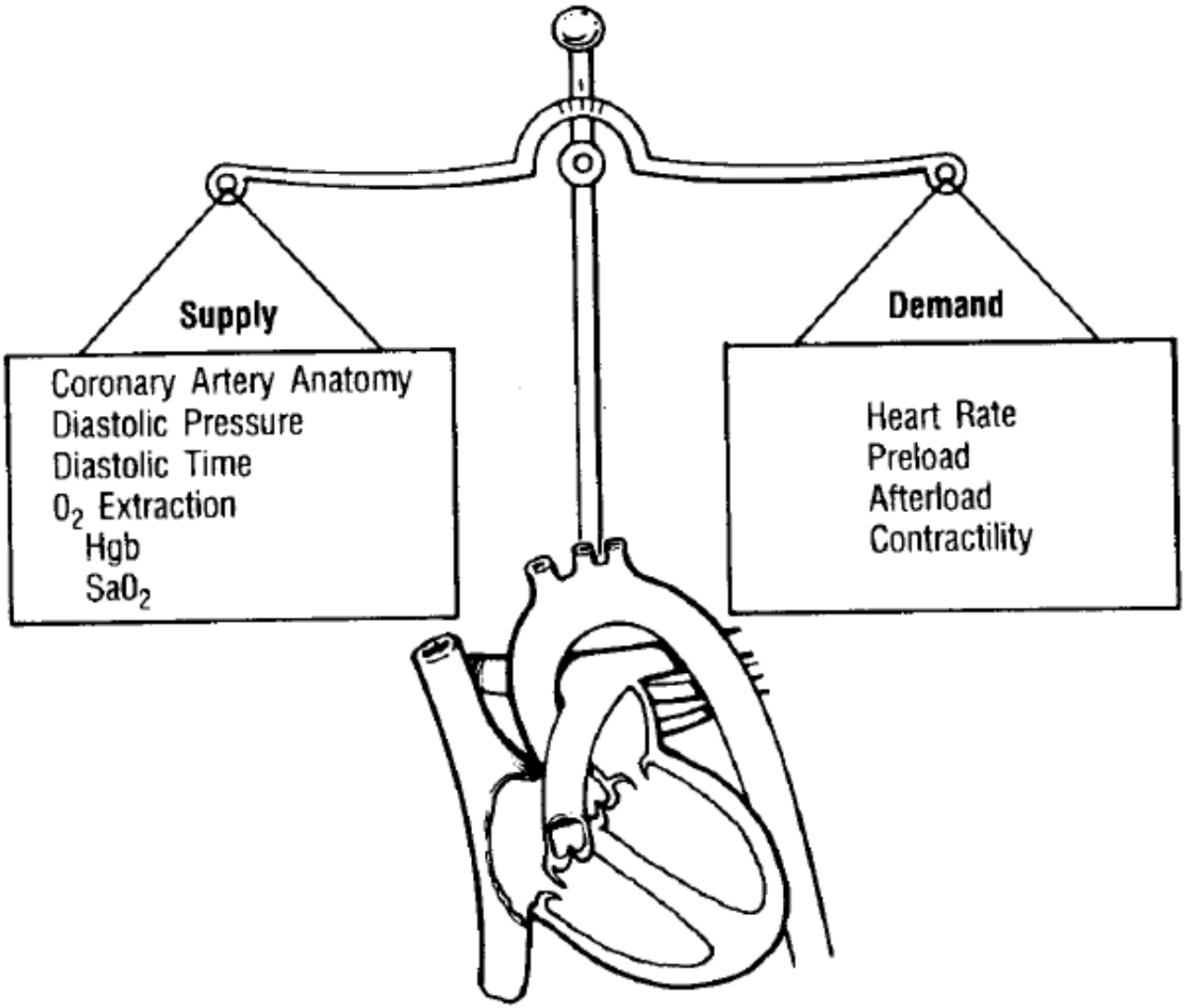
UMF
UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Hemodynamic dysfunction

SM COPOTOIU


Supply
Coronary Artery Anatomy
Diastolic Pressure
Diastolic Time
O_2 Extraction
Hgb
SaO_2
Demand
Heart Rate
Preload
Afterload
Contractility

Anatomy and physiology

UNIVERSITATEA DE MEDICINĂ ȘI FARMACIE TÎRGU MUREȘ

- Supply/delivery vs demand
- DO_2/min
- Oxygen content CaO_2
  - Arterial (20.1 ml/dL) & venous (15.5 ml/dL)
  - $CaO_2=1.38xHgbxSaO_2 + 0.0031xPaO_2$
- Cardiac output
- X 10 (ml/min)

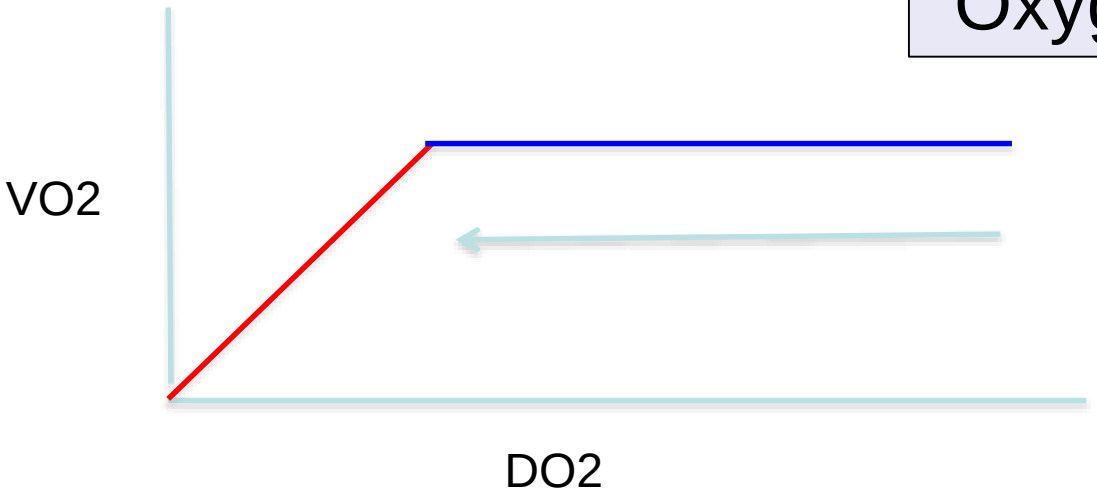
- Consumption (VO_2)
- Arterial - venous
  - $DCxHgbx13.8x(SaO_2-SvO_2)$
  - 200-250 ml/min

Anatomy and physiology

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

- Oxygen extraction fraction/index
  - 20-30%
  - CaO_2-CvO_2/CaO_2x100
- SvO_2
  - 1-(VO2/DO2)x10
- Relatia ofertă/consum

Oxygen debt



Functional anatomy

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Right

- Receives deoxygenated blood
- Low pressure system
- Volume pump
- RV thin walls, crescent shape
- Biphasic coronary perfusion

Left

- Receives oxygenated blood
- High pressure system
- Pressure pump
- LV thick walls, conical shape
- Diastolic coronary perfusion

Cardiac output

- CO = HR x SV
  - HR 60-100 bpm
  - SV 60-100 ml/b
- SV = EDV – ESV
- EF = (SV/EDV) x 100
  - – right 40-60%
  - – left 60-75%

Preload

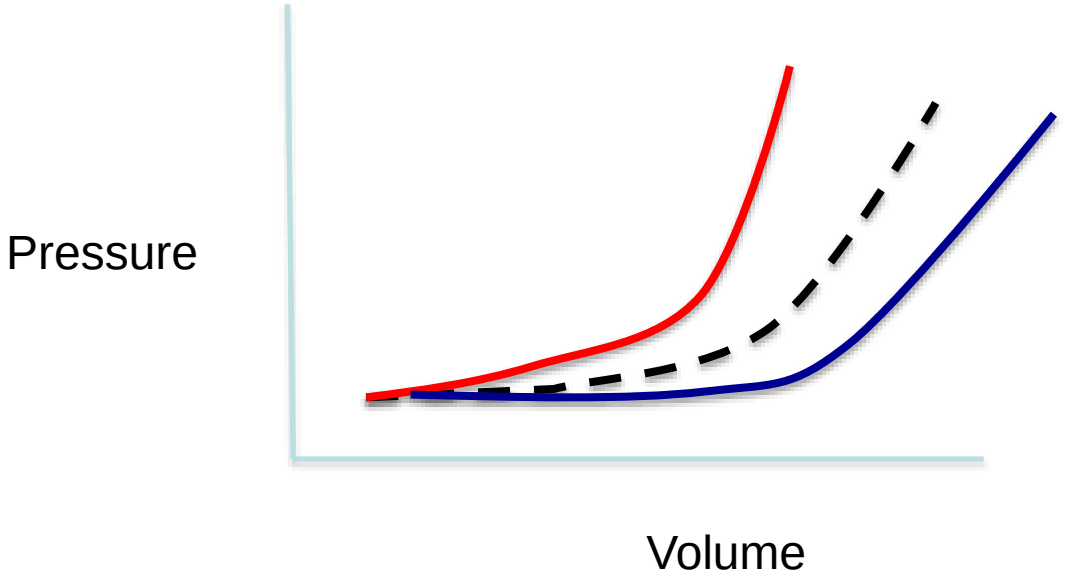
- Amount of myocardial fibre strech at the end of diastole
- VOLUME vs
- PRESSURE (influence of compliance)
  - Left
    - LAFP
    - PAOP
    - LAP

    6-12 mmHg
  - Right
    - RAP
    - CVP

    2-6 mmHg
- Relationship between myocardial fibre length and force of contraction

Ventricular compliance

- Relationship between volume and pressure



Ventricular compliance

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Decreased
- Ischemia
- ↑ afterload
- Hypertension
- Inotropes
- Restrictive cardiomyopathies
- ↑ intrathoracic pressure
- ↑ pericardial pressure
- ↑ abdominal pressure

Increased
- Dilated cardiomyopathies
- ↓ afterload
- vasodilators

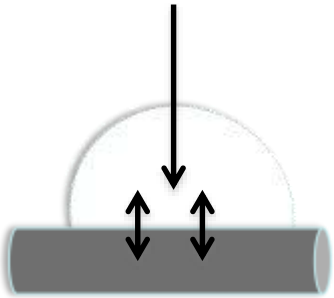
Afterload

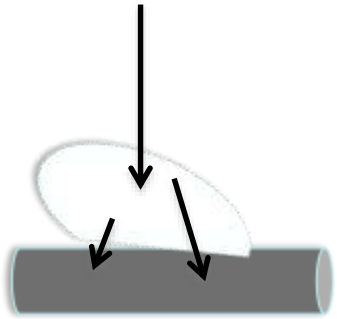
- Tension developed by the myocardial muscle fibers during ventricular systolic ejection
- Resistance/impedance/pressure that the ventricule must overcome to eject its blood volume
- Determined by
  - SV
  - Size/wall thickness of the ventricle
  - Vascular impedance
- RVS 800-1200
- RVP < 250
- TRANSMURAL !!!!!

Contractility/Inotropism

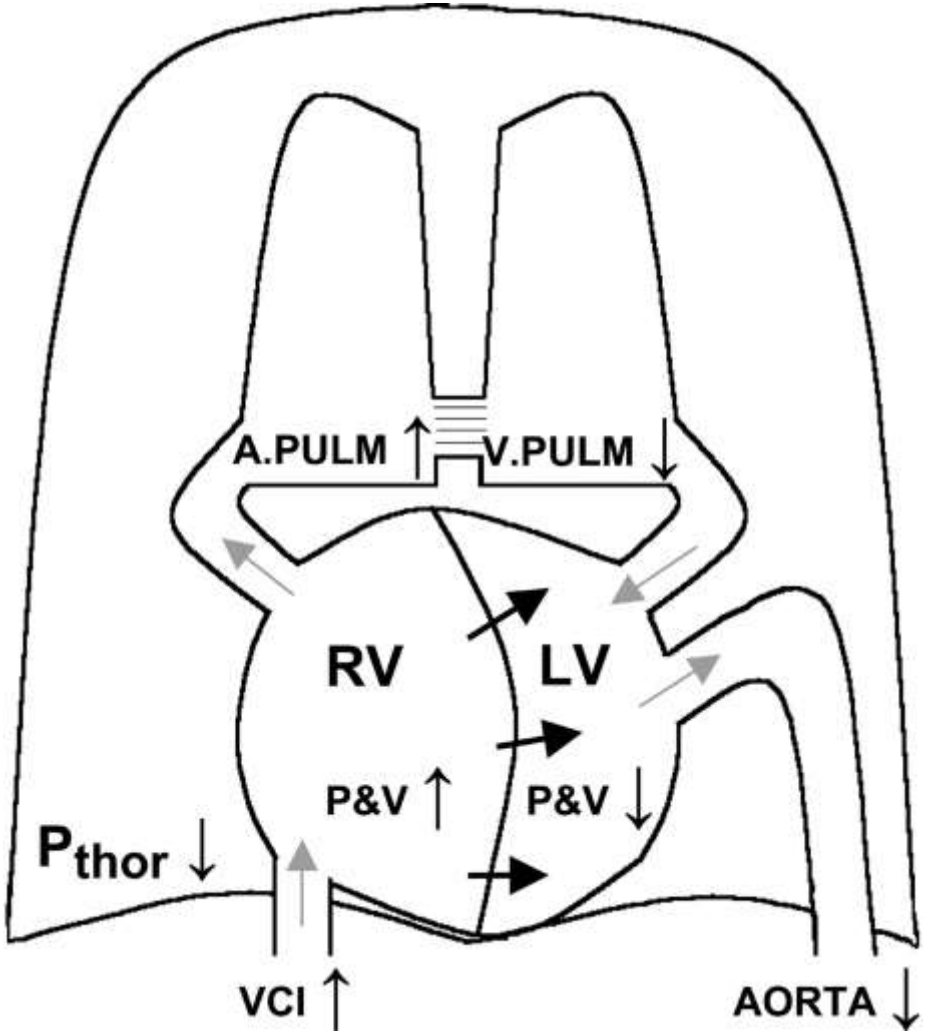
- Inherent property of the myocardial muscle fibers to shorten independent of preload and/or afterload
- It cannot be directly measured

Interactions



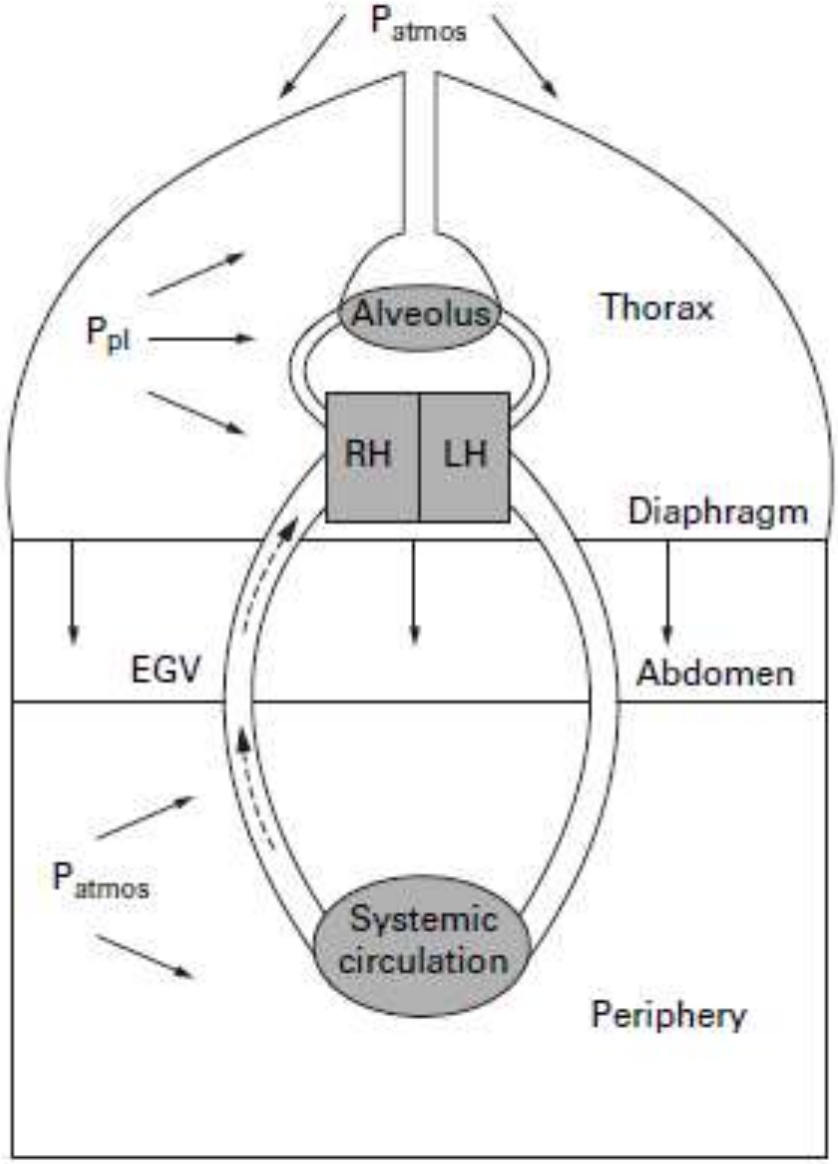


Hemadynamic events during inspiration



van den Hout R J et al. Radiology 2003;229:513-519

Radiology


P_{atmos}
P_{pl}
Alveolus
Thorax
RH
LH
Diaphragm
EGV
Abdomen
P_{atmos}
Systemic circulation
Periphery

Interactions – positive intrathoracic pressure

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

↑ CO if VIV is N (↓afterload)

↓ CO if VIV is ↓ (iandequate filling pressure)

PRELOAD

- ↓ITP: mobilizes blood from pulmn veins into the RV
- ↑ITP: RV afterload↑ ➔ ↓ LZ & RV filling

AFTERLOAD

- Right
  - Unchanged for N lungf
  - ↑ for stiff lung
- Left
  - ↓ if filling is unchanged

Normal pressures (mmHg)

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Location	Abbreviation	Mean value	Limits
Central vein	PVC/CVP	6	1-10
Right atrium	AD/RAP	4	-1,+8
Right ventricle systole	PVD/RVSP	24	15-28
Right ventricle end diastole	PDVD/RVEDP	4	0-8
Pulm a syst	PAsP	24	15-28
Pulm a diast	PAdP	10	5-16
Pulm a mean	PAP	16	10-22

Normal pressures (mmHg)

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Location	Abbreviation	Mean value	Limits
Pulmonary capillary	PCWP	9	5-16
Left atrium	PAS/LAP	7	4-12
Left ventricle systole	PSVS	130	90-140
Left ventricle diastole	LVEDP	7	4-12
Brachial a syst	TAs	130	90-140
Brachial a diast	TAd/dBP	70	60-90
Brachial a mean	TAm	85	70-105

Relationship between cavitary pressures

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

CVP – myocardial repletion

Pulmonary vascular resistance is 6x less than systemic vascular resistance

1mmHg = 1,36cmH_2O

1 cm H_2O = 0,74mmHg

1kPa = 7,5mmHg = 10,2cmH_2O

Hemodynamic parameters

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Parameter	Abbreviation	Formula	Units	Limits
Cardiac output	DC, CO	Measure	l/min	5-6
Cardiac index	IC, CI	CO/BSA	$l/min/m^2$	2,8-4,2
Heart rate	FC, HR	Measure	bpm	60-90
Stroke volume	SV	COx100/HR	ml/beat	60-90
Stroke index	SI	SV/BSA	$ml/beat/m^2$	45-60
Systemic vascular resistance	RSV, SVR	(TAm-PVC)x 80/DC	$dynexsec/cm^{-5}$	900-1500
Pulmonary vascular resistance	RVP/PVR		$dynexsec/cm^{-5}$	150-250

Monitoring good practice

1. Know what you are doing
2. Know how to do it
3. Understand what you see
4. Look out for early changes
5. Interpret
6. Notify
7. Write down: what you saw, what you did, what were the consequences
8. Treat the patient, not the monitor!

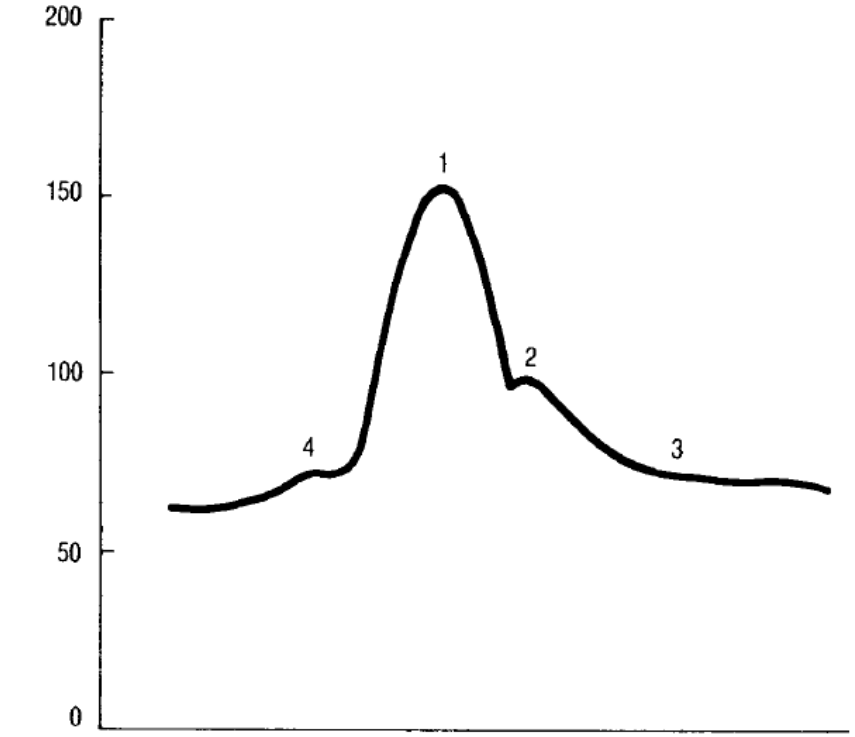
Golden rules

- CVP does not reflect RVEDV
- PAOP does not reflect R(L)VEDV
- PVC and PAOP cannot predict CO response to fluid challenge
- CO cannot be estimated on clinical examination
- CVP and PAOP cannot predict APE
- Normal MAP does not mean adequate CO

Golden rules

- Normal calculated oxygen delivery is no guarantee of adequate tissue perfusion
- SvO_2 normal values are not always equivalent to an adequate tissue perfusion
- Changes in oxygen consumption as a response to altered oxygen delivery (calculated) iare not always sinonimes to an existent oxygen debt
- PAOP is no substitute for pressure in pulmonary capillaries

Arterial catheterization

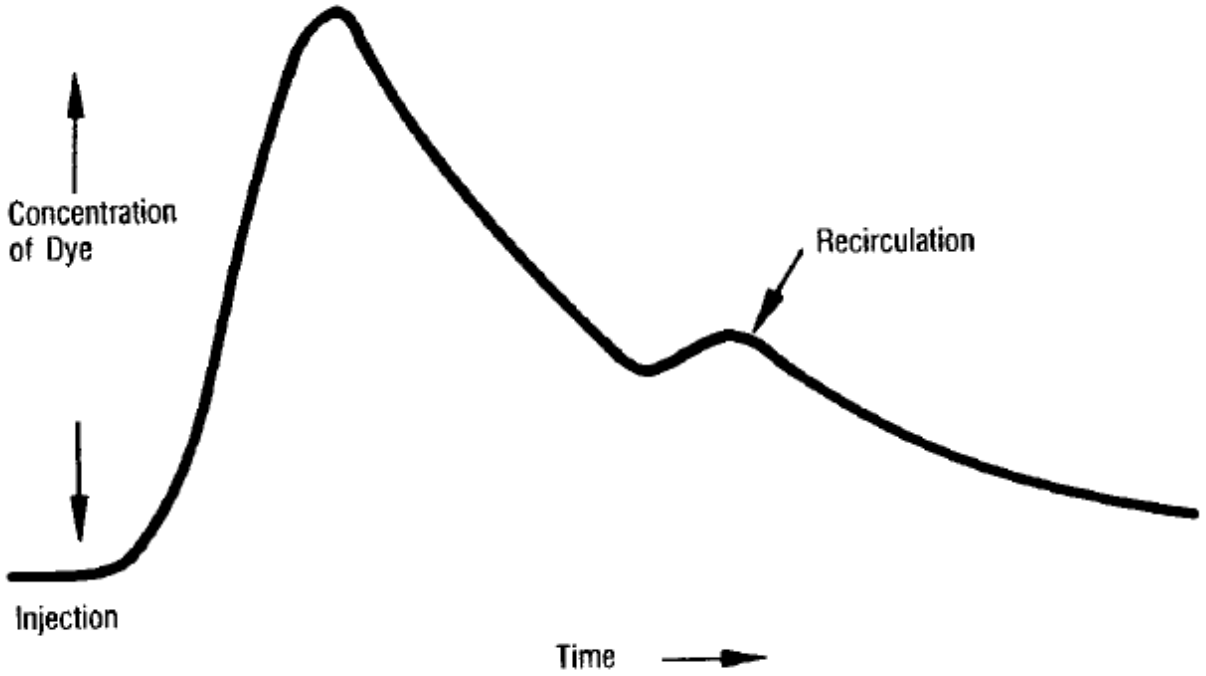


1. Peak Systolic Pressure
2. Dicrotic Notch
3. Diastolic Pressure
4. Anacrotic Notch

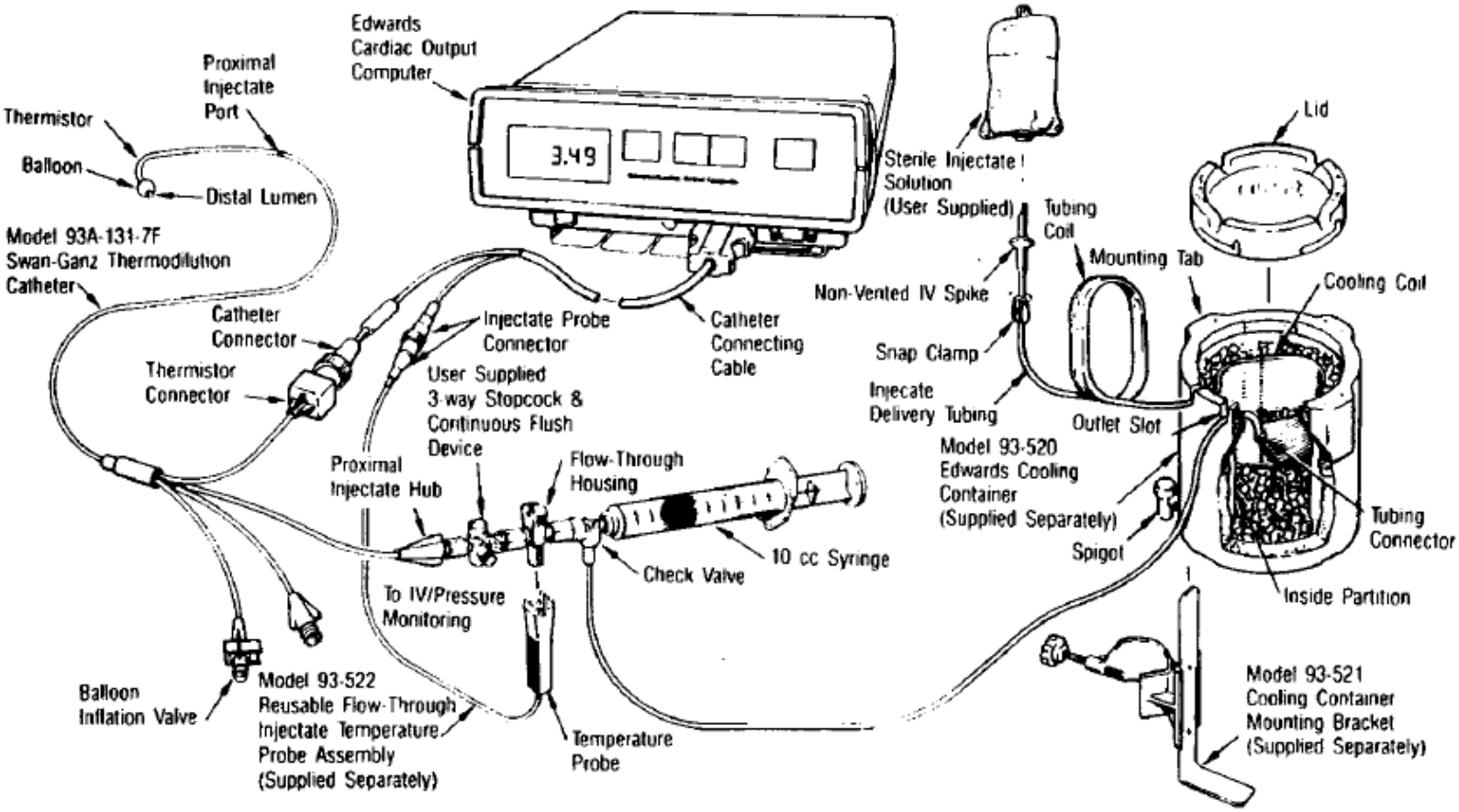
Central venous catheterization
Internal jugular vein

Central venous catheterization
Subclavian vein

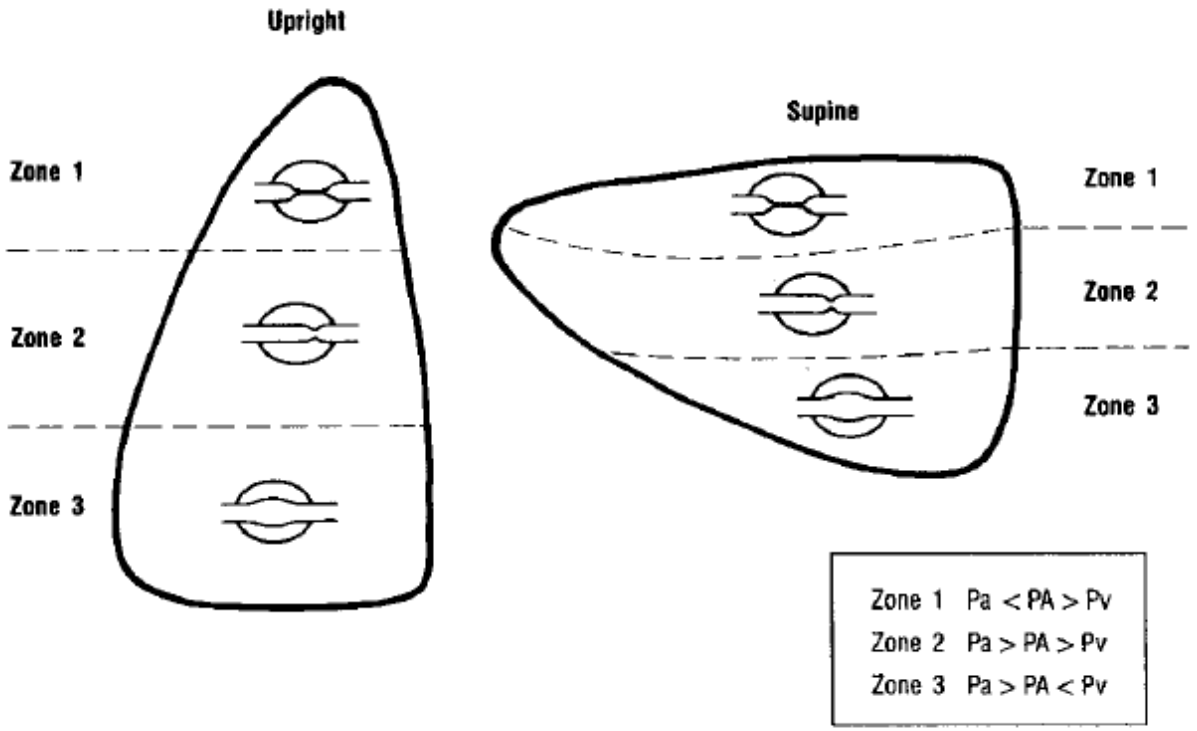
Dilution



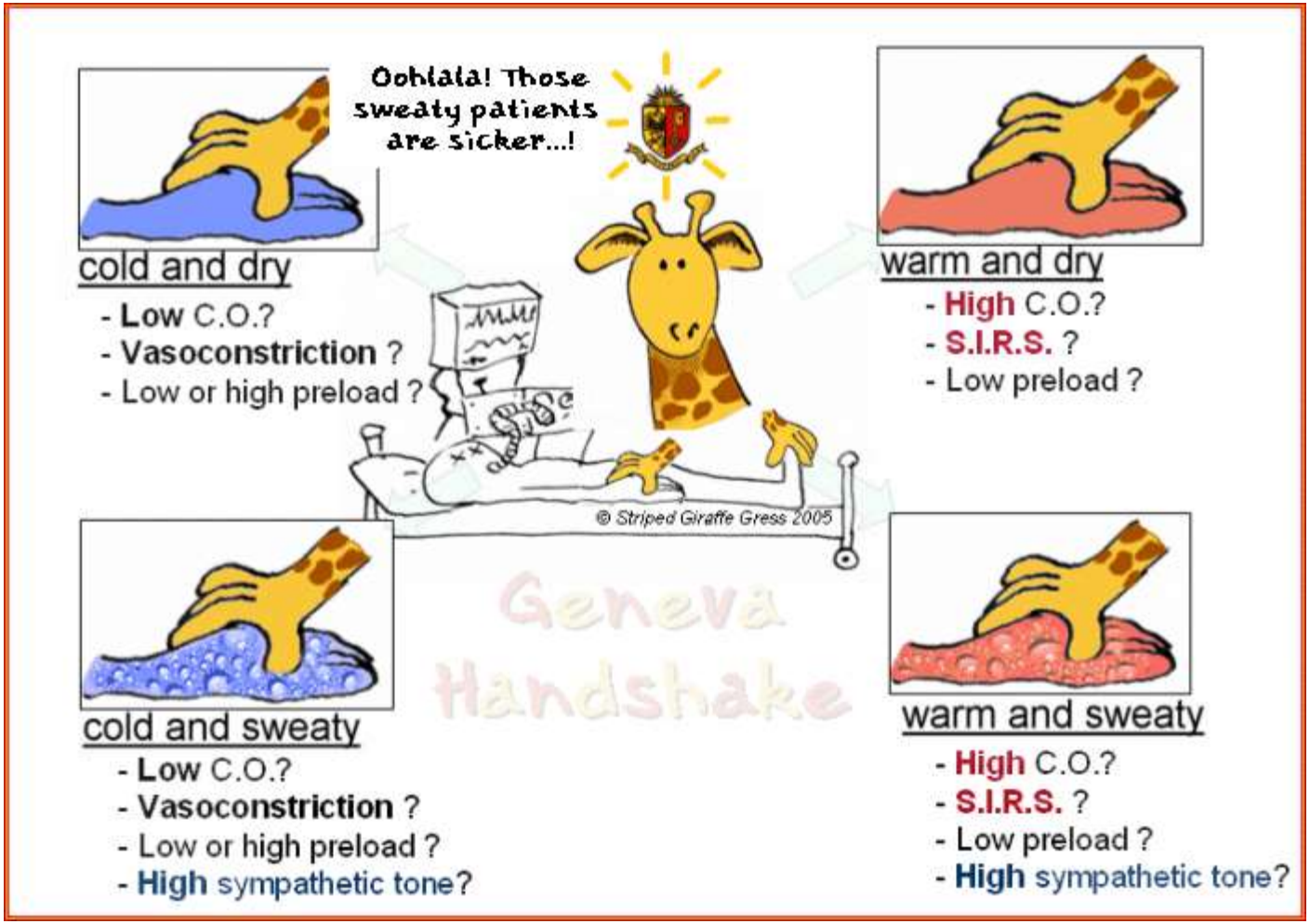
System


Edwards
Cardiac Output
Computer
3.49
Proximal
Injectate
Port
Thermistor
Balloon
Distal Lumen
Model 93A-131-7F
Swan-Ganz Thermodilution
Catheter
Catheter
Connector
Thermistor
Connector
Injectate Probe
Connector
Catheter
Connecting
Cable
User Supplied
3-way Stopcock &
Continuous Flush
Device
Proximal
Injectate Hub
Flow-Through
Housing
10 cc Syringe
Check Valve
To IV/Pressure
Monitoring
Balloon
Inflation Valve
Model 93-522
Reusable Flow-Through
Injectate Temperature
Probe Assembly
(Supplied Separately)
Temperature
Probe
Sterile Injectate
Solution
(User Supplied)
Non-Vented IV Spike
Snap Clamp
Injecate
Delivery Tubing
Tubing
Coil
Mounting Tab
Lid
Cooling Coil
Outlet Slot
Model 93-520
Edwards Cooling
Container
(Supplied Separately)
Spigot
Tubing
Connector
Inside Partition
Model 93-521
Cooling Container
Mounting Bracket
(Supplied Separately)

Lung zone palcement

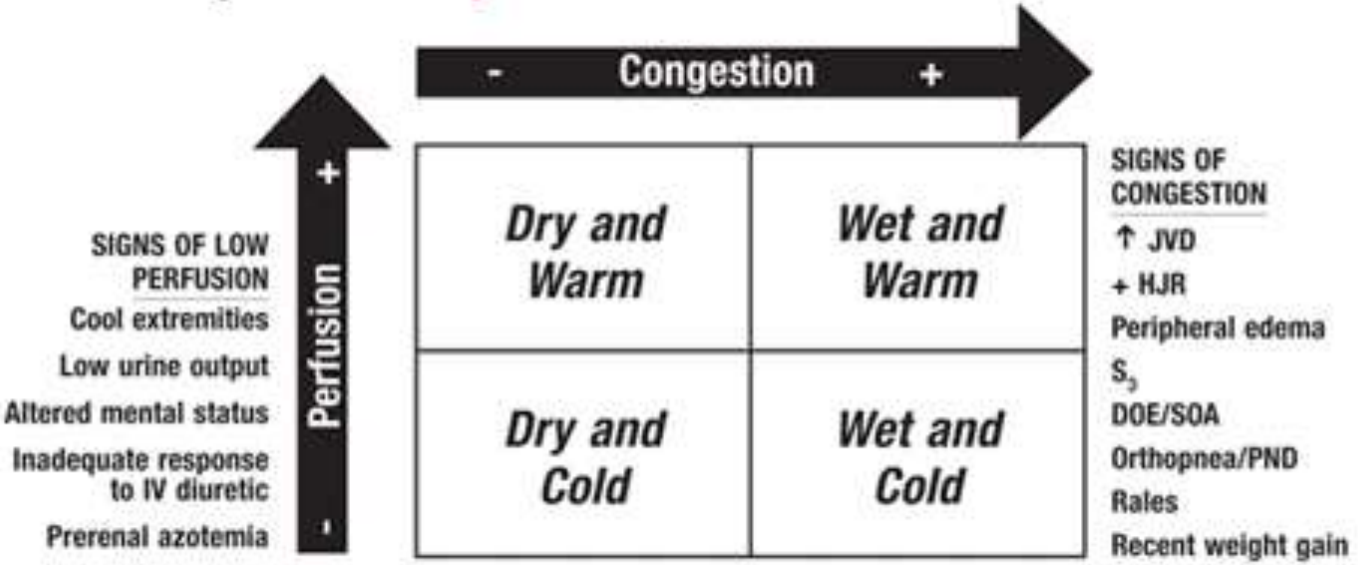


Clinical evaluation



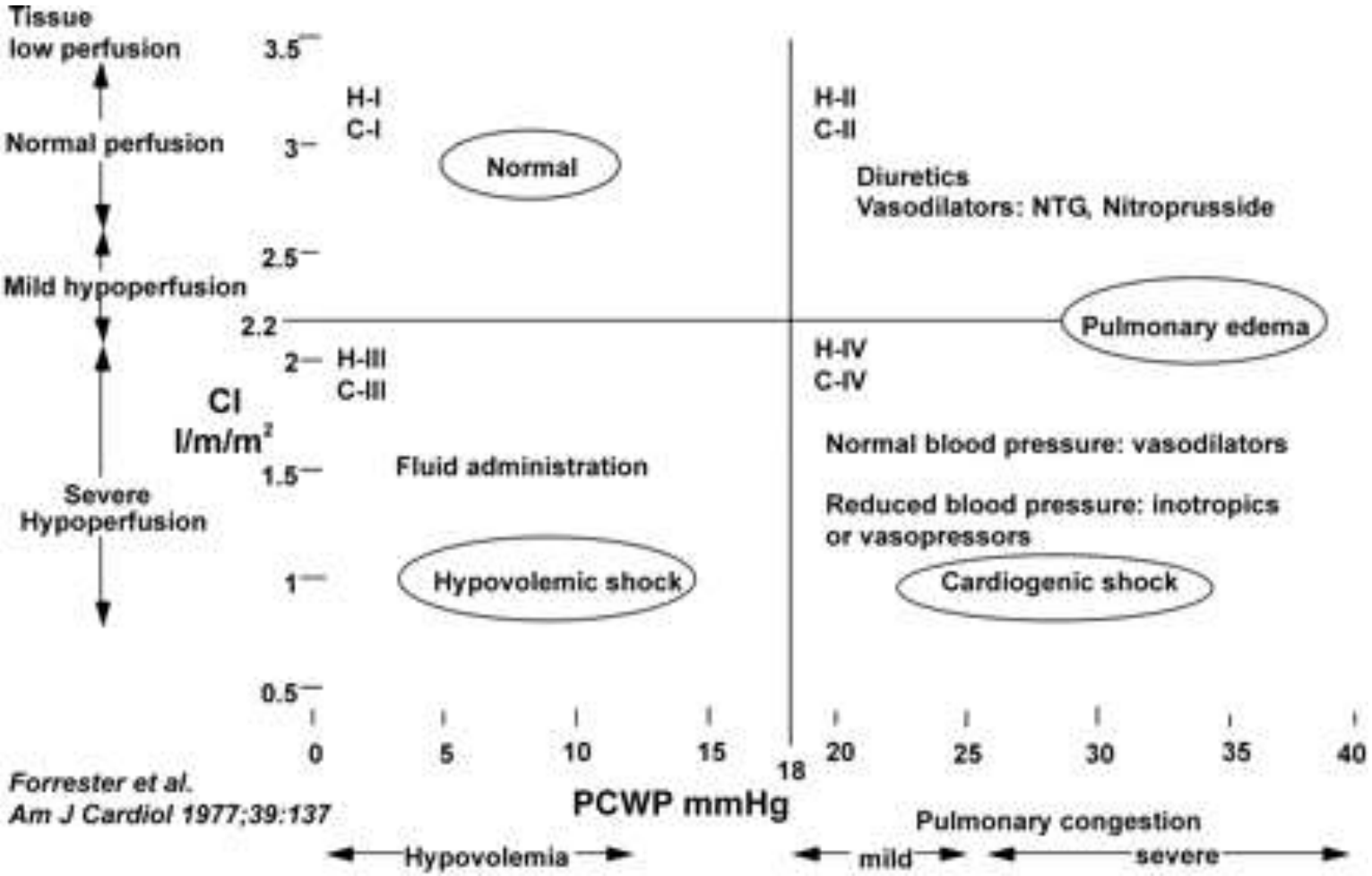
Heart failure

Figure 1. Hemodynamic/Clinical State in Acute Heart Failure



↑: increased; +: positive; -: negative; DOE: dyspnea on exertion; HJR: hepatojugular reflux; JVD: jugular venous distention; PND: paroxysmal nocturnal dyspnea; S_3: ventricular filling murmur; SOA: shortness of air.
Source: References 10, 11.

Forrester classification
Hemodynamic subsets



Forrester classification
Therapy and outcome

	Indications	PCW	Therapy	Mortality
SUBSET I No Failure	Cardiac Index Greater than 2.2 L/MIN/M²	Less than 18 mmHg	Sedate	3%
SUBSET II Pulmonary Congestion	Cardiac Index Greater than 2.2 L/MIN/M²	Greater than 18 mmHg	Normal Blood Pressure: Diuretics Elevated Blood Pressure: Vasodilators	9%
SUBSET III Peripheral Hypoperfusion	Cardiac Index Less than 2.2 L/MIN/M²	Less than 18 mmHg	Elevated Heart Rate: Add Volume Depressed Heart Rate: Pacing	23%
SUBSET IV Congestion & Hypoperfusion	Cardiac Index Less than 2.2 L/MIN/M²	Greater than 18 mmHg	Depressed Blood Pressure: Inotropes Normal Blood Pressure: Vasodilators	51%

Inotropic therapy

- USA
  - Low output syndrome
  - Left ventricular systolic dysfunction
  - Systolic blood pressure < 90 mmHg despite adequate filling pressure

- Europe
  - BP < 100 mmHg

Inotropic therapy

EPINEPHRINE

Inotropic therapy

NOREPINEPHRINE

Inotropic therapy

DOPAMINE

Inotropic therapy

DOBUTAMINE

Inotropic therapy

DOPEXAMINE

Inotropic therapy

ISOPROTERENOL (ISOPRENALINE)

Inotropic therapy

PHOSPHODIESTERASE INHIBITORS

Inotropic therapy

CALCIUM SENSITIZERS

Inotropic therapy
On trial

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

- **Cardiac myosin activators**
  - ↑ ATPase activity
  - Inotrop effect

- **Istaroxime**
  - Inhibits the Na/K ATPase
  - Inotrop & lusitrop effects