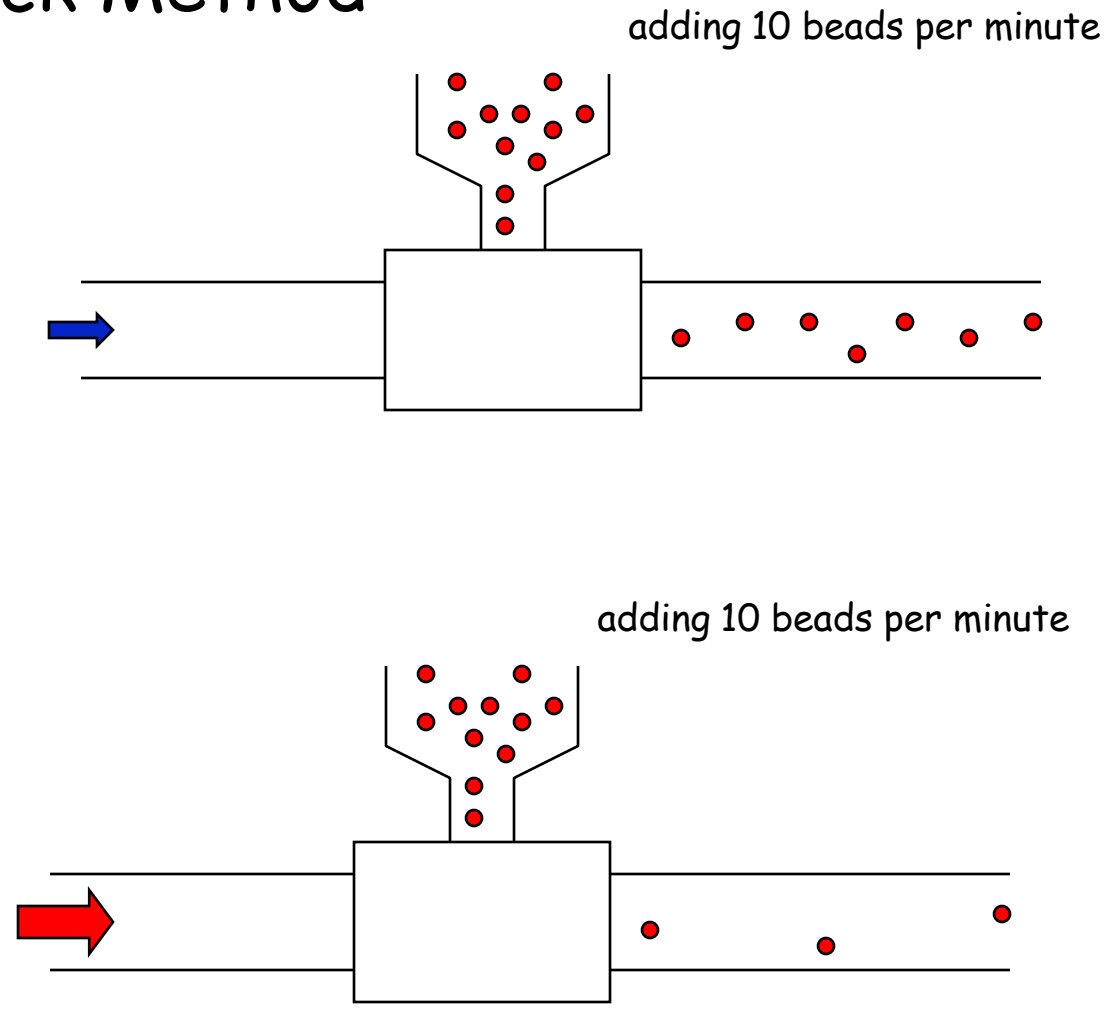
Cardiac Output Measurement

- Fick Principle: measure volume displacement
  - 1st proposed 1870
  - "the total uptake or release of a substance by an organ is the product of the blood flow through that organ and the arteriovenous concentration difference of the substance"
  - $CO = \frac{O_2 \text{ consumption (ml/min)}}{\text{artial} - \text{mixed venous } O_2 \text{ conc. (ml/l)}}$

$$CO = \frac{250 \text{ml/min}}{190\text{ml/L} - 140\text{ml/l}} = 250/50 = 5 \text{ lit/min}$$

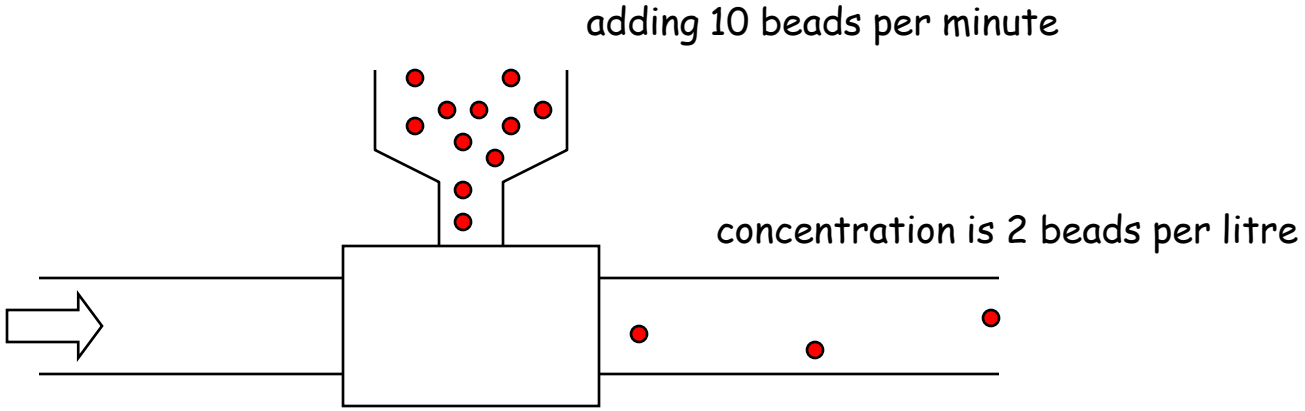
Measurement of cardiac output

- Fick Method



Measurement of cardiac output

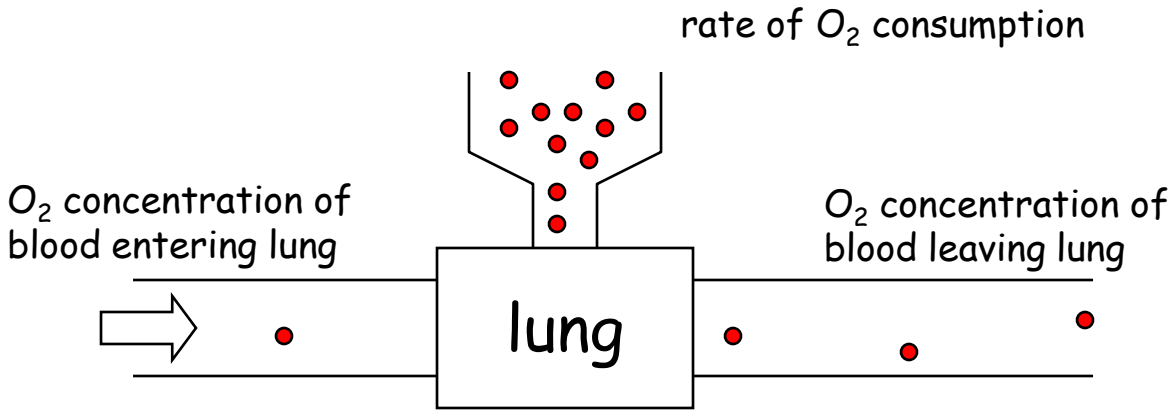
- Fick Method



$$\text{Flow} = \frac{\text{Rate added}}{\text{Concentration}} = \frac{10 \text{ beads/min}}{2 \text{ beads/litre}} = 5 \text{ litres/min}$$

Measurement of cardiac output

- Fick Method



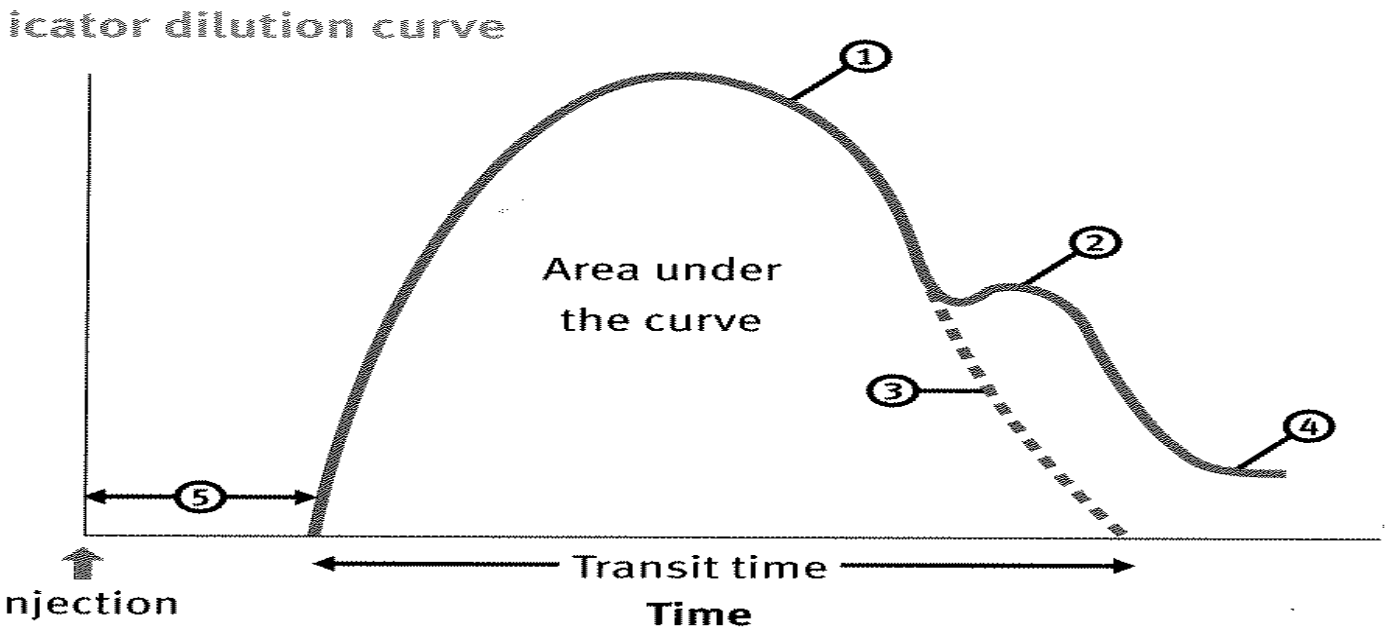
$$\text{Flow} = \frac{\text{rate of } O_2 \text{ consumption}}{[O_2] \text{ leaving} - [O_2] \text{ entering}} = \frac{250 \text{ ml/min}}{190 - 140 \text{ ml/litre}} = 5 \text{ litres/min}$$

Cardiac Output Measurement

- Indicator dilution techniques

- Dye dilution
  - Inert dye – indocyanin green
  - Injected into pulmonary artery and arterial conc. measured using a calibrated cuvette densitometer
  - Plot indicator dilution curve (see diagram)
  - CO derived from area under curve

Indicator Dilution Curve

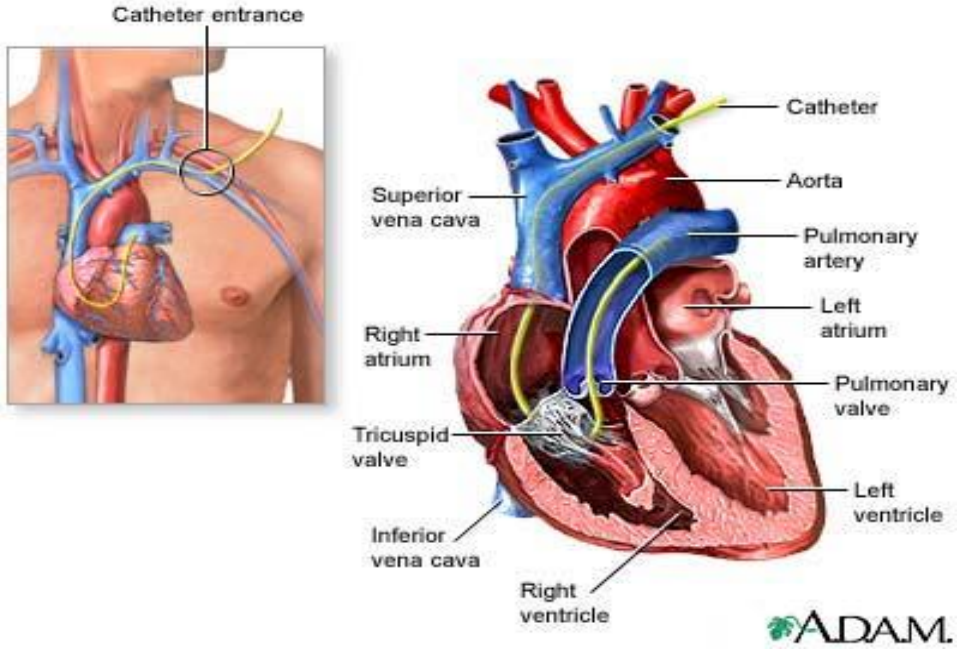


① Primary curve
② Recirculation peak
③ Extrapolation of primary decay curve
④ Elevation of baseline secondary to circulation of dye
⑤ Appearance time

ce: Hinds C J, Watson D. *Intensive care.* Philadelphia: Saunders, 1997.

Cardiac Output Measurement

- Swan Ganz Catheter



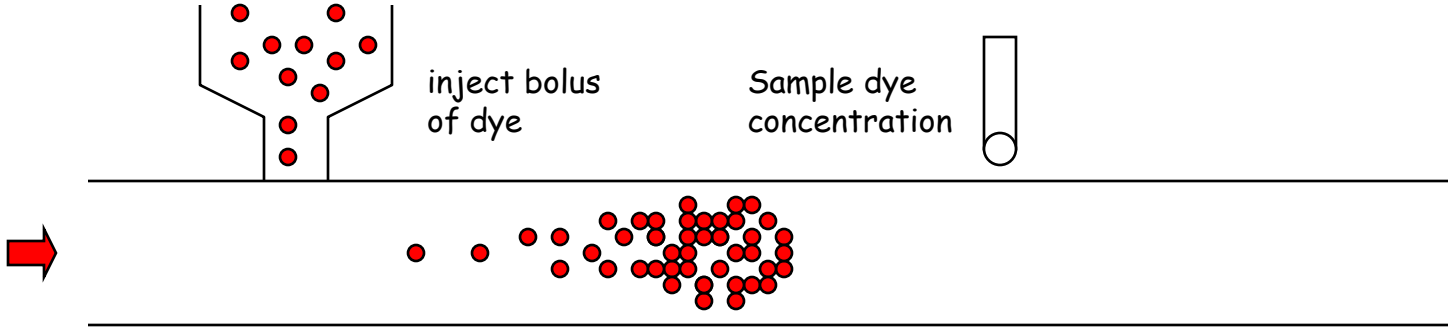
Measurement of blood flow and cardiac output

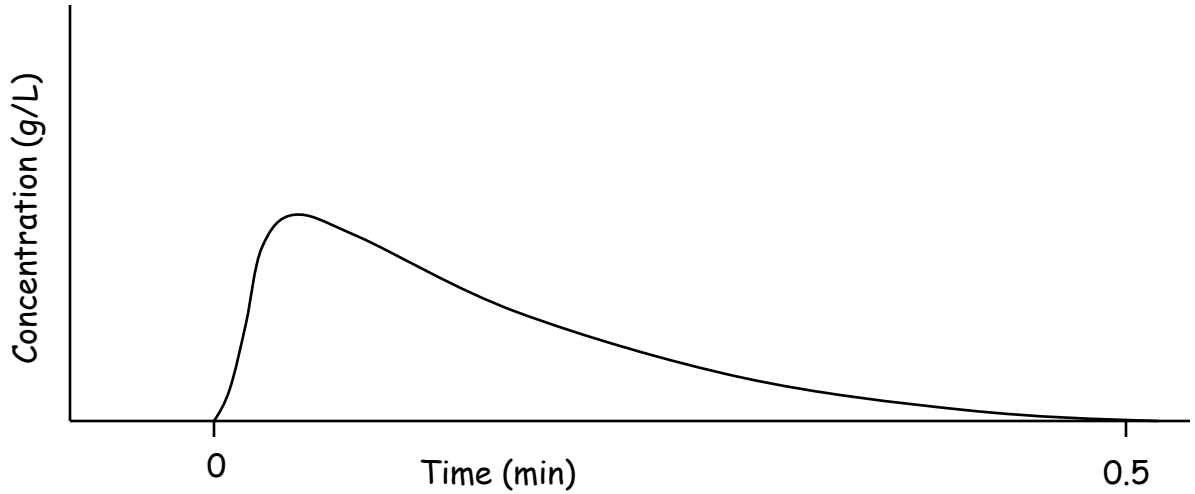
- Electromagnetic flow meters
  - Accurate, but invasive
- Ultrasonic flow meters
- Venous occlusion plethysmography

- Fick method
- Indicator-dilution method
- Doppler echocardiography

Measurement of cardiac output

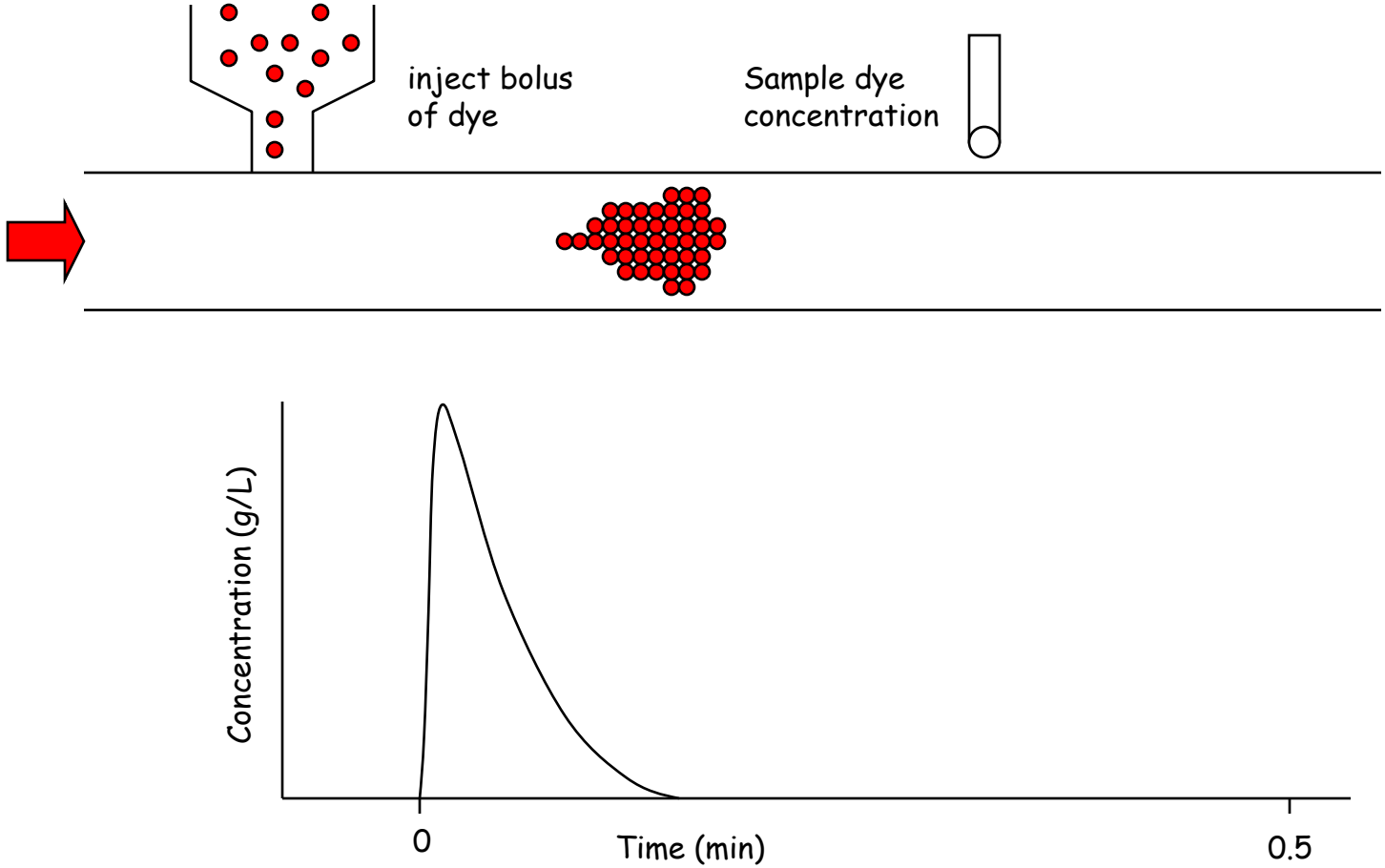
Indicator dilution method



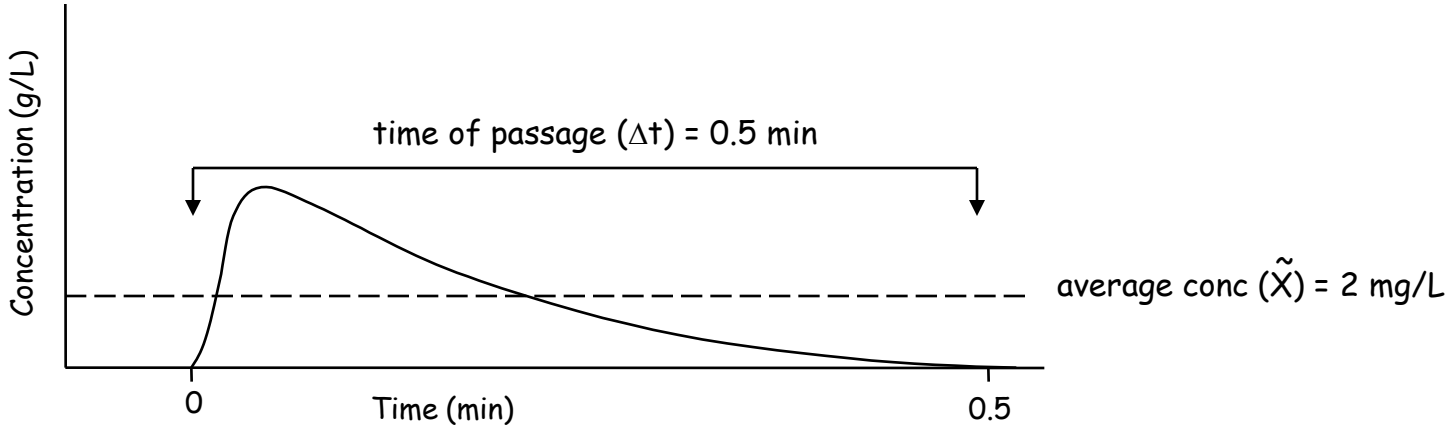


Measurement of cardiac output

Indicator dilution method



Measurement of cardiac output

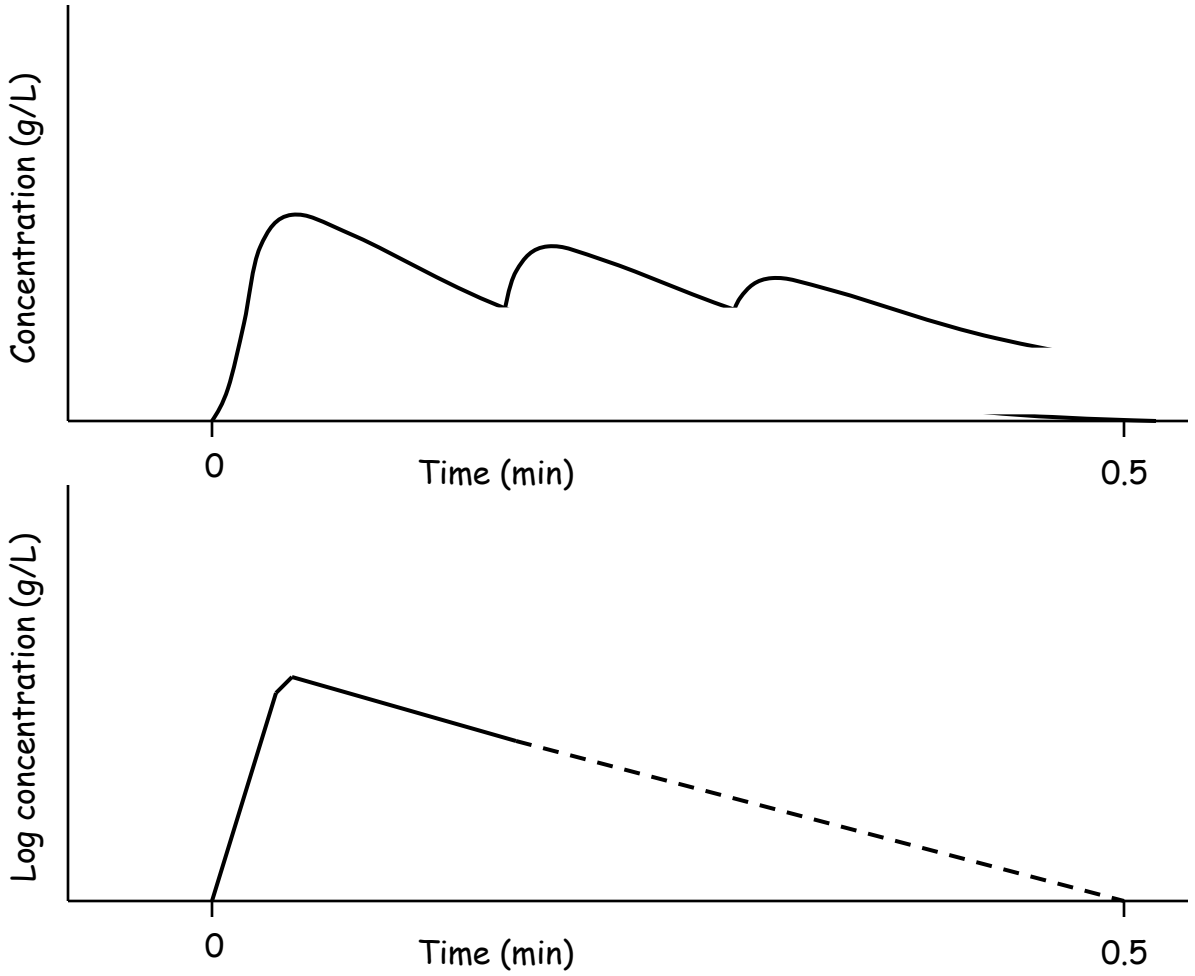


- Amount of dye added = 5 mg
- Average dye concentration = 2 mg/L
- Therefore the volume that diluted the dye = $\frac{5\text{mg}}{2\text{ mg/L}}$ = 2.5 L
- Time it took to go past = 0.5 min
- ie flow rate = $\frac{2.5\text{ L}}{0.5\text{ min}}$ = 5 L/min
- General equation:

$$\text{Flow rate} = \frac{\text{mass of dye (Q g)}}{\text{average dye conc } (\tilde{X}\text{ g/L}) \times \text{time of passage } (\Delta t\text{ min})}$$

Measurement of cardiac output

- Practical considerations



Measurement of cardiac output

- Practical considerations
  - dye recirculates in the CVS
  - estimate of first transit time is facilitated by plotting log concentration
  - Dye must be non-toxic and not immediately absorbed eg indocyanine green
  - Injected into pulmonary artery
  - Measured in brachial artery
  - Like the Fick method, is invasive, & discontinuous

- Same principle
  - Measure thermodilution of cold saline

CO in various conditions

- SV is about 70ml in a resting man in supine position.(70ml of R and L ventricles)
- CO of resting man in supine position is ~5L/min (70ml X 72 beats/min = 5040ml/min)
- Correlation between CO and body surface area, CO/min per M^2 of body surface is called Cardiac Index ~ 3.2L

CO in various conditions

	Condition or Factor
No change	Sleep
	Moderate changes in environmental temperature
Increase	Anxiety and excitement (50-100%)
	Eating (30%)
	Exercise (up to 700%)
	High environmental temperature
	Pregnancy, Epinephrine
Decrease	Sitting or standing from lying position (20-30%)
	Rapid arrhythmias
	Heart disease

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The End

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