Institute of Surgical Research
Basic Medical Skills

B 1-2. practicals – Introduction to invasive monitoring

B 3-4. practicals – Monitoring of the cardiovascular system

Cannulation of *jugular vein* → CVP measurement;

Cannulation of *femoral a.* → Arterial pressure measurement;

Thermodilution cardiac output measurement;

Positioning of Swan Ganz catheter to the *pulmonalis artery*;

Disection of *carotis* artery → Blood flow measurement;

B 5-6. practicals – Complex monitoring

INVASIVE HEMODYNAMIC MONITORING

„When a patient is critically ill, even the most thorough examination by the most experienced physician is not enough; then we have to measure, and measure particularly accurately."

Gábor Petri

Dissection of veins - Cannulation of jugular vein

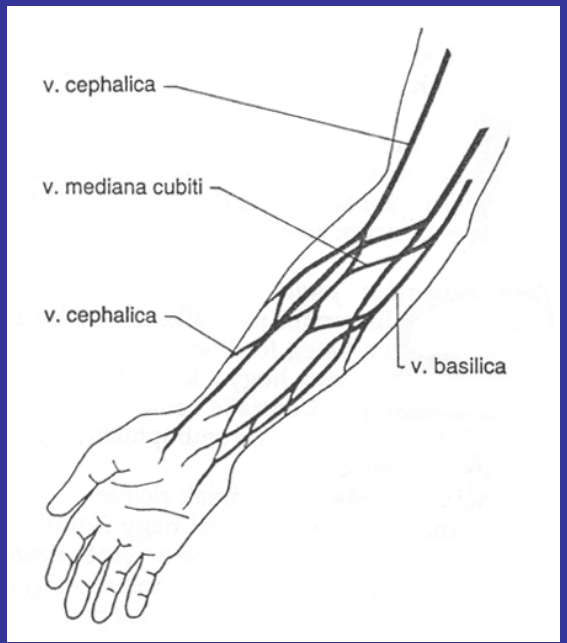
Venous cutdown, that is surgical exposure of a peripheral vein, is necessary if it is impossible to insert a cannula into a satisfactory vein - or the percutaneous insertion of a vena cava catheter is contraindicated.

Indications for catheterization of a vein

1. Replacement of fluids (infusion, transfusion)
2. Iv. administration of drugs
3. Obtaining serial blood samples

Venous catheter can be introduced into the following veins

1. Arm veins (median cubital vein, basilic vein, sometimes cephalic vein)
2. External jugular vein
3. Superficial veins of the foot and the leg (saphenous vein)



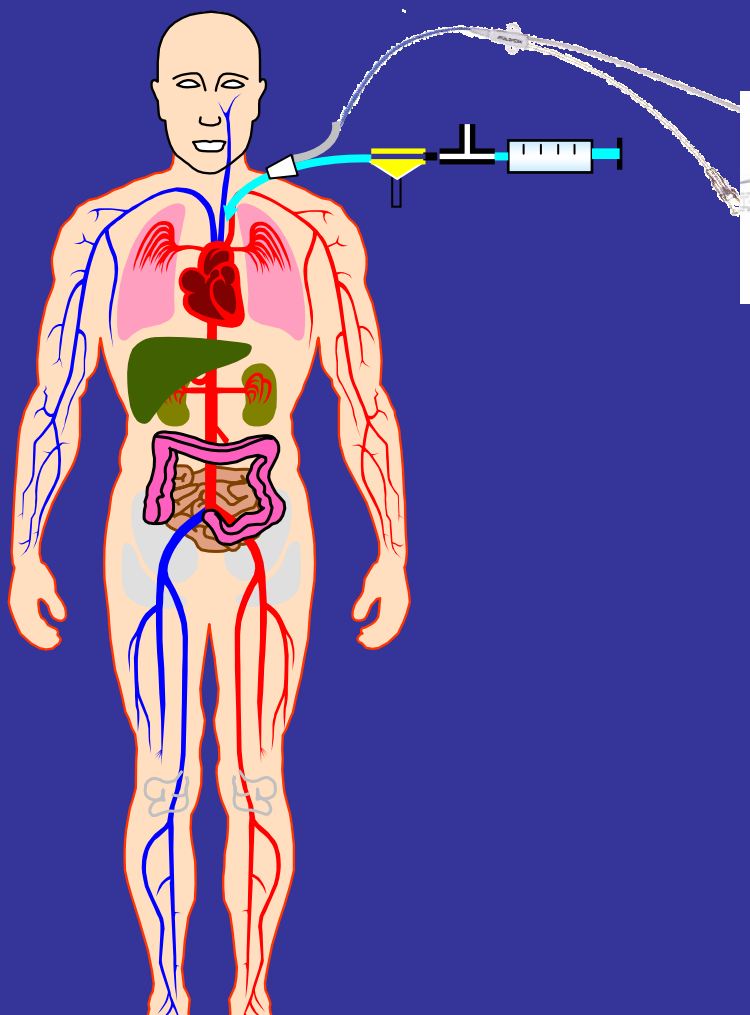
Venous cutdown, cannulation (video)

Removal of venous catheter (video)

Arterial/venous catheterization with percutaneous punction

1. Measurement of central venous pressure

Central venous catheter



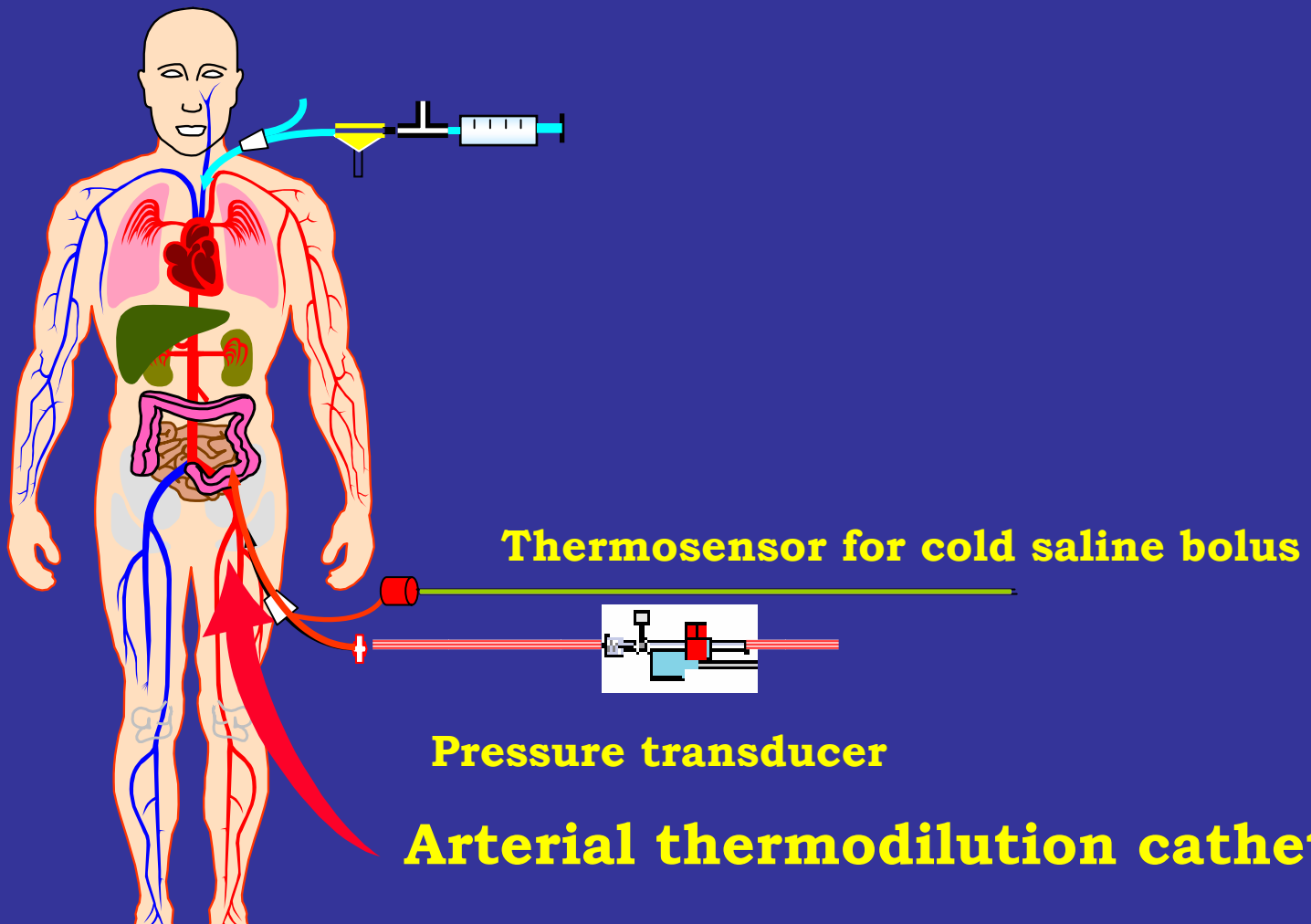
Pressure transducer (sensor)

1. Central Venous Catheterization

Surgical Team 1.

- **Surgical exposure of the left jugular vein:**
  1. Stretching the skin on both sides of the planned incision;
  2. Skin incision (5-7 cm) with a skin scalpel;
  3. Dissection of subcutaneous tissues with diathermy pencil;
  4. Handling bleeding if necessary;
  5. Localisation of the vein (in approx. 2 cm deptht);
  6. Blunt dissection of the vein;
  7. Opening the vessel and introduction of the CV catheter
- **Fix the cannula securely and connect it to the pressure measurement system;**
- **CVP measurement**

2. Measurement of arterial pressure in the femoral artery

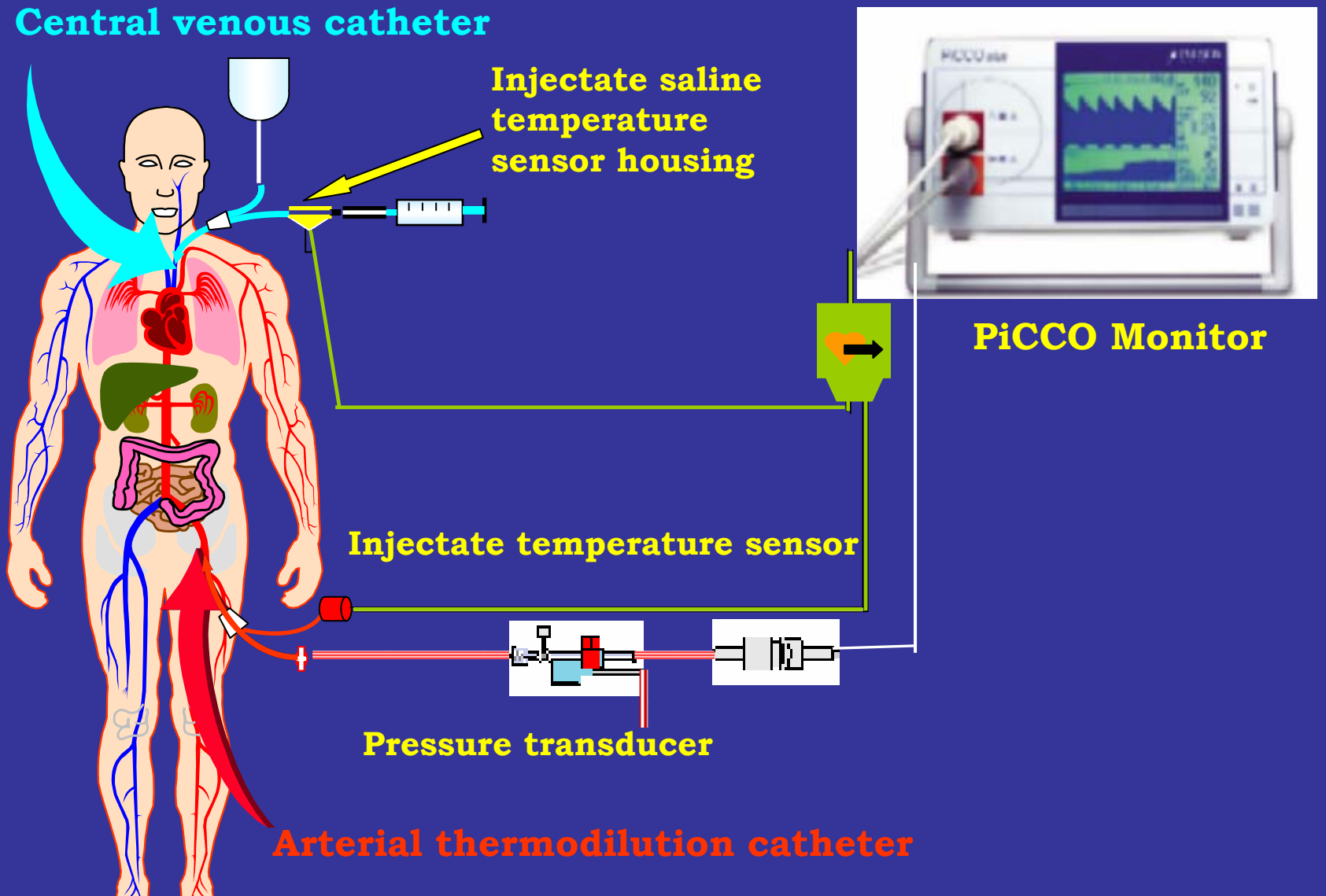


2. Catheterization of femoral artery

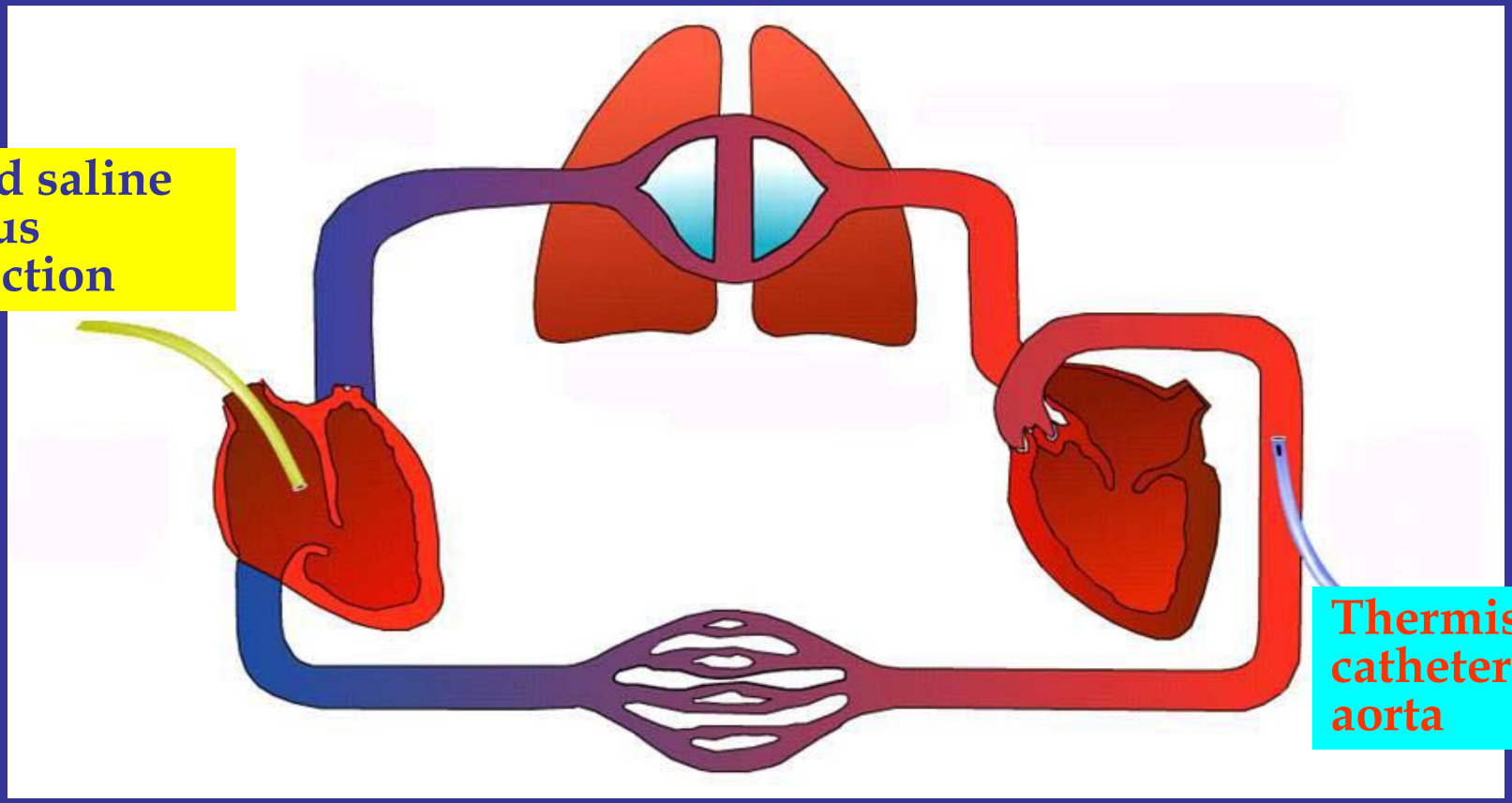
Surgical Team 2.

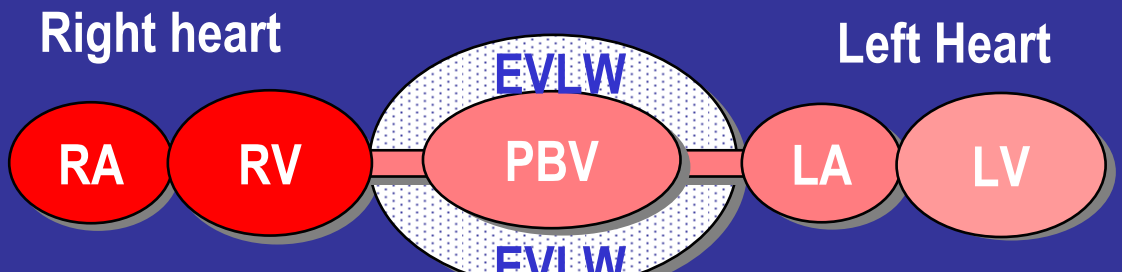
- Skin incision on the inguinal area;
- Cutting the connective tissue by diathermy;
- Abdominal wall is retracted;
- Careful, blunt disection of the femoral artery
  by using dressing forceps only (!);
- Catheterization with a thermistor-pressure supplied catheter;
- Fix the catheter securely and connect it to the pressure sensor;
- Arterial pressure measurements

3. Cardiac Output measurement with a transpulmonary thermodilution (TDa) method



Scheme for the Transpulmonary Thermodilution Method





Measurement of Cardiac Output (CO)

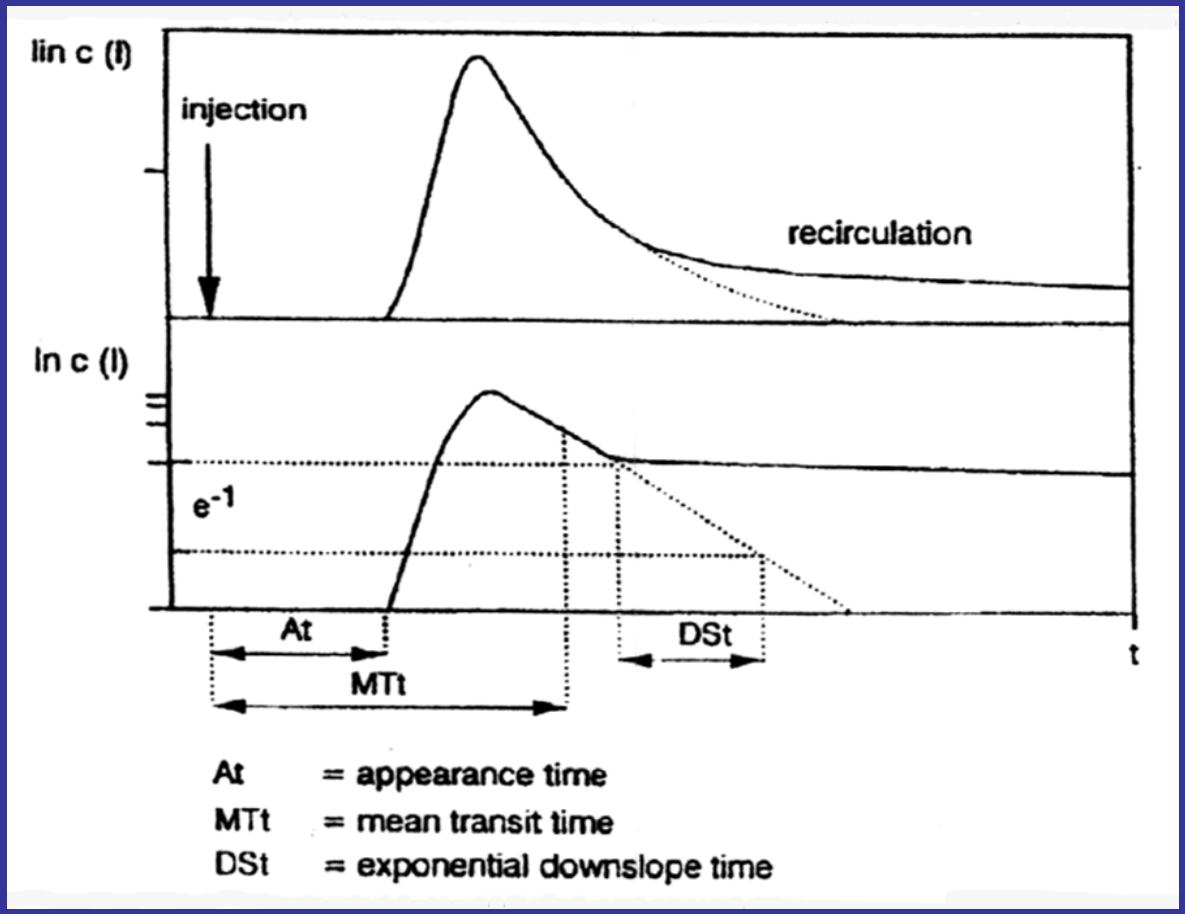
A known volume of cold saline (5-10-20 ml) is injected iv, as fast as possible. Saline temperature is at least 10°C lower than blood temperature.

The passage of the heat bolus injected into the central vein is registered by a thermistor catheter positioned in the femoral artery.

The temperature change recorded downstream is depending on the flow and on the volume through which the cold indicator has passed. As a result, a thermodilution curve can be obtained.

The cardiac output is calculated from the area under the thermodilution curve.

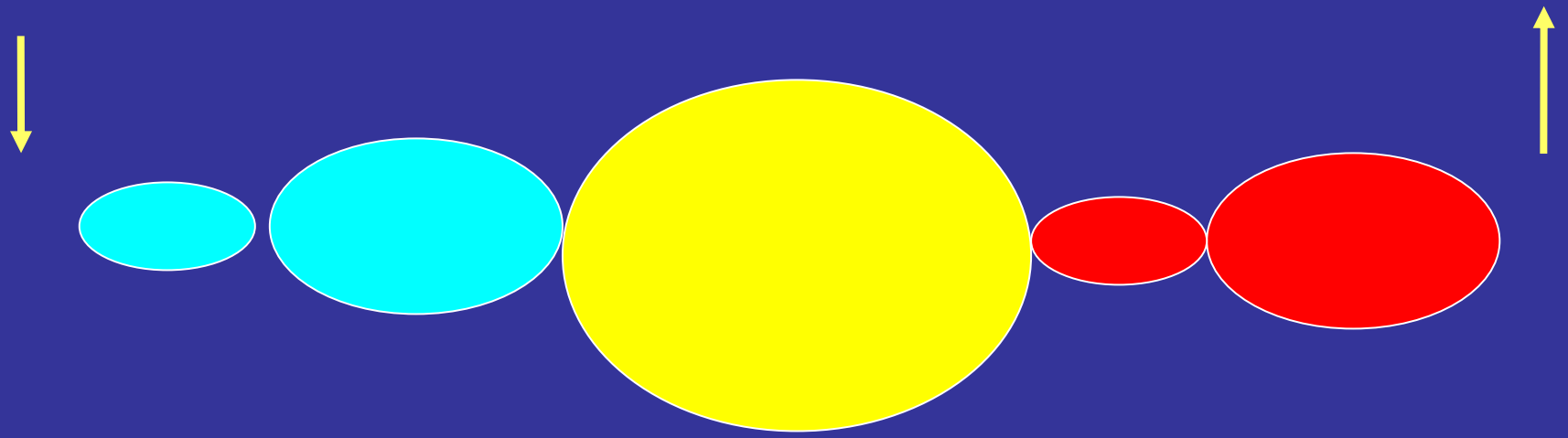
Time components of the thermodilution curve



MTt: Mean transit time ≈ half of the indicator passed the point of detection.

DSt: Downslope time ≈ exponential downslope time of TD curve.

ITTV = IntraThoracic Total Volume



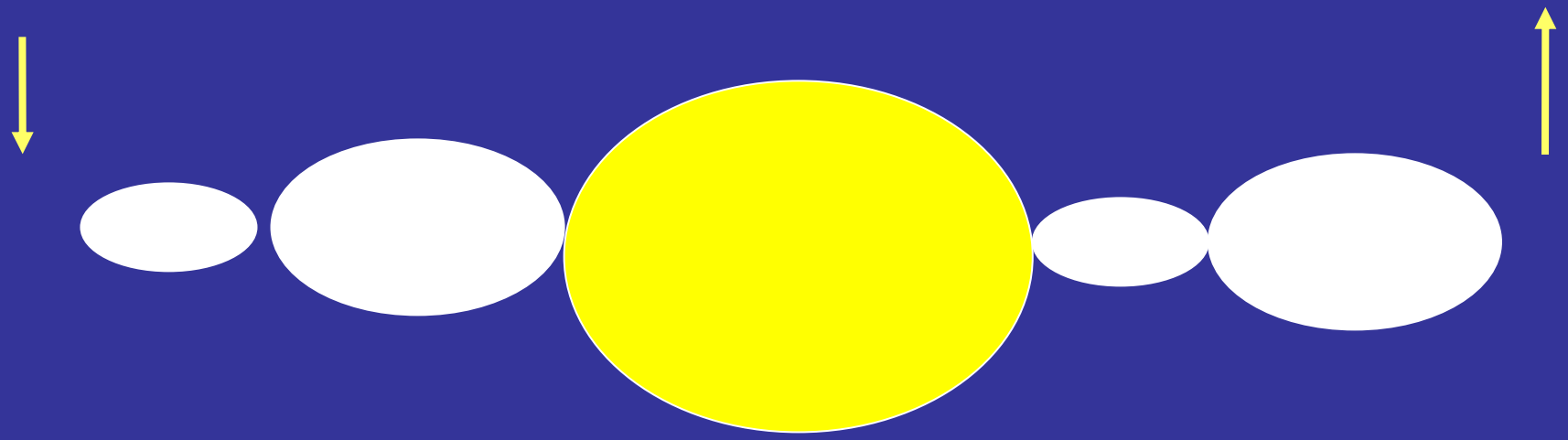
ITTV = MTt x CO

(V = t x Q)

ITTV = volume from the point of injection to the point of detection.

Flow measurement between two points, based on the V = t x Q relationship;

PTV = Pulmonary Total Volume

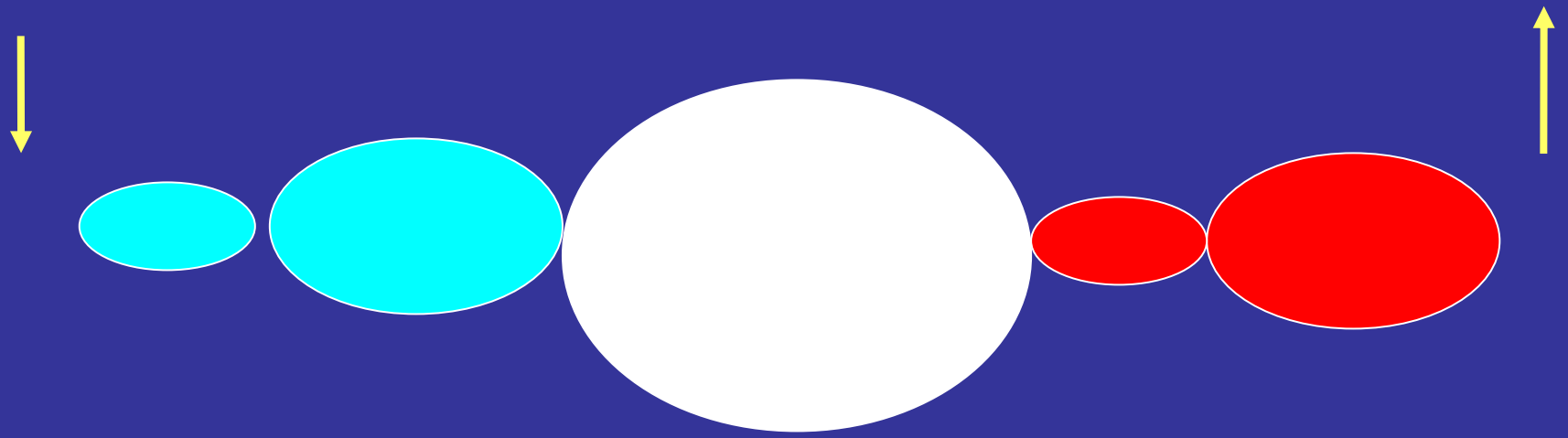


PTV = DSt x CO

(V = t x Q)

Between the two detection points, the lung is the largest volume space, where the flow slowes down and the rate of thermodilution is the highest → this is shown by the DSt time component.

GEDV = Global End-Diastolic Volume



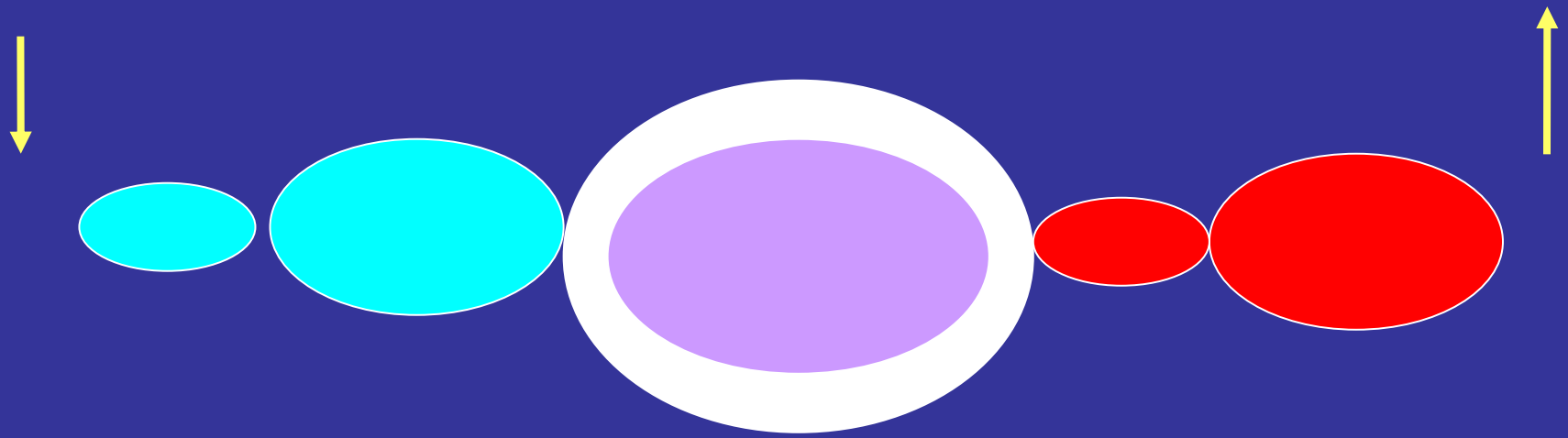
GEDV = ITTV - PTV

GEDV = (MTt - DSt) x CO

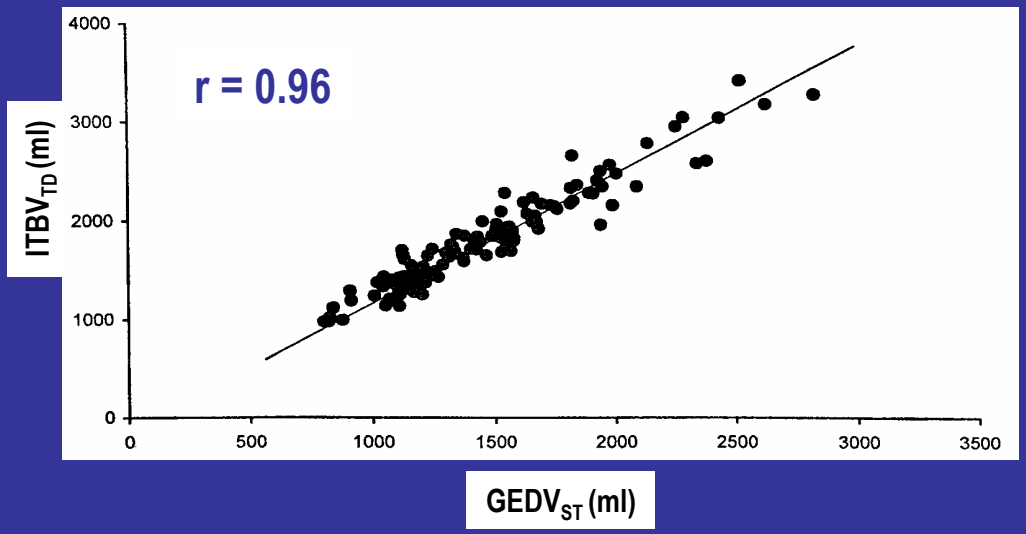
GEDV= End-diastolic volume of the 4 heart chambers

GEDV = Preload

ITBV* = IntraThoracal Blood Volume

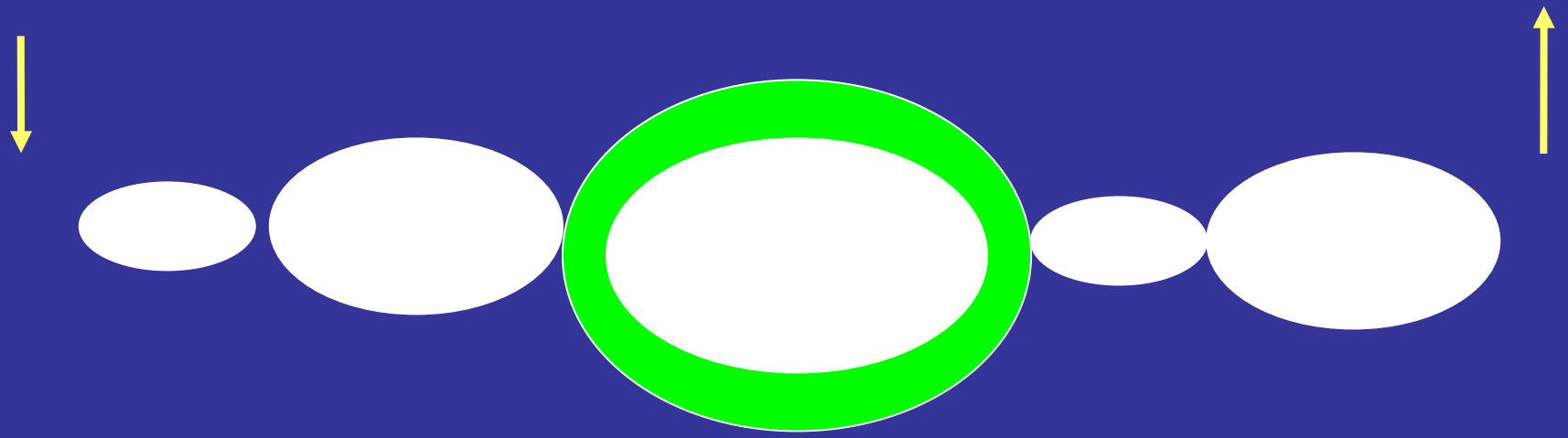


ITBV* = 1,25 x GEDV



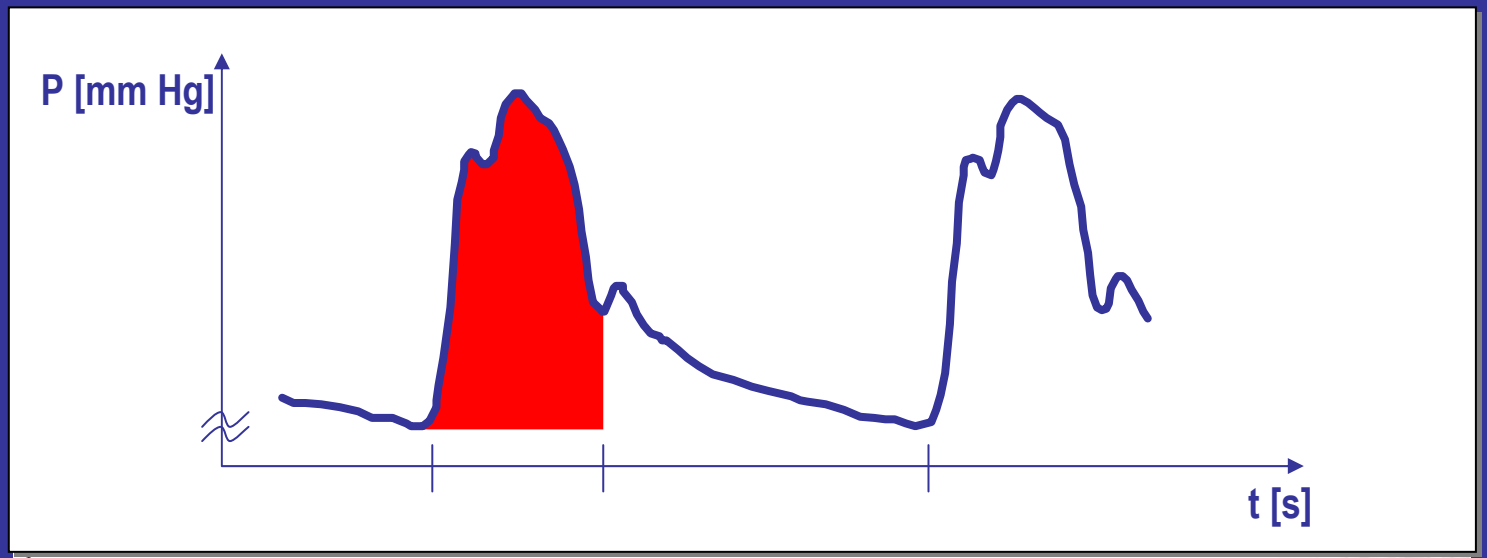
Sakka et al, Intensive Care Med 26: 180-187, 2000

EVLW* = ExtraVascular Lung Water



EVLW* = ITTV - ITBV*

Arterial Pulse Contour Analysis
Pulse Contour Cardiac Output (PCCO)



$$PCCO = cal \cdot HR \cdot \int_{Systole} \left(\frac{P(t)}{SVR} + C(p) \cdot \frac{dP}{dt} \right) dt$$

- cal: Patient-specific calibration factor (determined with thermodilution)
- HR: Heart rate
- $\int_{Systole}$: Area under pressure curve
- $\frac{P(t)}{SVR}$: Compliance
- $C(p) \cdot \frac{dP}{dt}$: Shape of pressure curve

Measured and calculated parameters

1) Thermodilution parameters

CO → Cardiac output (L/min)

CI → Cardiac index = CO/body surface ($ml/min/m^2$)

GEDV → Global End-diastolic volume = PRELOAD (ml)

ITBVI* → Intrathracic blood volume (estimated) (ml)

EVLWI* → Extravascular lung water (estimated) (ml)

2) Pulse Contour parameters

PCCO → Pulse contour cardiac output (continouos) (L/min)

SV → stroke volume = CO/heart rate (ml)

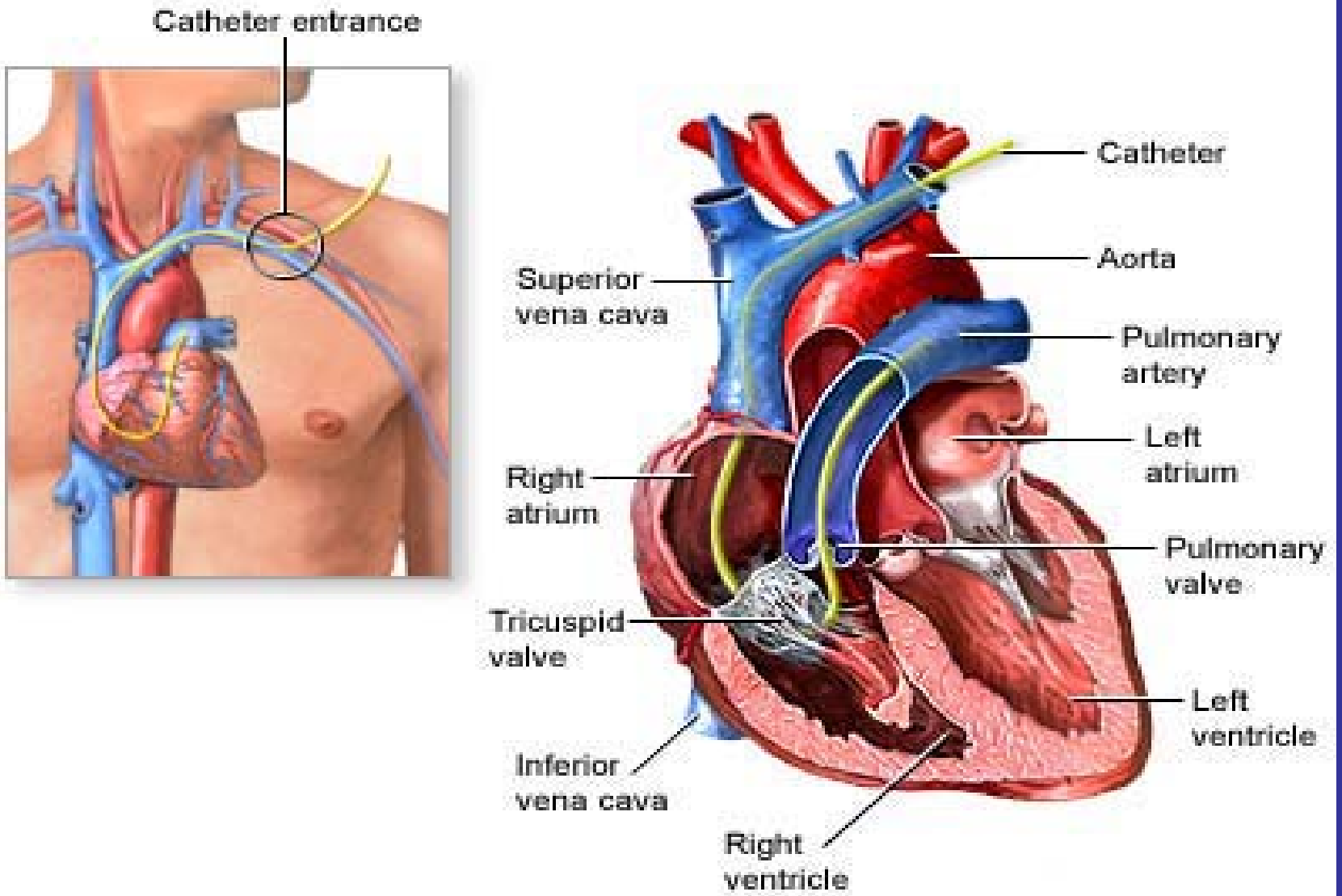
AP → arterial pressure (systolic, diastolic, mean) (mmHg)

SVR → Systemic vascular resistance = (AP-CVP)/CO

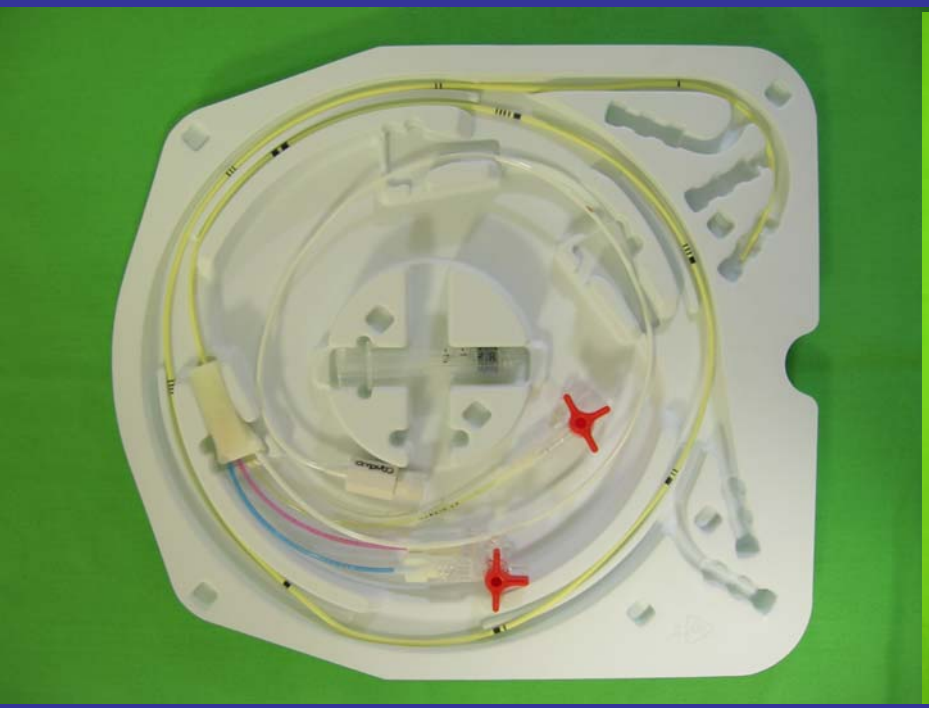
dP/dtmax → heart contractility index (mmHg/sec)

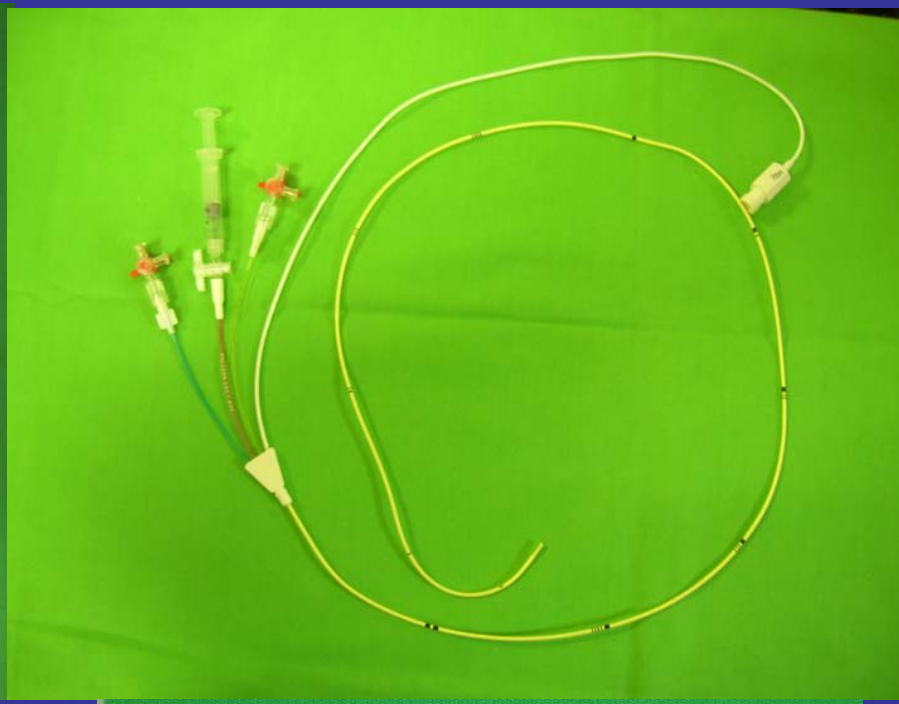
4. Monitoring of pulmonary circulation

Positioning of Swan-Ganz catheter into the pulmonary artery



Swan-Ganz catheter, a device of monitoring of pulmonary circulation: Pressure and CO





Yellow: PA pressure
Blue: for CVP and saline injection
White: thermistor cabel
Red: catheter balloon

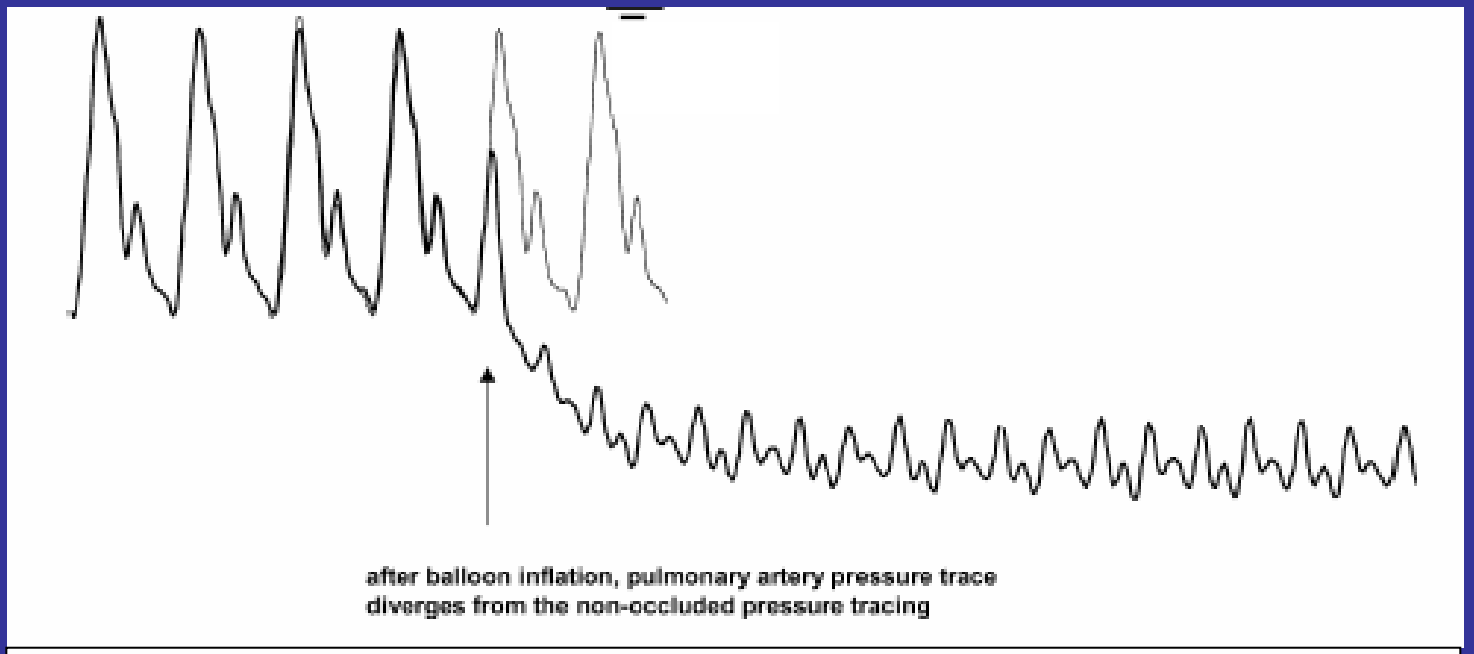
4. Monitoring of pulmonary circulation

Surgical Team 2.

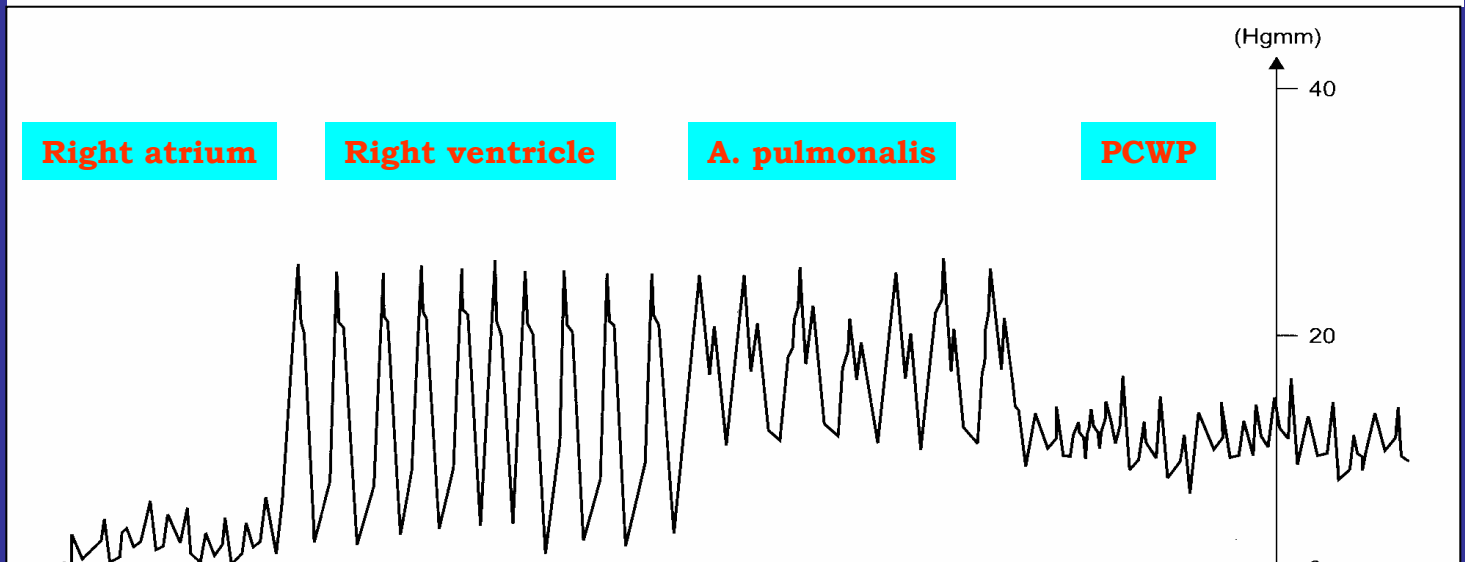
Introduce a Swan-Ganz catheter into the *a. pulmonalis* from the jugular vein, through the right heart

1. **Exposure of the right *jugular vein*;**
2. **Catheterisation with a Swan-Ganz catheter;**
3. **Introduce the catheter into the *arteria pulmonalis* witth the help of continous monitoring of the pressure signal and the inflatable balloon at the tip of catheter;**
4. **Pulmonary artery pressure, pulmonary capillary wedge pressure and cardiac output can be measured simultaneously**

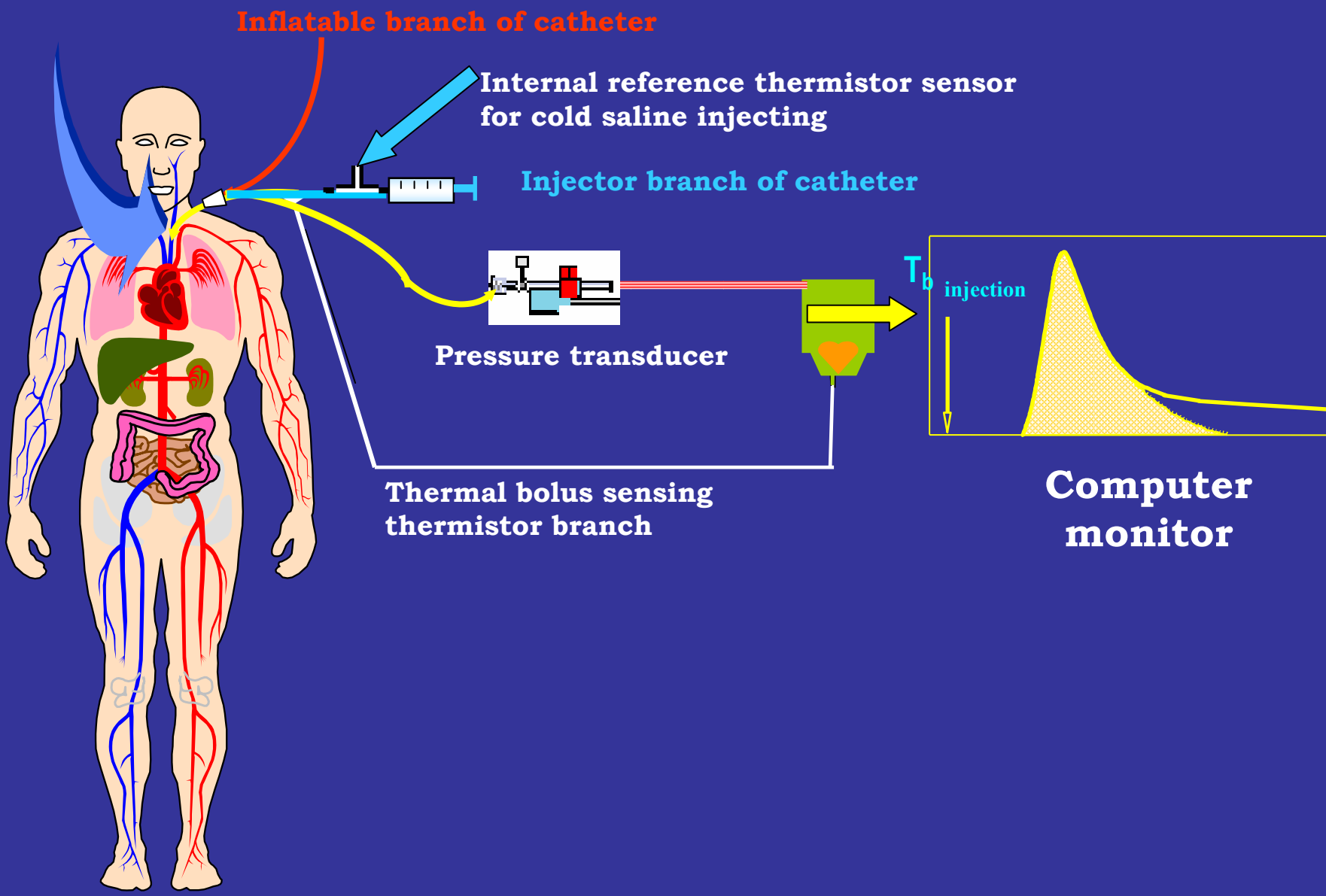
Pulmonary artery and wedge pressures



after balloon inflation, pulmonary artery pressure trace diverges from the non-occluded pressure tracing



Thermodilution cardiac output measurement with Swan-Ganz catheter in clinical practice



5. Blood flow measurement on carotid artery

The transonic research flowmeter consists of a bench-top electronic flow detection unit with enhanced frequency resolution and volume flow sensing probes.

5. Disecting of *carotis artery*

- **Surgical exposure of the right *carotis artery* from a previous incision**
- **Localisation of the artery betwwen the trachea and *jugular vein*, under a muscle bundle, together with *nervus vagus*.**
- **Fix the artery by a double thread securely.**
- **Take around of artery a perivascular flow probe.**

The execution of the practical

Scrub preparation, gowning, gloving: approx. 8 min;

6-8 students/operating tables

Two surgical teams /operating table:
as surgeon, first and second assistants and nurse

Surgical Team 1:
Dissection and cannulation of left *jugular vein* and *femoral artery;*

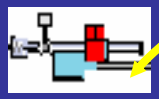
Surgical Team 2:
Dissection and cannulation of right *jugular vein* and *carotid artery;*

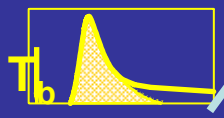
Summary of the Practical

4. Dissecting of right *jugular vein*

1. Dissecting of left *jugular vein*

Swan-Ganz catheter





CVP catheter

3. Transpulmonary (TDa) cardiac output measurement

5. Dissecting of right *carotid artery*

Blood pressure and thermosensor

2. Dissecting of left *femoral artery*