HEMODYNAMIC MONITORING IN THE INTENSIVE CARE UNIT

Ashutosh N. Aggarwal

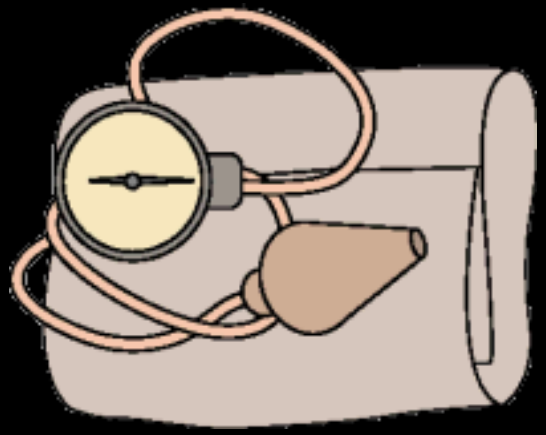
Assistant Professor
Department of Pulmonary Medicine
Postgraduate Institute of Medical Education and Research
Chandigarh (India)

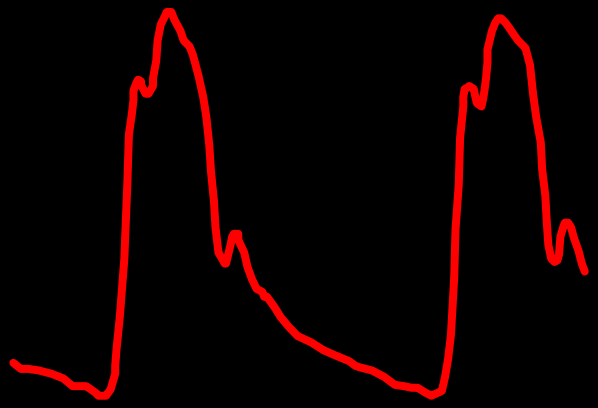
Noninvasive Assessment

- Heart rate
- Blood pressure
- Peripheral pulses
- Urine output
- Jugular venous pulse
- Cardiopulmonary examination

Invasive Assessment

Blood Pressure Measurement





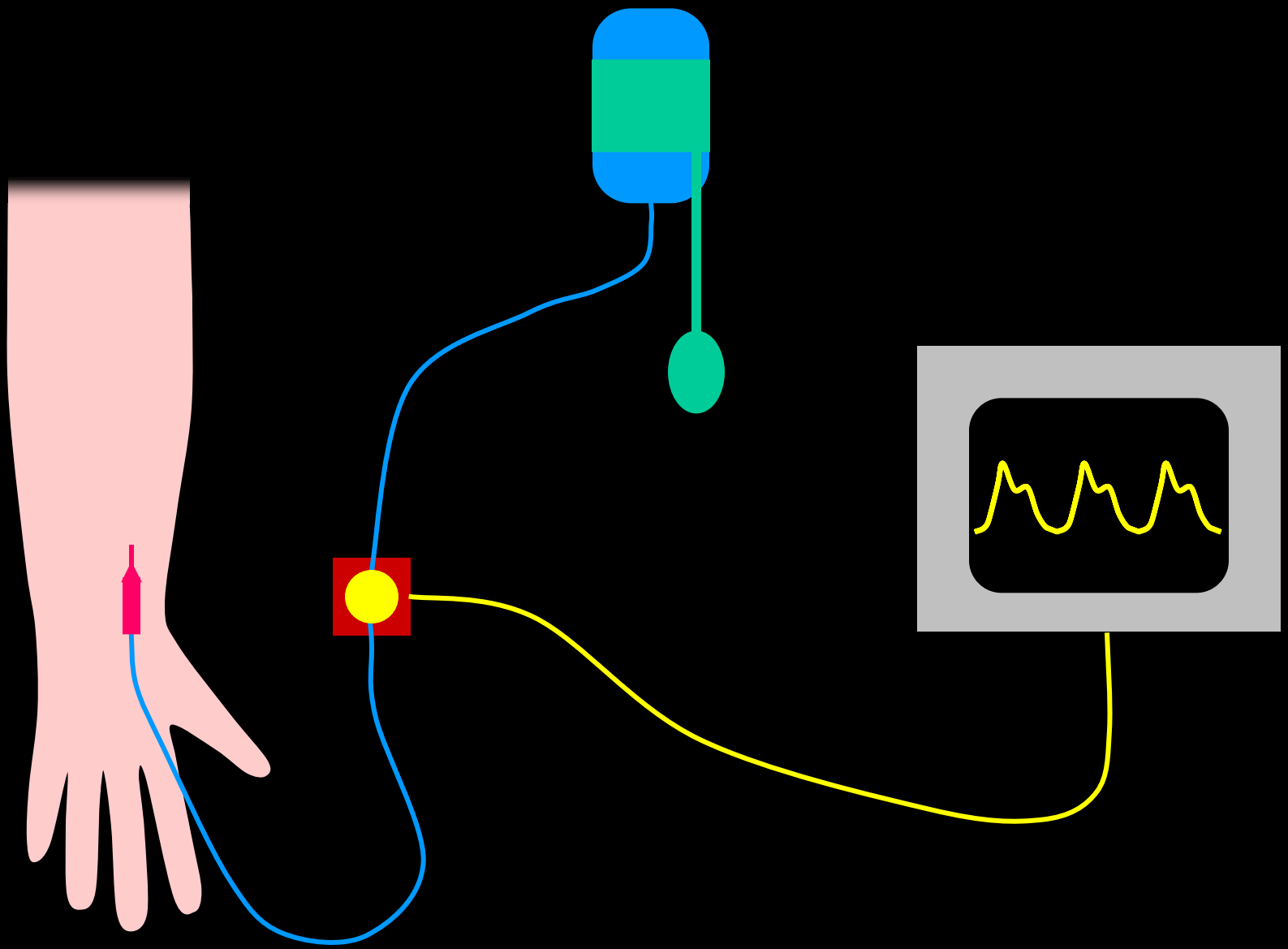
Noninvasive

- Manual (traditional)
- Automated

Invasive

- Arterial cannulation
- Continuous data
- Better for hypotensive patients

Intra-arterial Blood Pressure



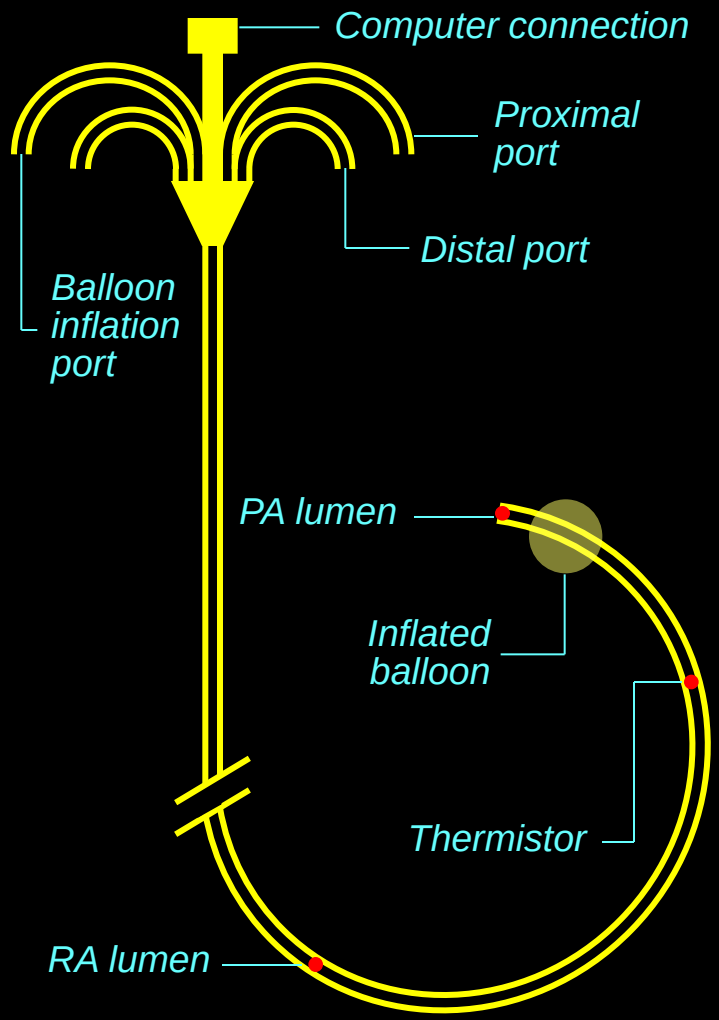
Central Venous Pressure

- Simple method of invasive hemodynamic monitoring
- Catheter inserted via subclavian, internal jugular or femoral vein
- Use simple manometers or transducers
- Parallels right atrial pressure, and hence right ventricular preload and filling
- Although a low CVP indicates impaired hemodynamics, a normal CVP does not always predict adequate blood volume

Central Venous Pressure

- Body position — Supine
- Reference — 4th IC space, midaxillary line
- Zeroing — Atmospheric pressure
- Timing — End expiration
- PEEP — Subtracted (?)

The Swan-Ganz Catheter



Internal lumen - Distal (at tip)
- Proximal (30 cm)

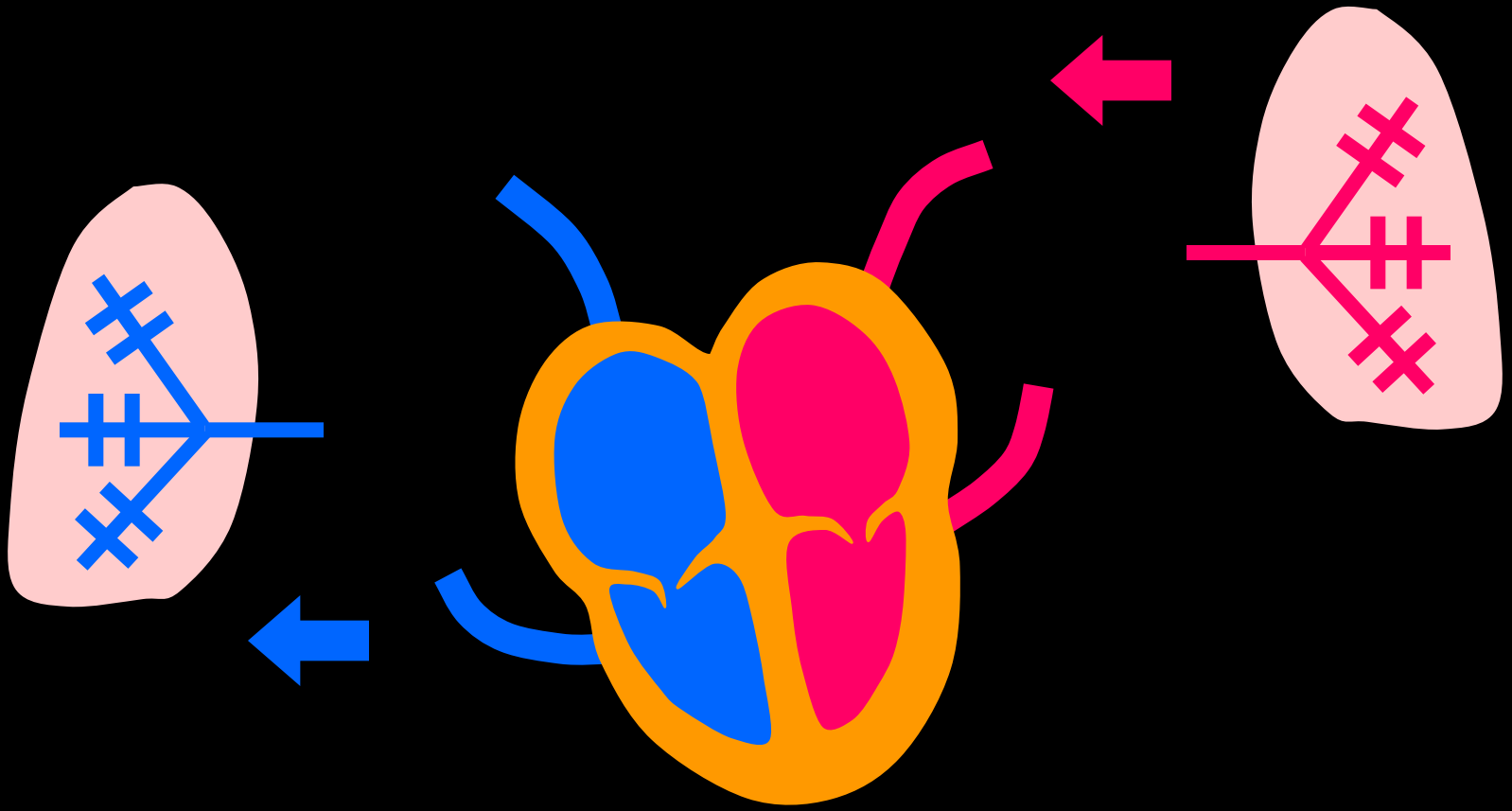
Balloon - acts as sail to guide passage
- used for wedging

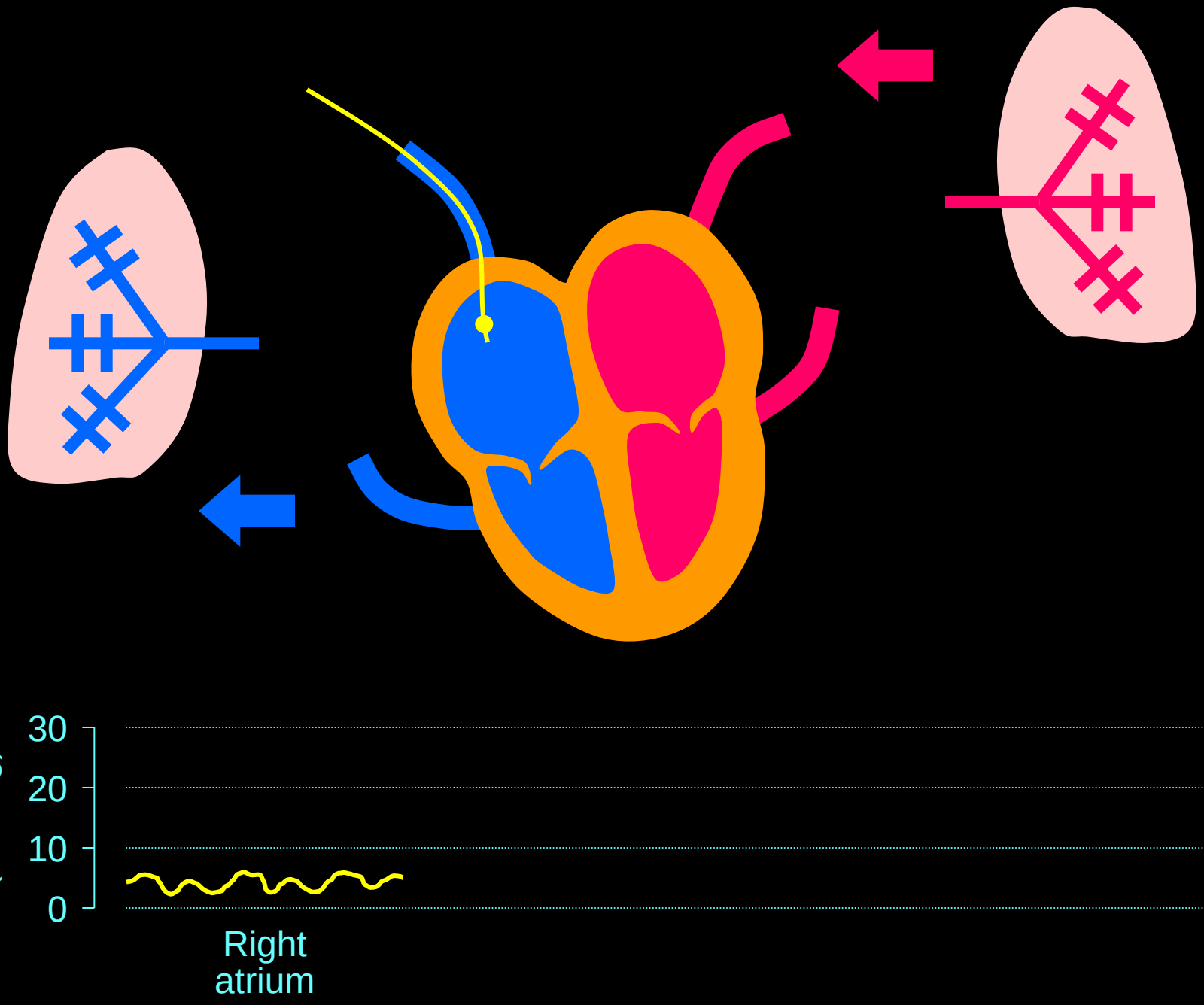
Thermistor (4 cm from tip)

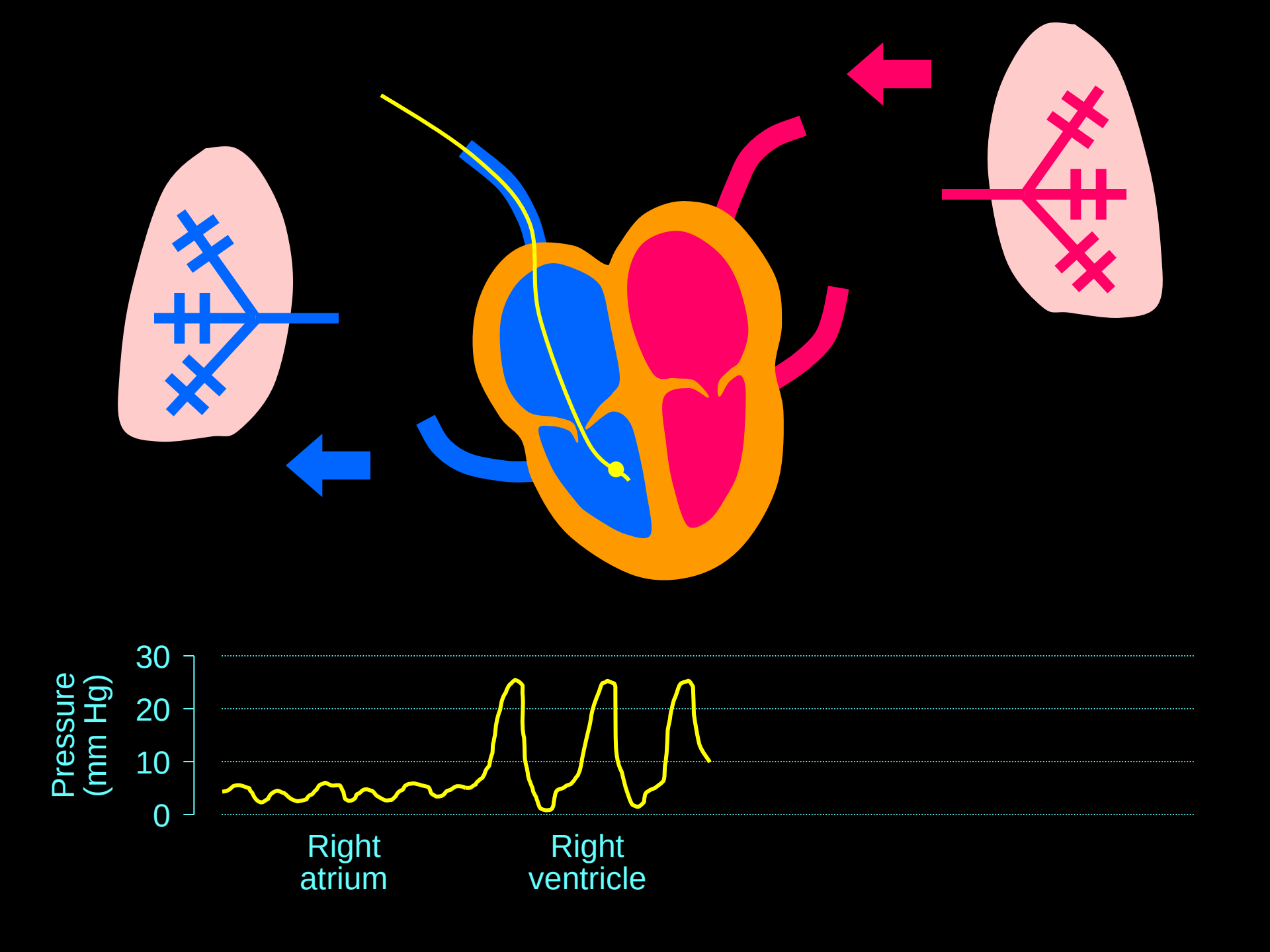
Injection and sampling ports

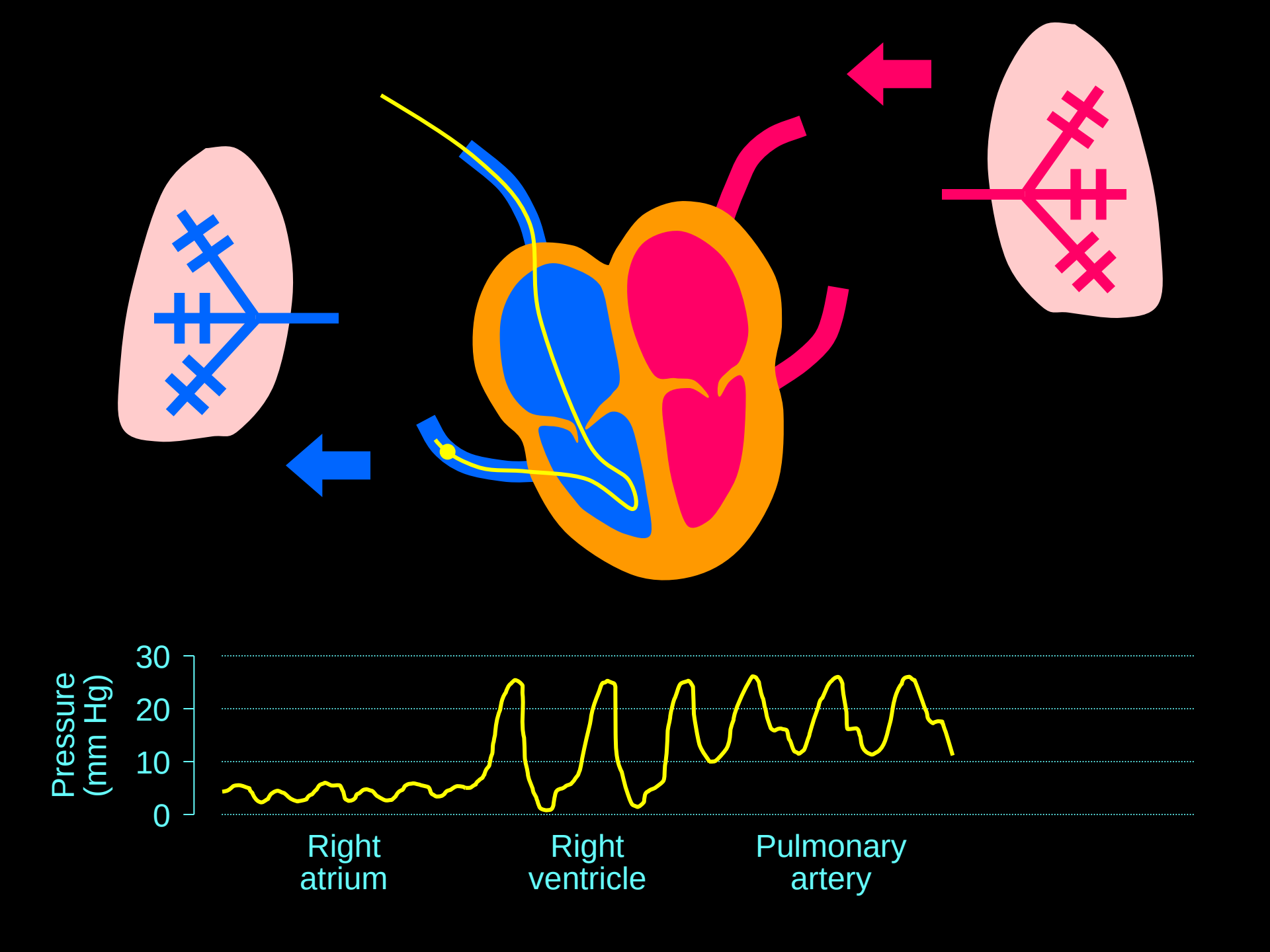
Measurements
- Cardiovascular - Pressures
- Cardiac output
- Mixed venous oxygenation

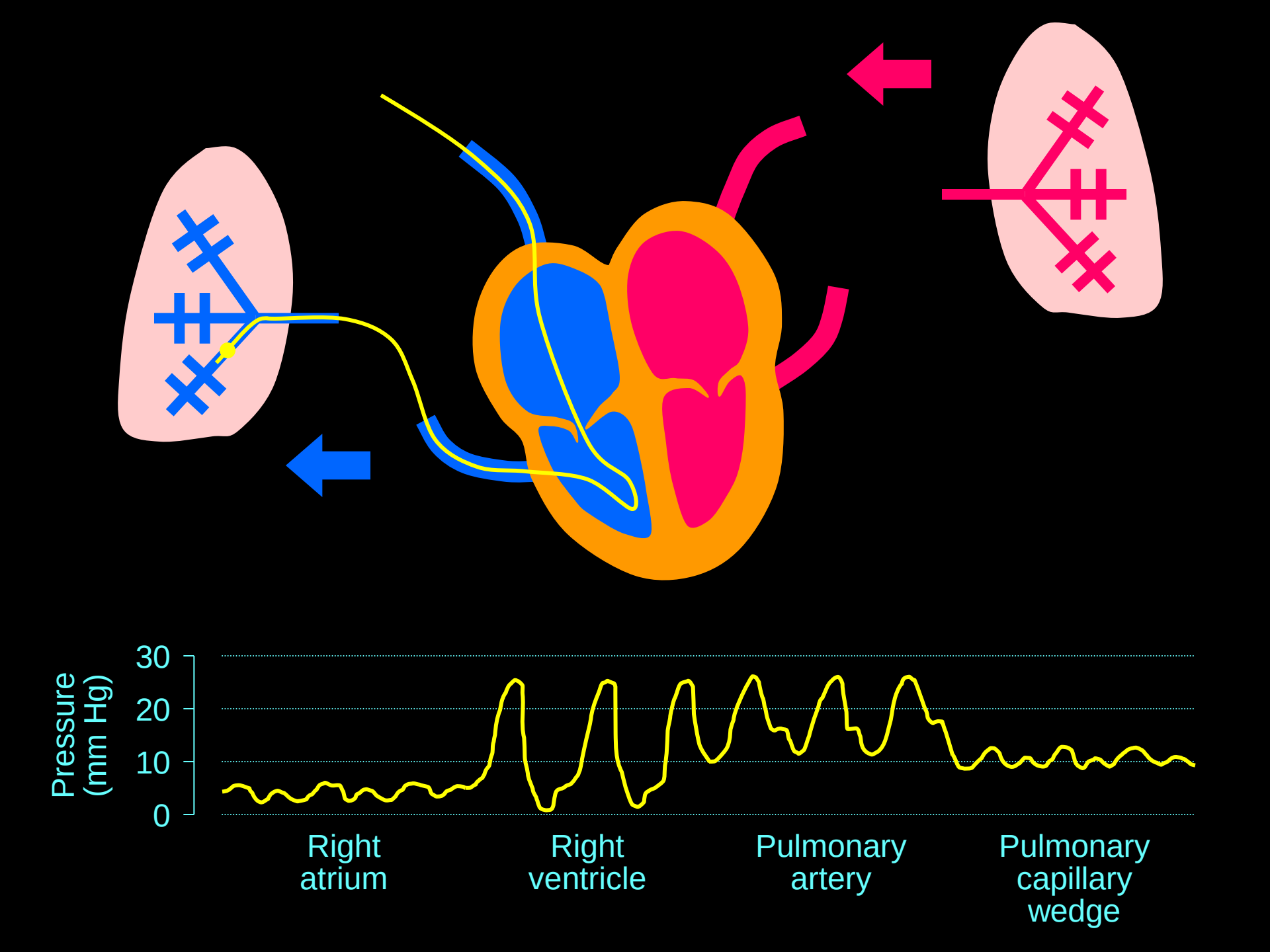
Additional accessories
- Channel for pacemaker
- Fibreoptic system (oxygenation status)




Pressure
(mm Hg)
30
20
10
0
Right
atrium


Pressure
(mm Hg)
30
20
10
0
Right
atrium
Right
ventricle


Pressure
(mm Hg)
30
20
10
0
Right
atrium
Right
ventricle
Pulmonary
artery


Pressure
(mm Hg)
30
20
10
0
Right
atrium
Right
ventricle
Pulmonary
artery
Pulmonary
capillary
wedge

Physiological Measurements From Pulmonary Artery Catheter

Measured variables

- Pulmonary artery pressure
- Pulmonary artery occlusion pressure
- Cardiac output
- Mixed venous oxygen concentration

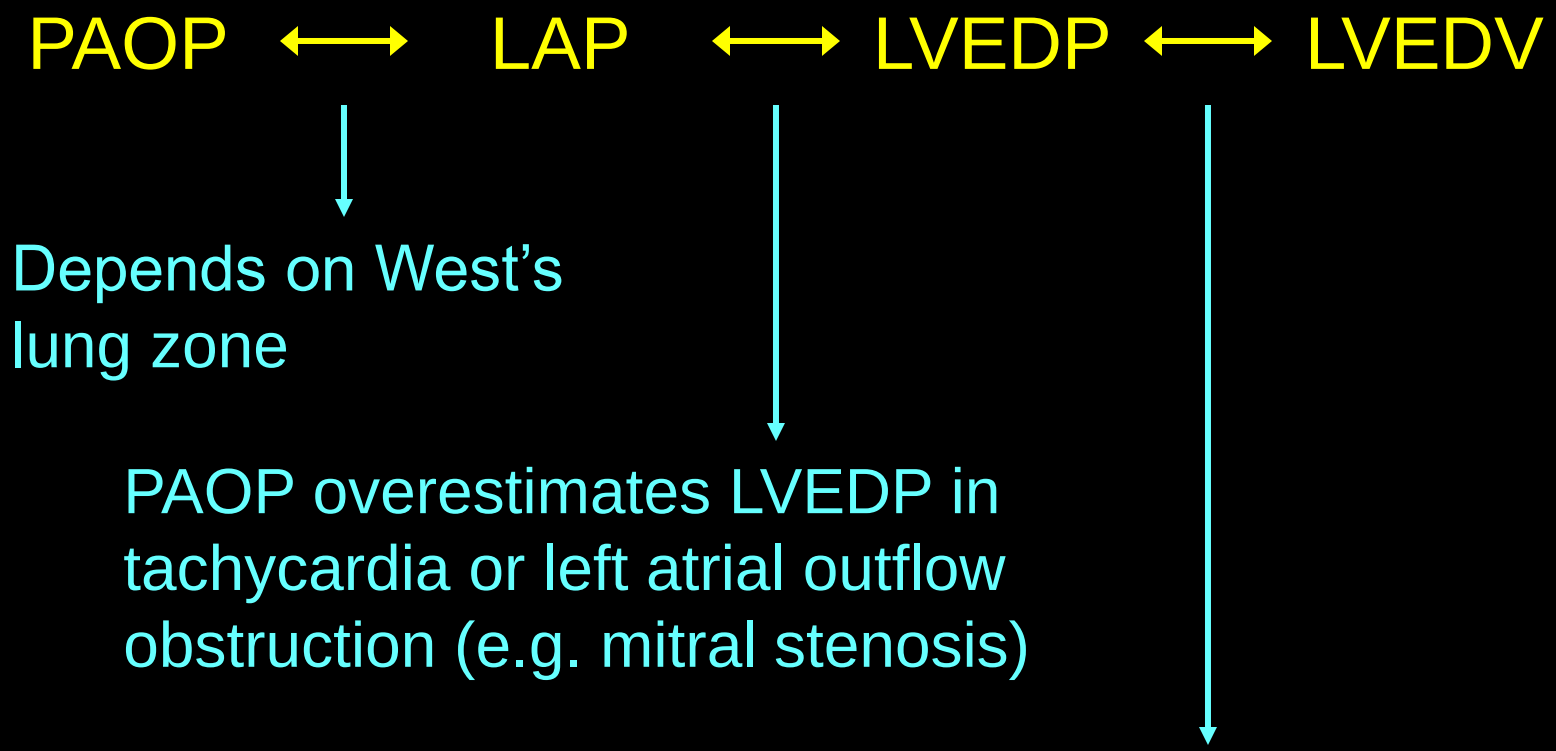
Calculated variables

- Stroke volume
- Systemic vascular resistance
- Pulmonary vascular resistance
- Coronary perfusion pressure
- Oxygen delivery
- Oxygen uptake

Normal Pressure Measurements

Right atrial	Mean	0 – 5 mm Hg
Right ventricular	Systolic	20 – 30 mm Hg
	Diastolic	0 – 5 mm Hg
Pulmonary Artery	Systolic	20 – 30 mm Hg
	End-Diastolic	10 – 15 mm Hg
	Mean	10 – 20 mm Hg
Mean Pulmonary Artery Occlusion		6 – 12 mm Hg

Assumptions in PA Catheter Data



Measuring Cardiac Output Using Pulmonary Artery Catheter

- Bolus of cold saline injected into central venous lumen of PA catheter
- Change in blood temperature detected by a fast response thermistor located at catheter tip

- *Stewart-Hamilton equation:*

$$\text{Cardiac output} = \frac{V \bullet (T_B - T_I) \bullet K_1 \bullet K_2}{T_B(t)^{dt}}$$

To Swan or not to Swan?

Physiological measurements
- Higher in number
- Better in quality ? Better ICU care
- Improved overall assessment

Important considerations
- Waveform interpretation and relevance
- Problems with positioning & obtaining valid tracing
- Absolute values and trends
- Care of system (patency, sterility, deflation)

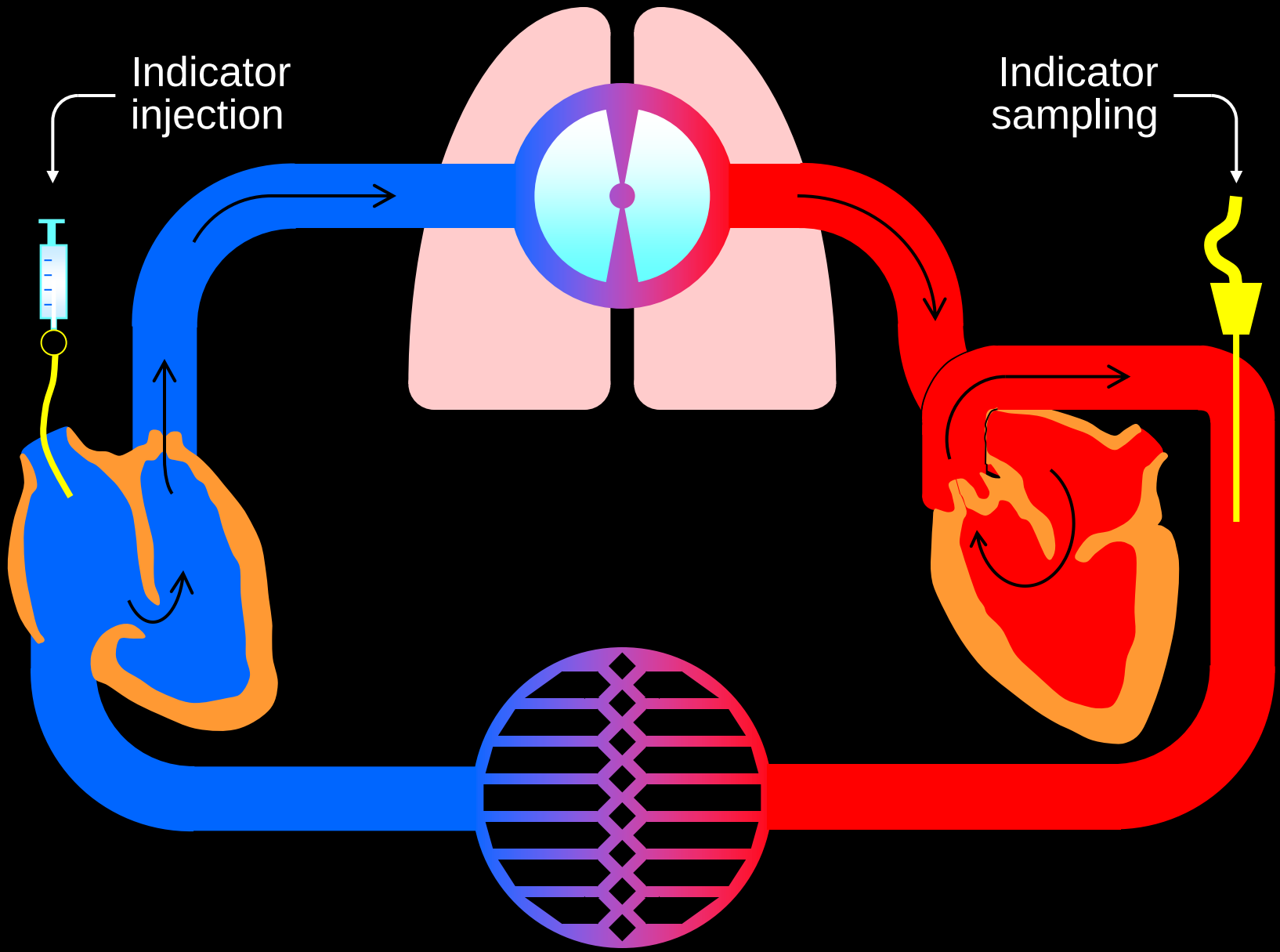
Risks and complications
- Pneumothorax, hemothorax
- Arrhythmias, heart blocks
- Venous thrombosis and venous / air embolism
- Thrombophlebitis, endocarditis, sepsis
- Arterial puncture, PA rupture
- No survival benefit; ? increased mortality

Important Questions

Whether the PA catheter

- Implements easily with low risk of complication ✓
- Provides data not obtainable by other means ✓
- Provides data that can be interpreted uniformly ×
- Leads to change in therapy that affects outcome ?

Transpulmonary Dilution Techniques



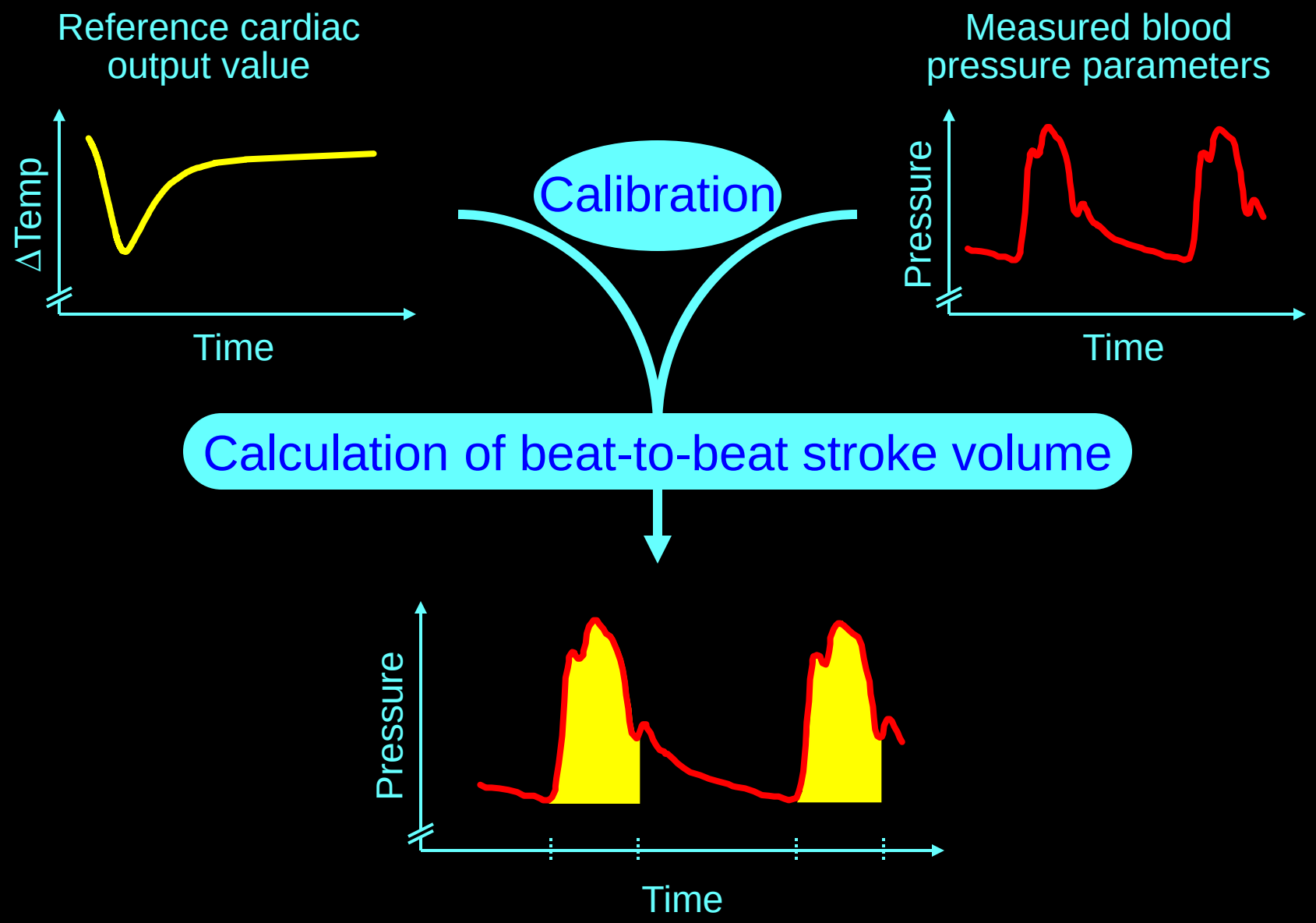
Transpulmonary Dilution Techniques

PiCCO Based on thermodilution

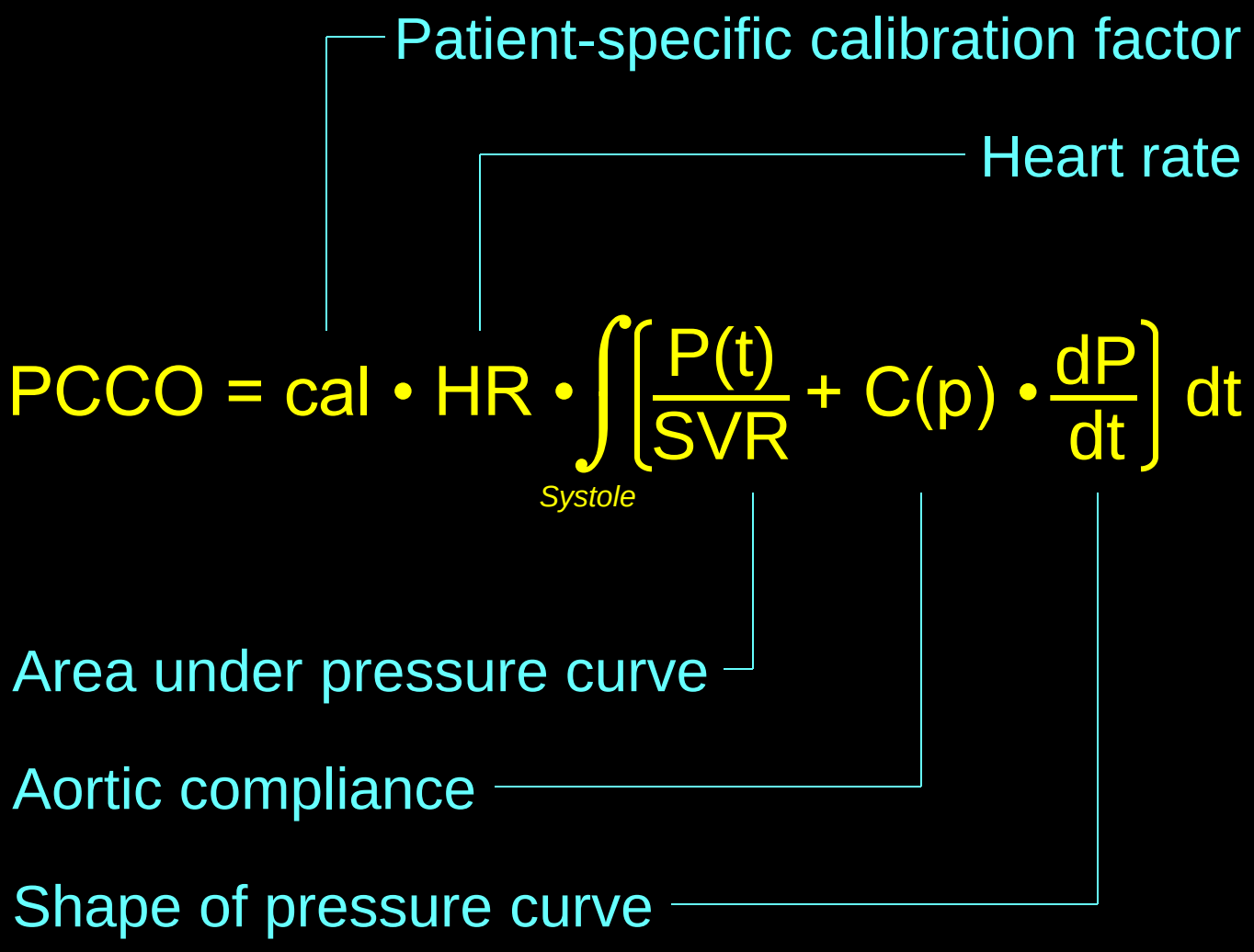
LiDCO Based on lithium chloride dilution

Can be used with arterial pulse contour analysis to give continuous display of cardiac output

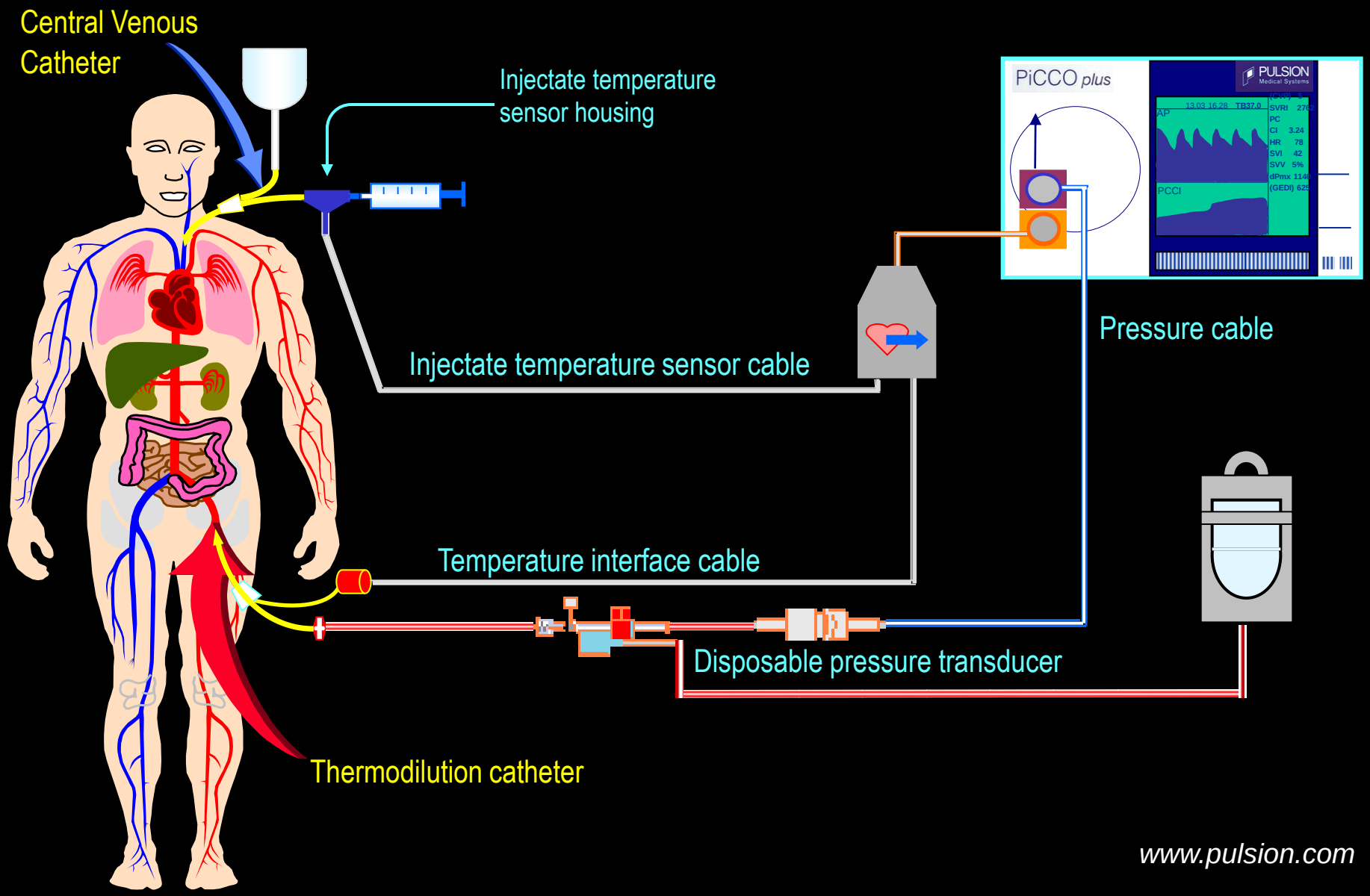
Arterial Pulse Contour Analysis



Arterial Pulse Contour Analysis



PiCCO

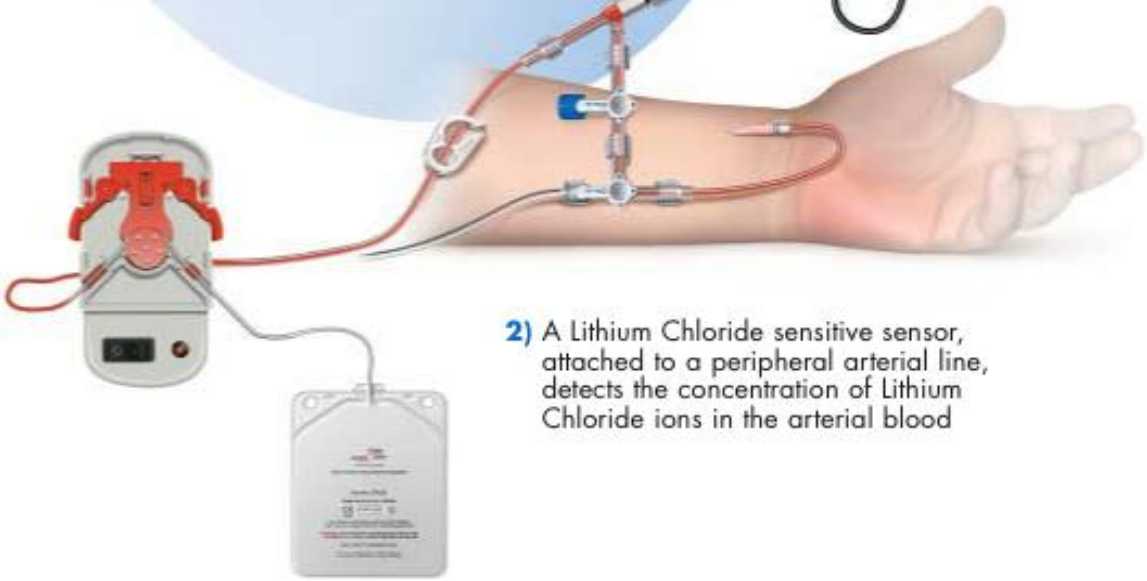


www.pulsion.com

4) This value is then used to calibrate the monitor to give continuous cardiac output and derived variables from arterial waveform analysis.

3) The Lithium Chloride indicator dilution 'wash-out' curve on the LiDCO™*plus* provides an accurate absolute cardiac-output value

1) A bolus of Lithium Chloride is flushed through a central or peripheral venous line



2) A Lithium Chloride sensitive sensor, attached to a peripheral arterial line, detects the concentration of Lithium Chloride ions in the arterial blood

LiDCO

www.lidco.com

Comparison Between Invasive Methods

	PAC	PiCCO	LiDCO
Cost	+	++	++
Operator dependence	+	+	+
Continuous monitoring	+	+	+
Learning curve difficulty	++	+	+
Time from setup to results	+++	++	++
Preload information	+	+++	+++
Invasiveness	+++	++	+

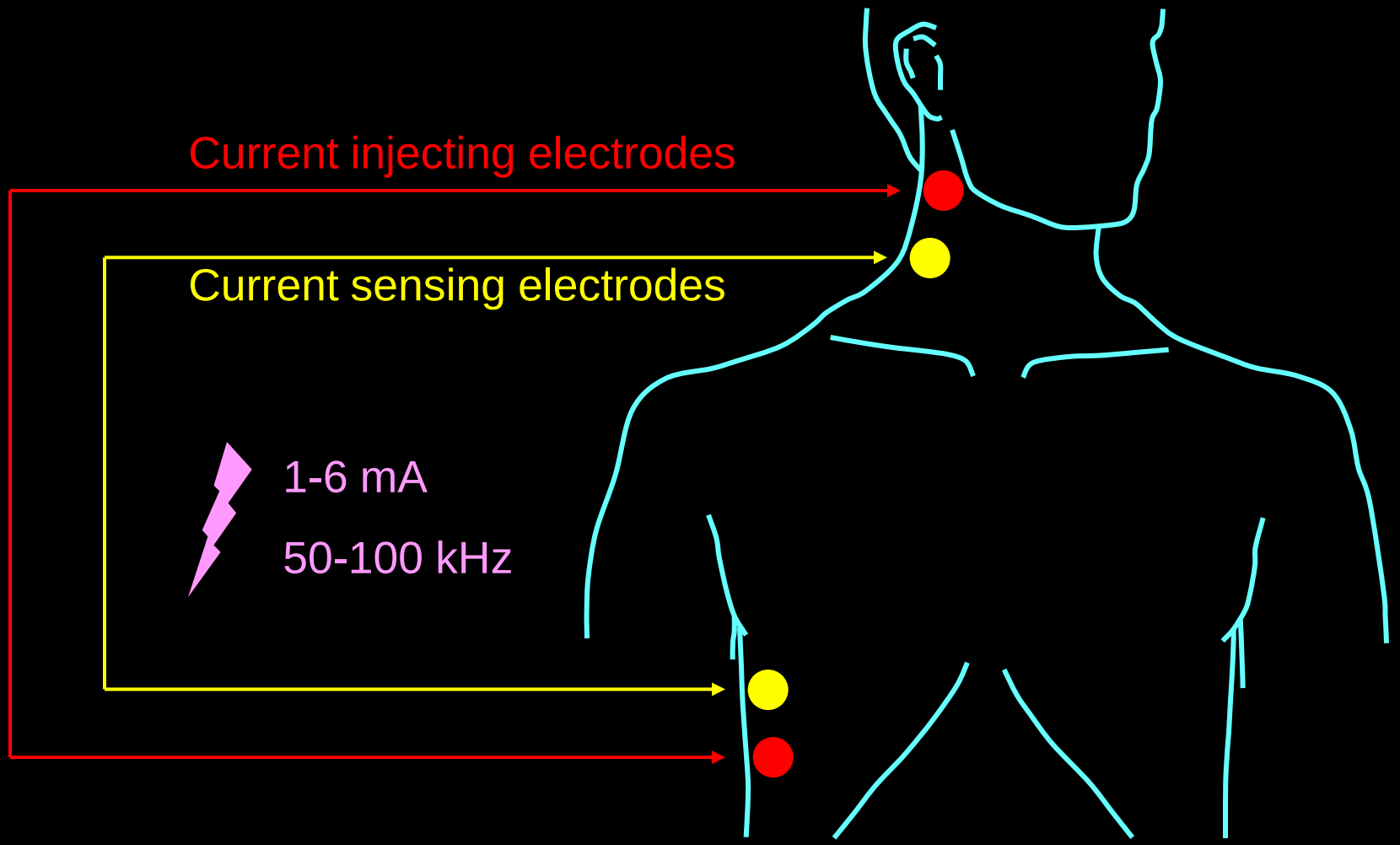
Comparison Between Invasive Methods

	PAC	PiCCO	LiDCO
PA pressure	+	–	–
Cardiac output	+	+	+
PA occlusion pressure	+	–	–
Mixed venous oxygen	+	–	–
Extravascular lung water	–	+	–
Pulse pressure variation	–	+	+
Stroke volume variation	–	+	+

Noninvasive Estimation of Cardiac Output

- Transthoracic bioimpedence
- Transesophageal echocardiography
- Partial CO_2 rebreathing technique

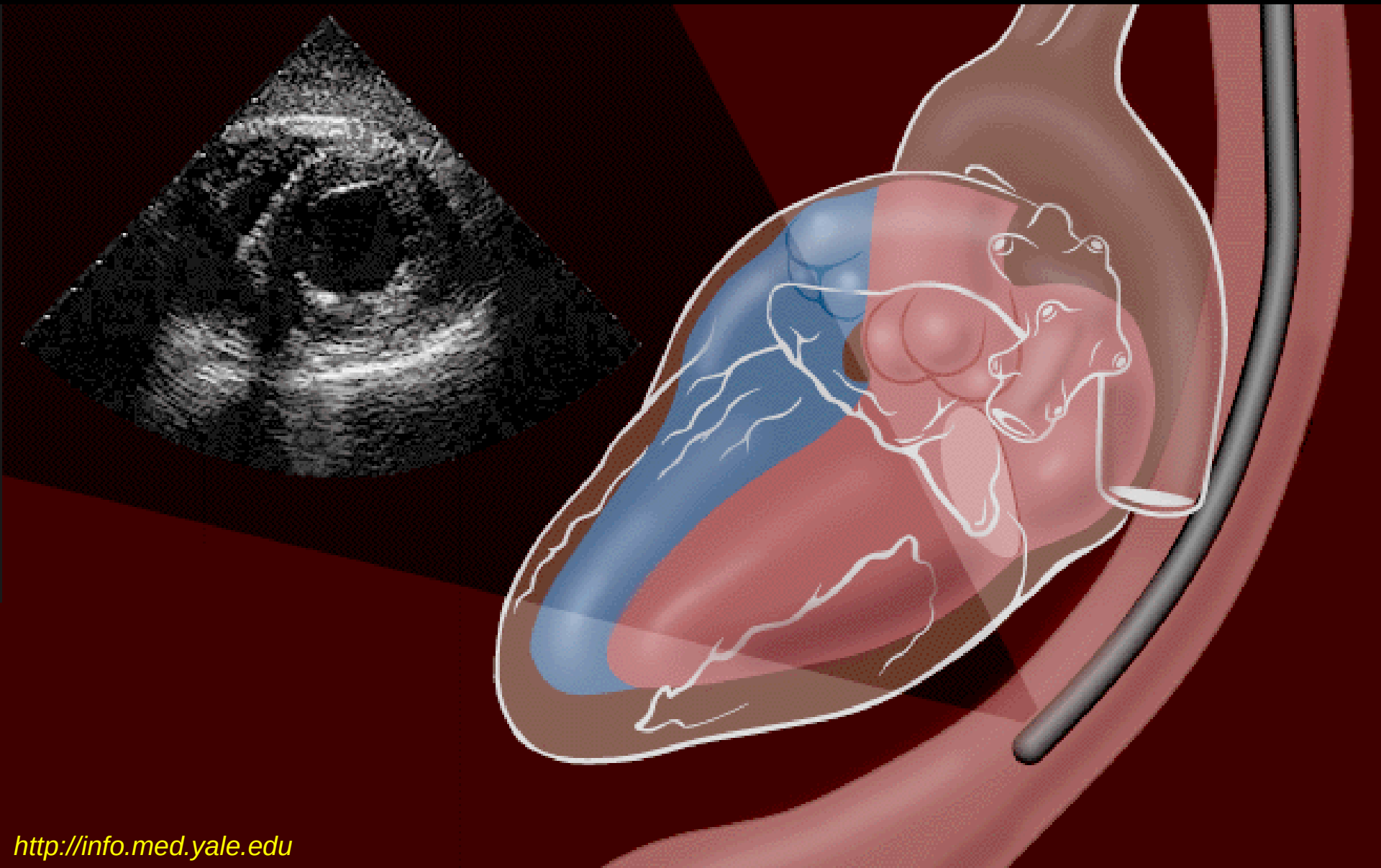
Transthoracic Bioimpedence



Transthoracic Bioimpedence

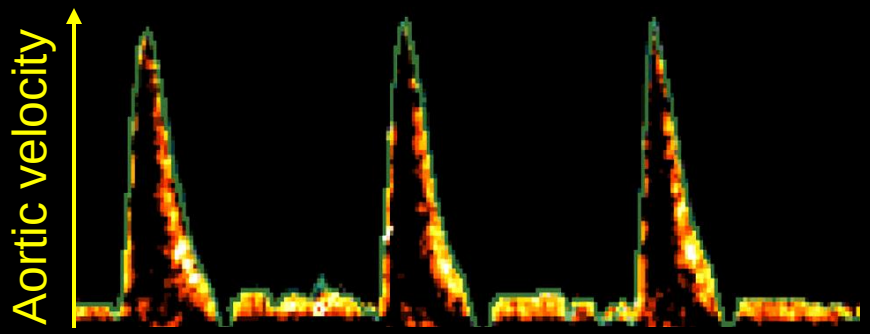
- Truly noninvasive nature, convenience and impeccable safety are major positive points
- Methodological limitations restrict use to research settings only
- Reliability not proven, especially in critically ill patients (mainly due to excessive fluid in the lungs)
- Newer, and more versatile and accurate systems being commercially developed

Transesophageal Echocardiography



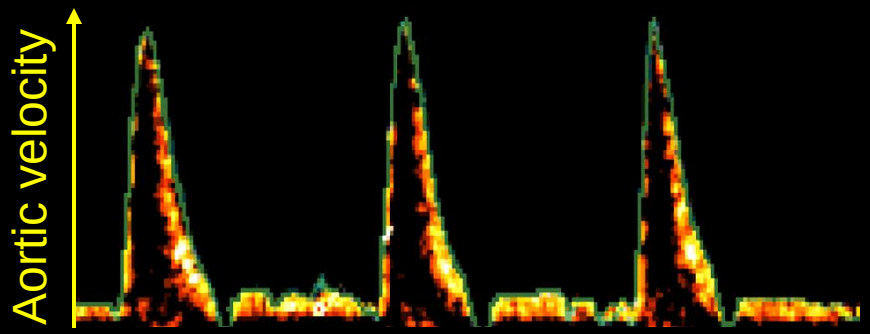
http://info.med.yale.edu

Transesophageal Echocardiography



Velocity waveform in descending aorta with spectral representation of red blood cell velocity

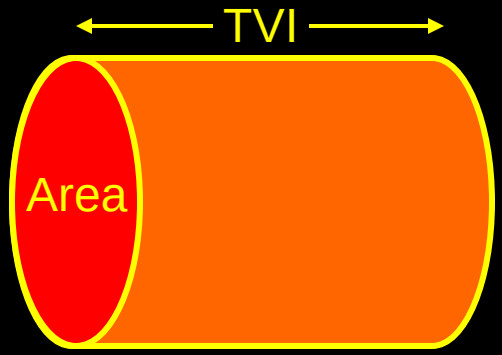
Transesophageal Echocardiography



Velocity waveform in descending aorta with spectral representation of red blood cell velocity

Stroke distance = Time velocity integral (TVI)

Distance a RBC travels in one cardiac cycle



Stroke volume is obtained by multiplying stroke distance & aortic cross-sectional area

Transesophageal Echocardiography

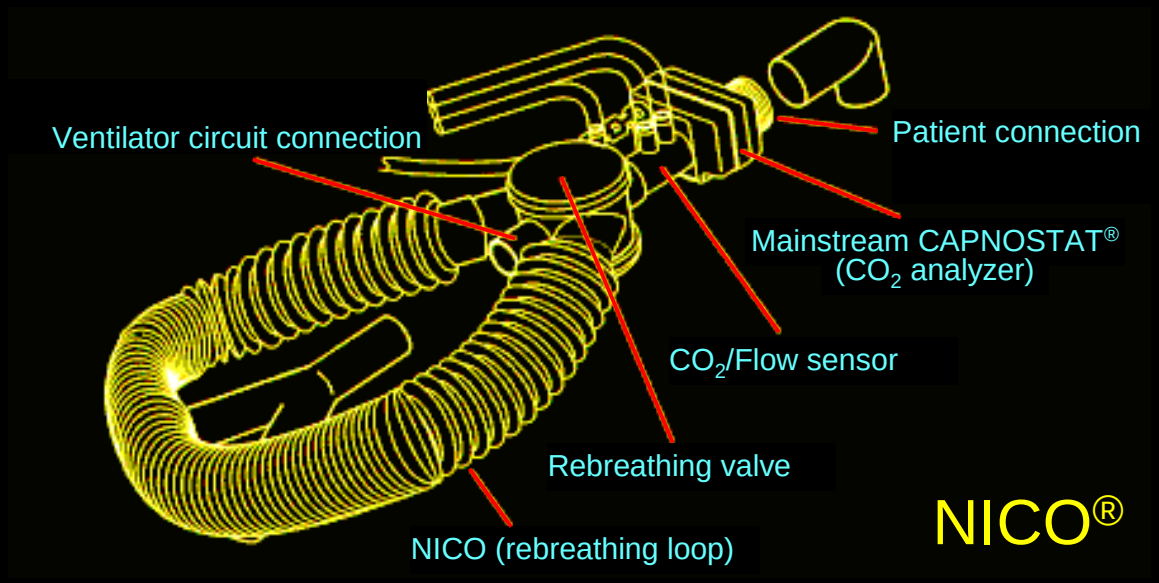
Advantages

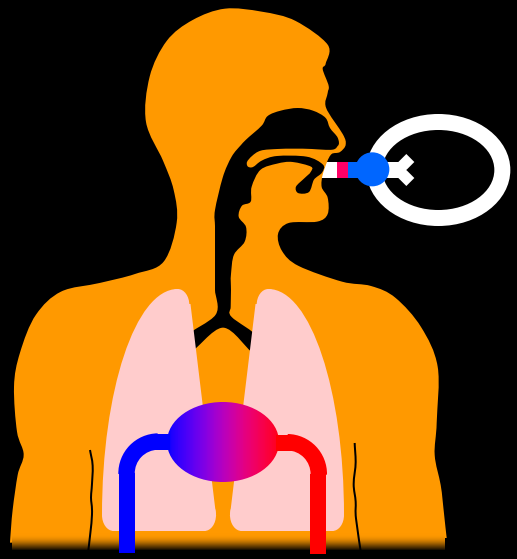
- Less invasive

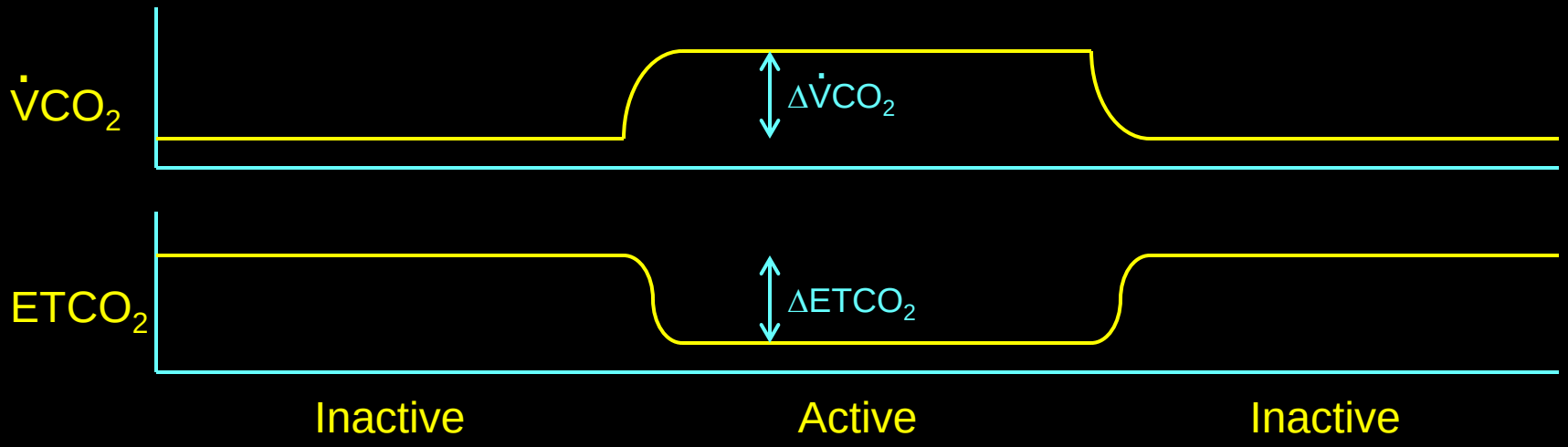
Disadvantages

- Skilled operator needed
- Very expensive equipment
- Heavy sedation / anesthesia
- Probe cannot be fixed to give continuous readings
- Moderate / poor agreement with other methods

Partial CO_2 Rebreathing Technique







Not everything that counts can be counted, and not everything that can be counted counts.

Albert Einstein