Concept du retour veineux

André Denault MD PhD

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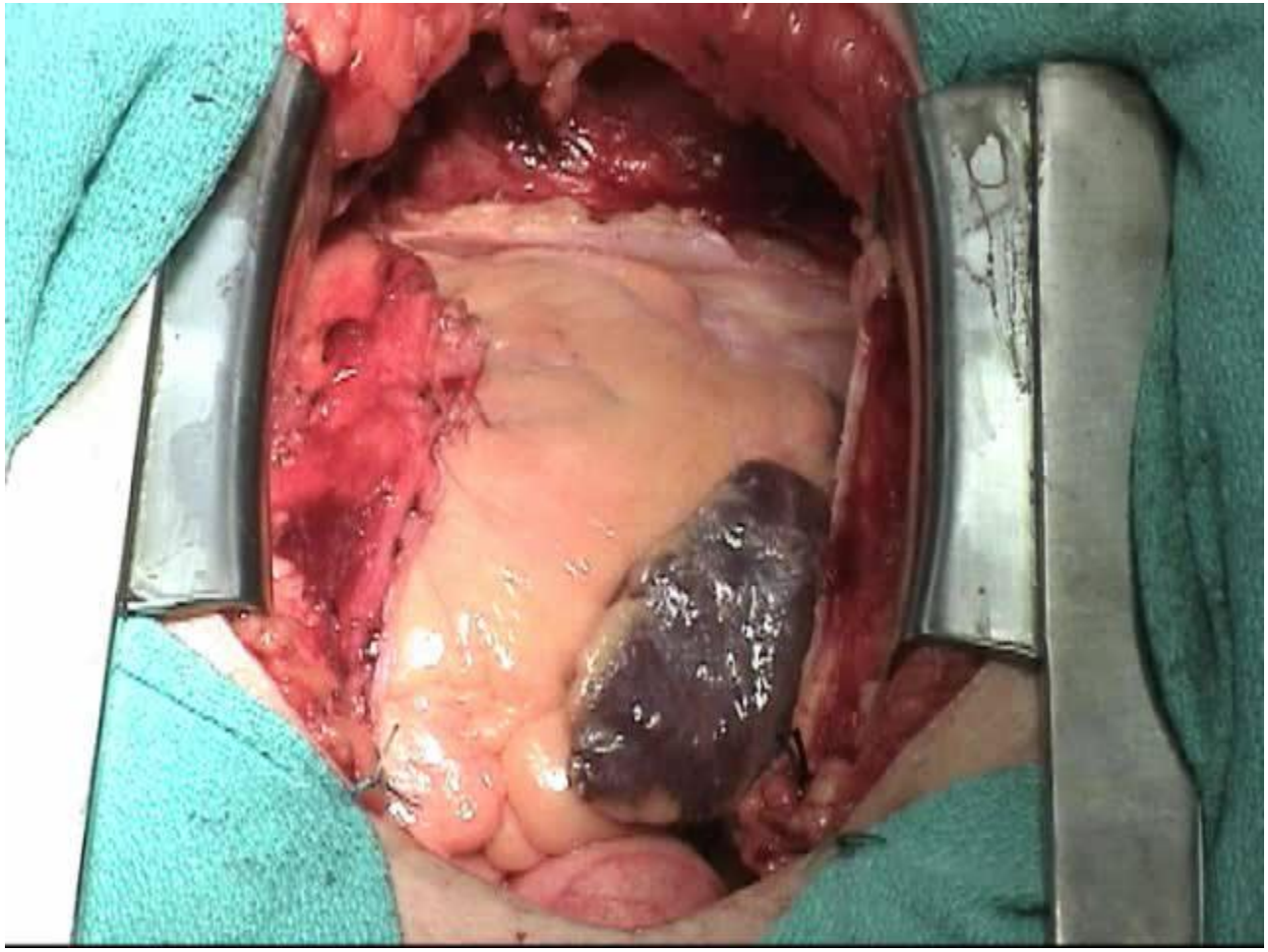
INSTITUT DE CARDIOLOGIE DE MONTRÉAL

CHUM

Montréal, le 25 septembre 2013



Ressources

The Role of Venous Return in Critical Illness and Shock—Part I: Physiology

Duane J. Funk, MD[1,2]; Eric Jacobsohn, MD[1,2]; Anand Kumar, MD[1,3]

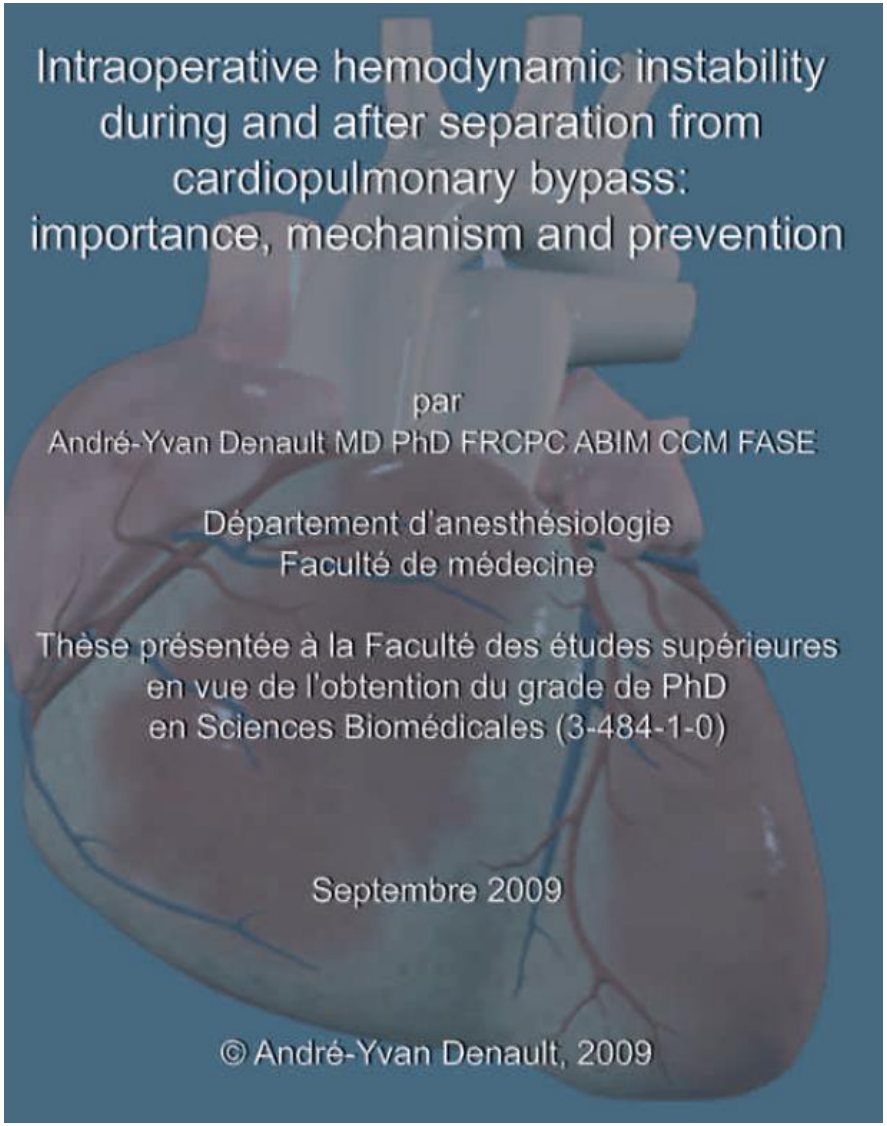
CCM 2013

Acute abdominal compartment syndrome

Nancy Deslauriers, MD · Renée Déry, MD · André Denault, MD

Can J Anesth/J Can Anesth (2009) 56:678–682

Chapter 3 Mechanisms of difficult separation from cardiopulmonary bypass



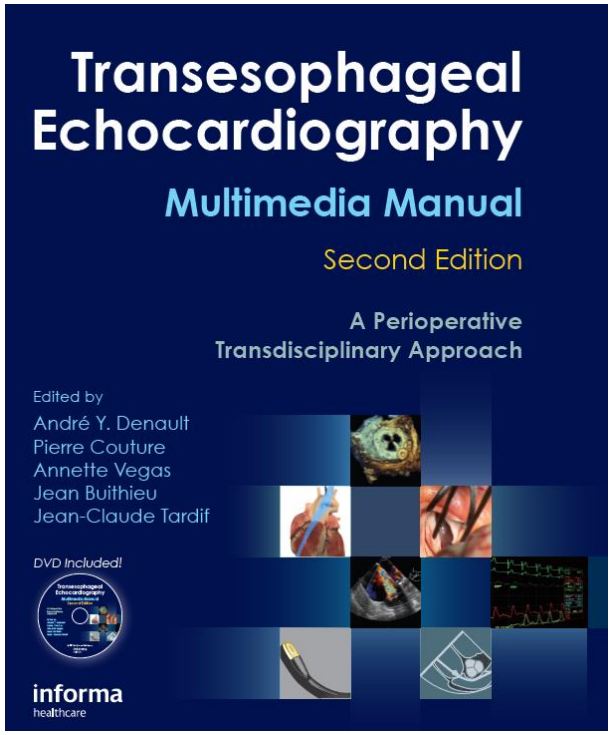
10

Global Ventricular Function and Hemodynamics

André Y. Denault and Pierre Couture
Université de Montréal, Montreal, Quebec, Canada

Jean Buithieu
McGill University, Montreal, Quebec, Canada

Annette Vegas
University of Toronto, Toronto, Ontario, Canada



andre.denault@umontreal.ca

Objectifs

- Revoir les mécanismes d'instabilité hémodynamique en combinant le concept du retour veineux, les courbes pression-volume et l'échographie
- Proposer une approche systématique en présence d'un patient instable hémodynamiquement en SOP ou aux SI

Plan des cours

1-Concept du retour veineux

2-Courbes pression-volume

3-Fonction diastolique

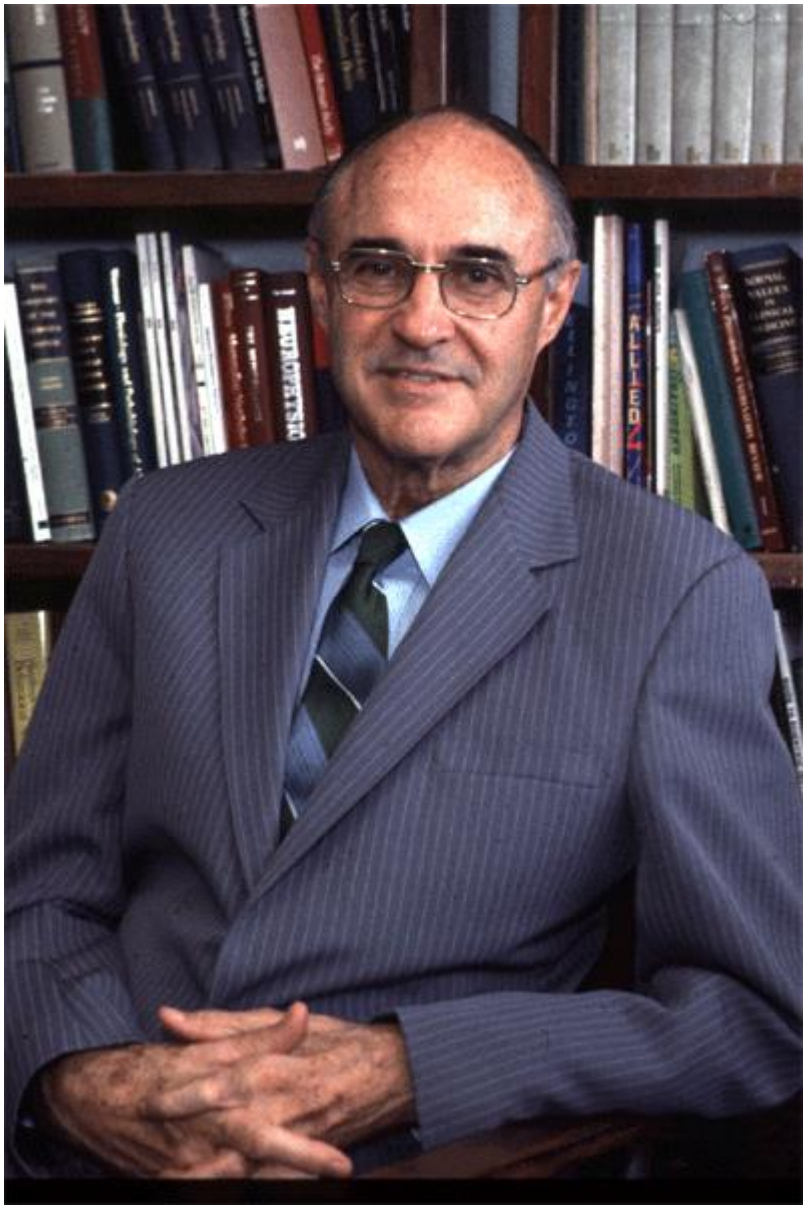
4-Fonction ventriculaire droite

5-Approche au patient instable

Homme de 24 ans sténose dû une prothèse tricuspidienne

- Pression artérielle = 120/65
- Pod = 28 mmHg
- Que va-t-il se passer après la correction percutanée de la sténose tricuspidienne?

Arthur C. Guyton



1919 - 2003

Eric Jacobsohn MB CHB FRCPC,*
Robin Chorn BSc MB CHB FRCPC,†
Michael O'Connor MD*

Review Article

The role of the vasculature in regulating venous return and cardiac output: historical and graphical approach

CAN J ANAESTH 1997 / 44: 8 / pp 849–867

The Role of Venous Return in Critical Illness and Shock—Part I: Physiology

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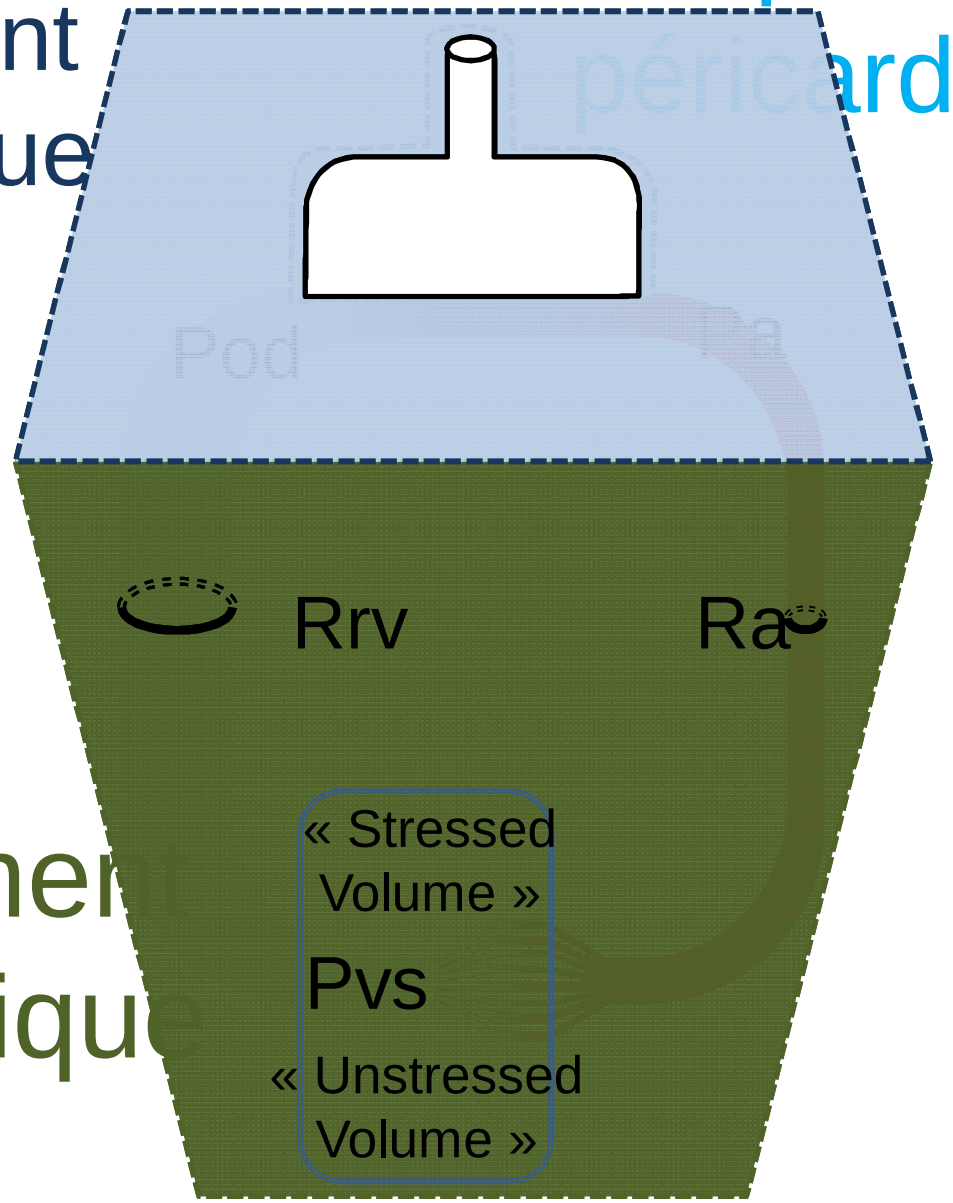
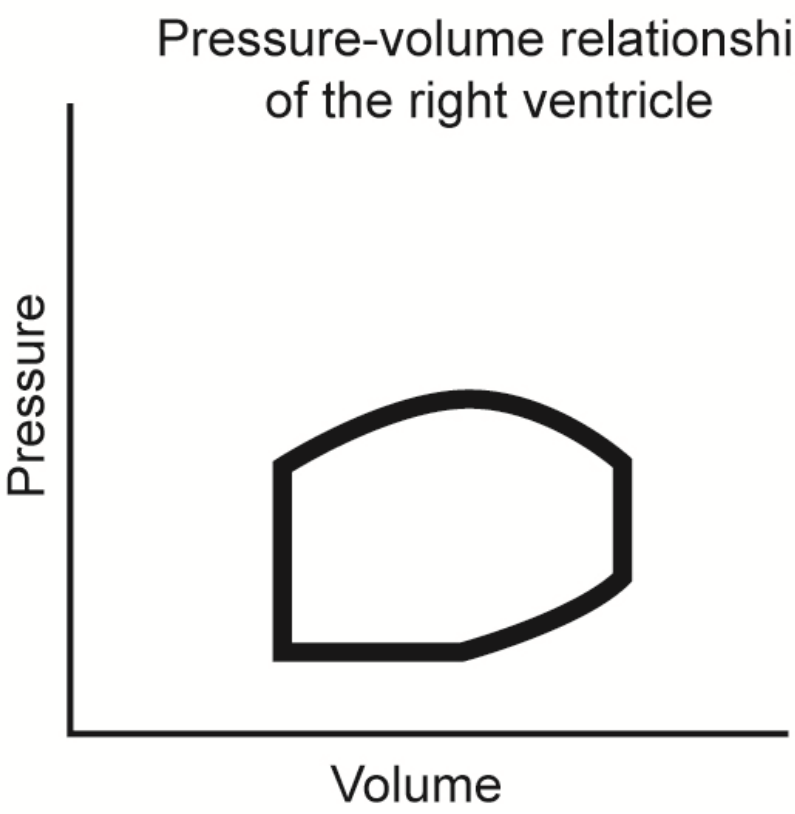
CCM 2013

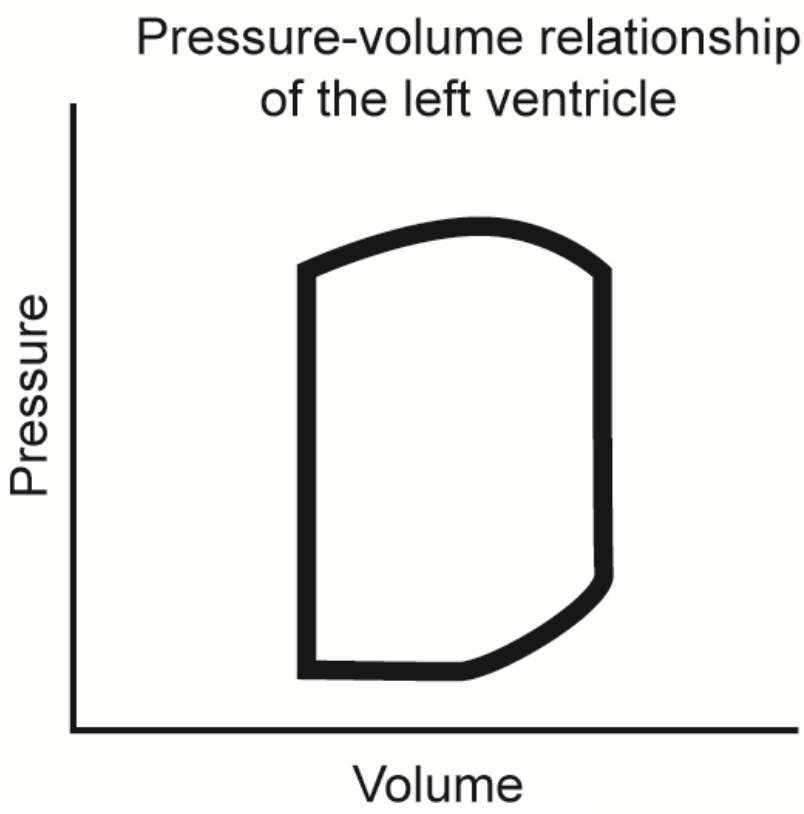
Compartiment intrathoracique

Compartiment péricardique



Compartiment extrathoracique


Pressure-volume relationship
of the right ventricle
Pressure
Volume


Pressure-volume relationship
of the left ventricle
Pressure
Volume

Can J Anesth/J Can Anesth (2009) 56:678–682
DOI 10.1007/s12630-009-9140-8

PERIOPERATIVE CARDIOVASCULAR ROUNDS

Acute abdominal compartment syndrome

Nancy Deslauriers, MD · Renée Déry, MD · André Denault, MD


Robert Hannah
Le retour veineux
60ml X 60/min = 3600 X 60 X 24 = 5184 litres die
Exercitatio Anatomica de Motus Cordis et Sanguinis in Animalibus 1615

Formules-1

Débit cardiaque = ϕPression/ Résistance

= MAP-Pod /Rvs

Retour veineux = ϕPression/résistance

= Pvs-Pod/Rrv

Formules-2

Compliance = Volume /ϕPression

Pression = Volume / Compliance

Compliance = 1/ Élastance

= ϕPression / Volume

Retour veineux: points essentiels

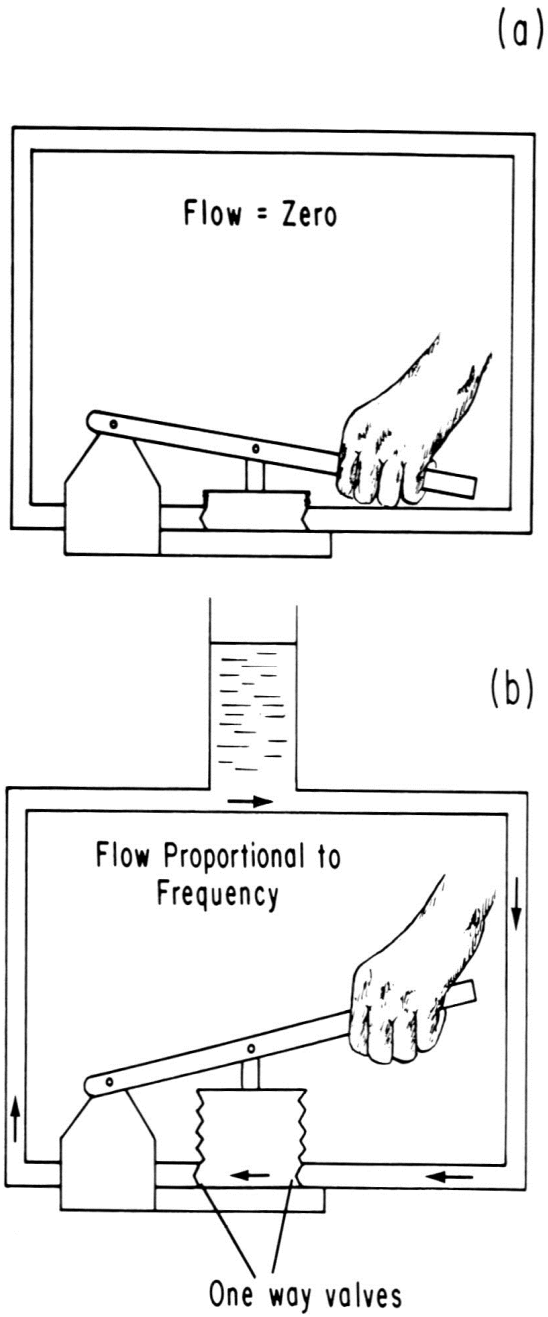
Intensive Care Med (1998) 24: 651–653

EDITORIAL

S. Magder

More respect for the CVP

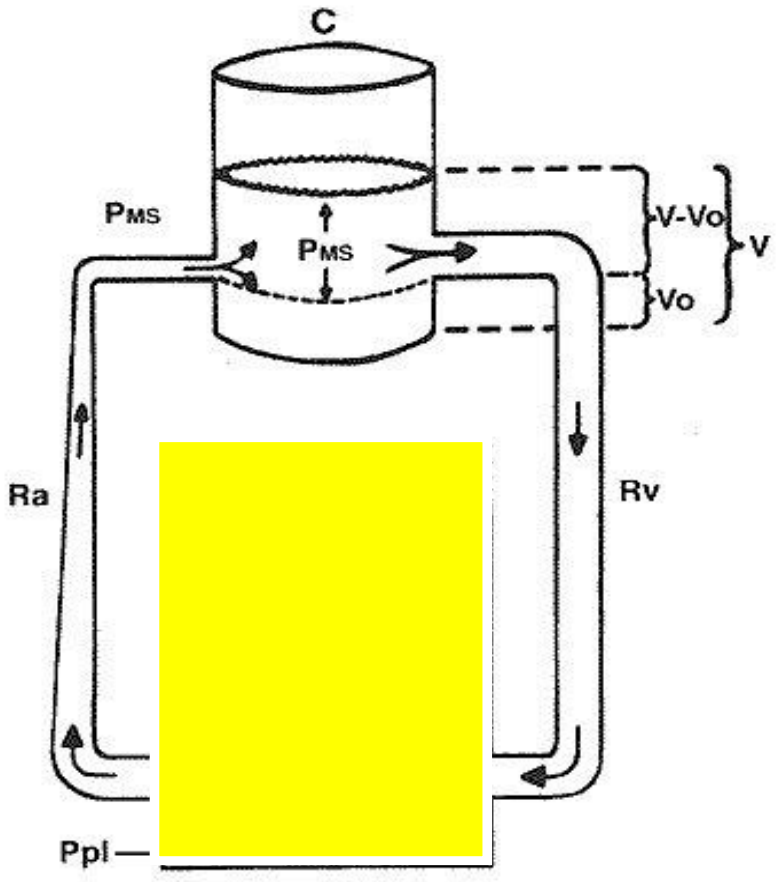
- Débit cardiaque = retour veineux
- Rôle du cî ur = vider le réservoir veineux en abaissant la pression de lôoreillette droite
- Limite ou plateau à lôaugmentation du retour veineux
- Si le cî ur droit ne peut abaisser ses pressions = mauvais pronostique



Aucun flot car pas de réservoir (« prime »)

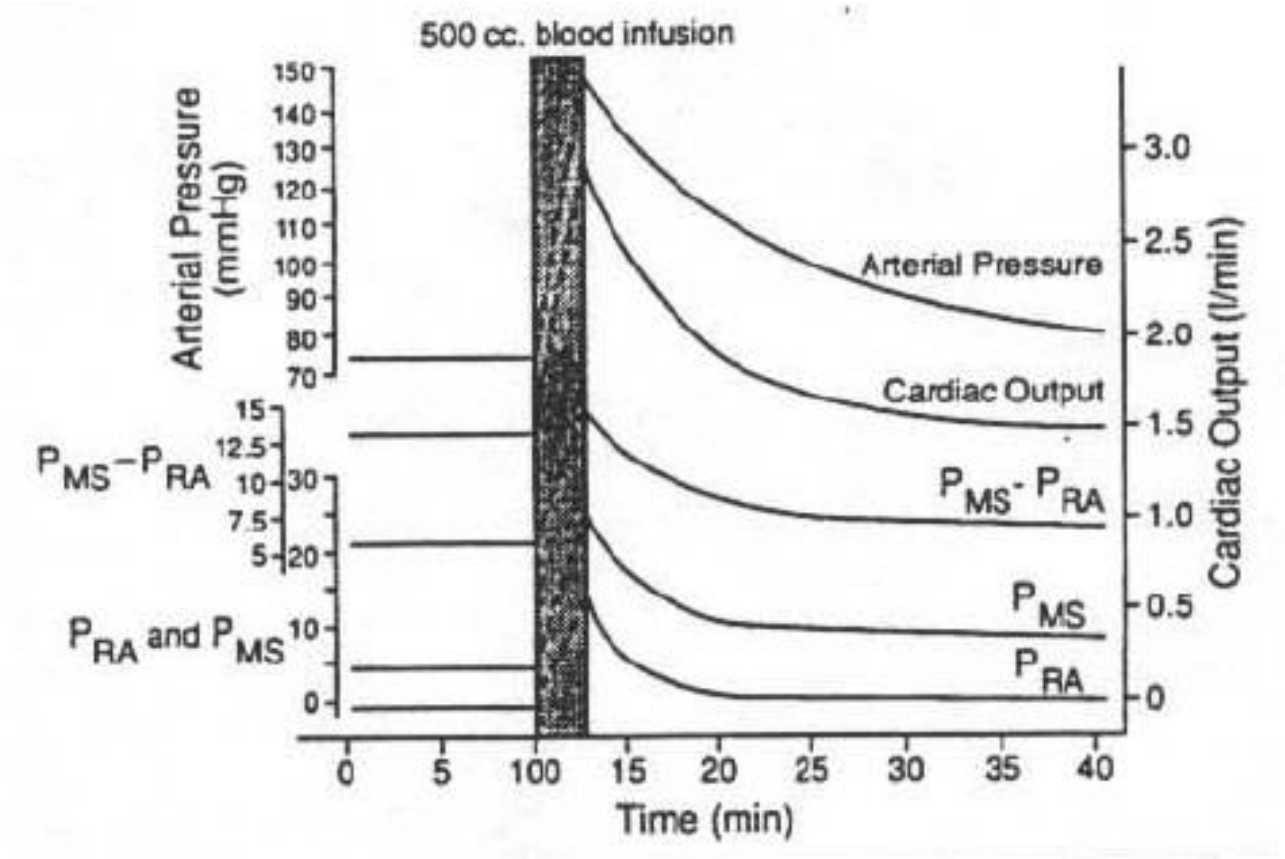
Limite de flot = fréquence car si trop vite, pas le temps de se remplir.

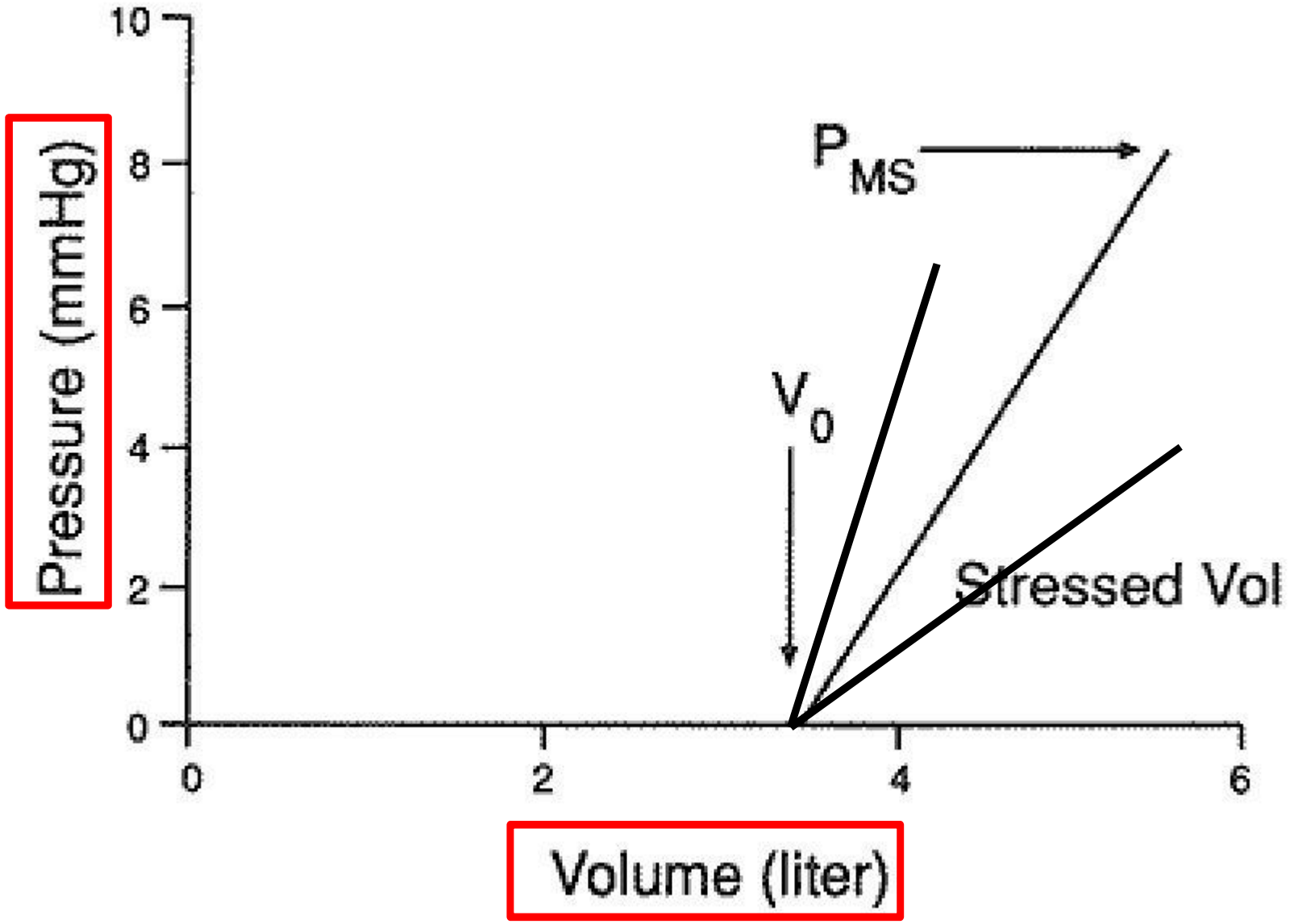
Fundamental cardiovascular and pulmonary physiology JF Green



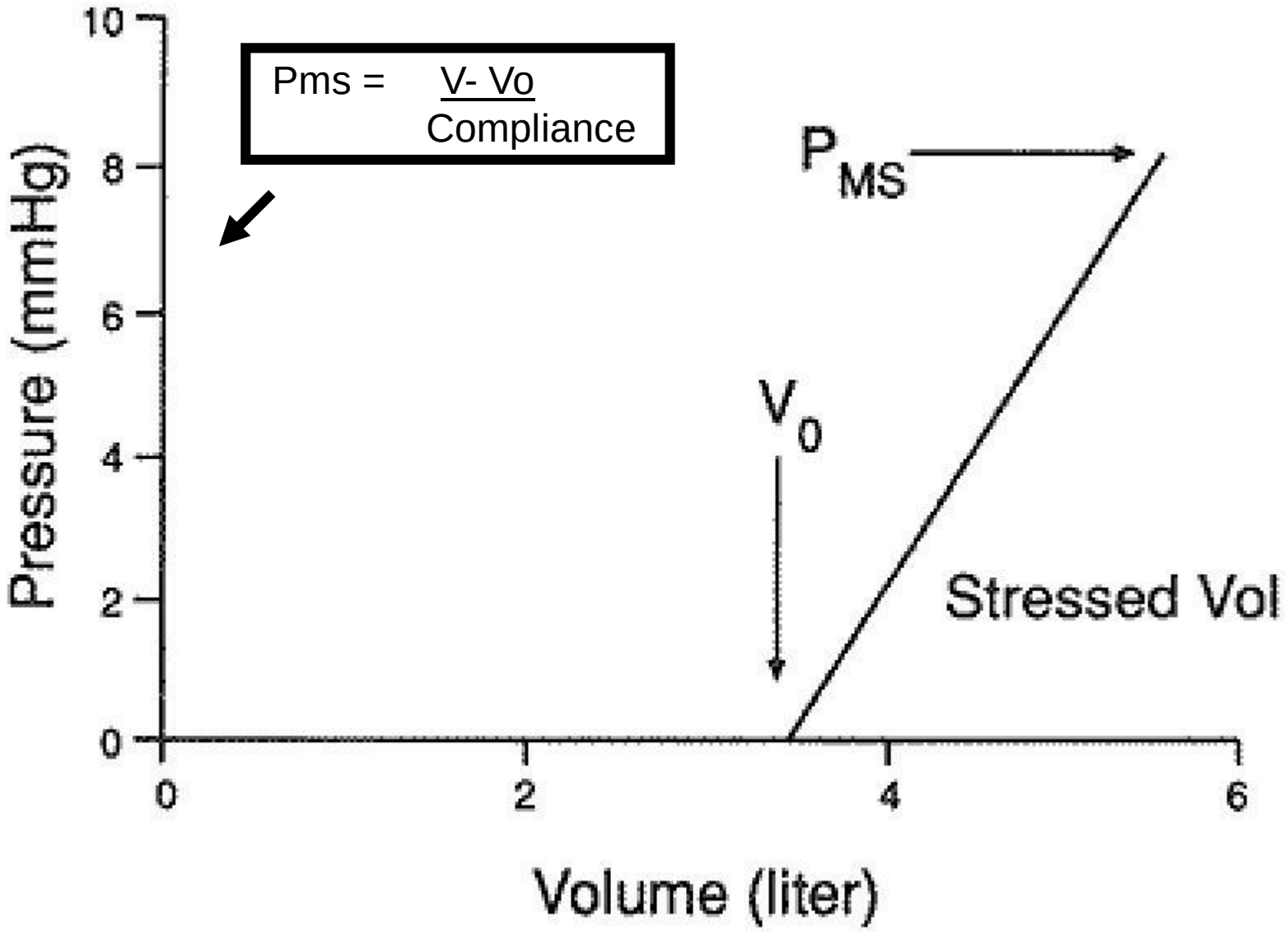
C = Capacitance du réservoir veineux (V + Vo)
V = 70 ml/kg
V-Vo= Volume constraint (Stressed volume): 20 ml/kg
Vo = Volume non-constraint (Unstressed volume): 50 ml/kg
Pms = 10 cm H2O
Compliance veineuse = 1.4-4.2 ml/kg/mmHg ou 0.2 L/mmHg (20 X artérielle)
Compliance artérielle = 0.0067 ml/kg/mmHg

La preuve: modèle de CEC



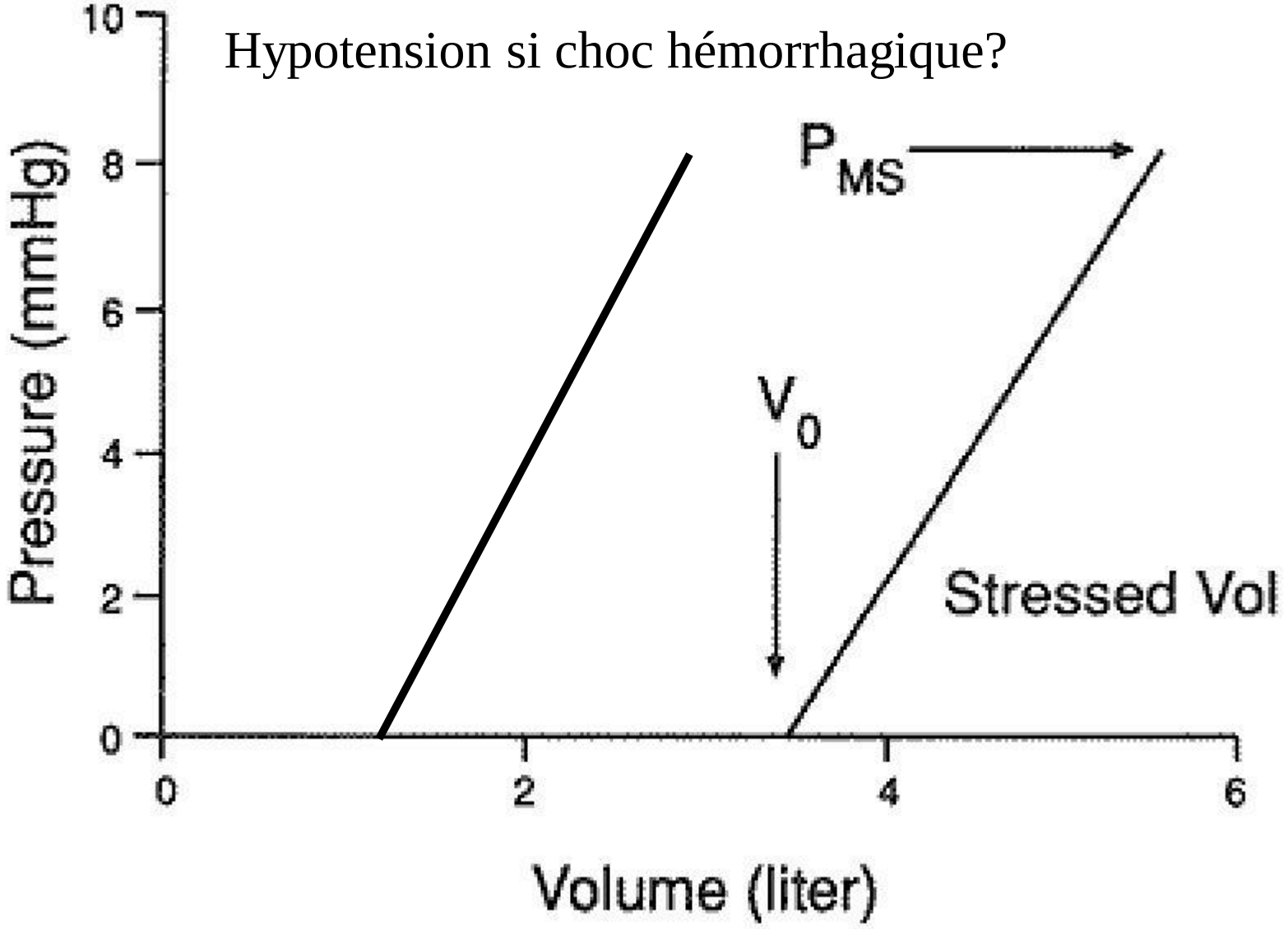


Jacobsohn J Can Anesth 1997



Jacobsohn J Can Anesth 1997

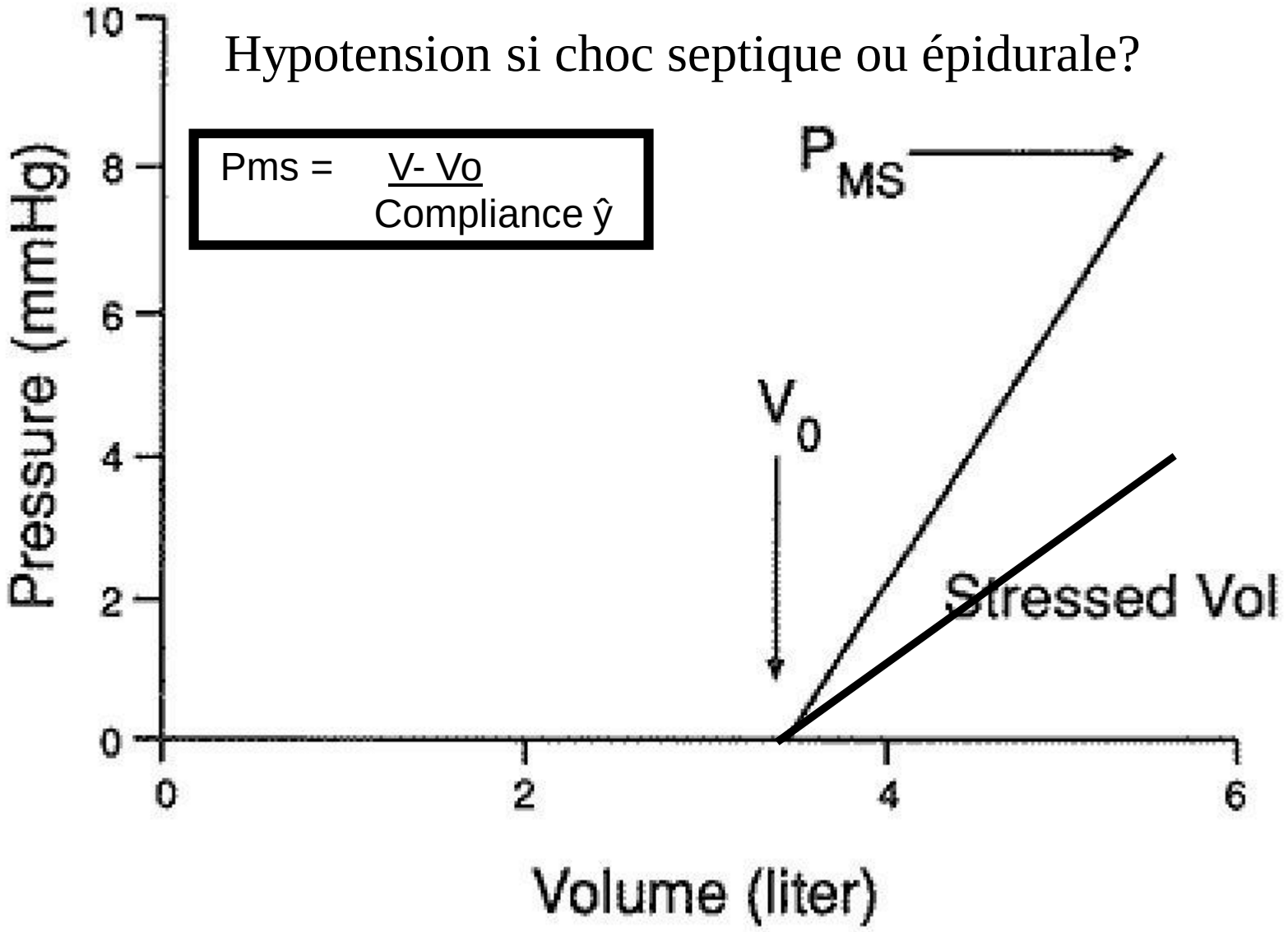
Hypotension si choc hémorrhagique?



Jacobsohn J Can Anesth 1997

Hypotension si choc septique ou épidurale?

Pms = $\frac{V - Vo}{\text{Compliance } \hat{y}}$



Jacobsohn J Can Anesth 1997

Exemple: 100ml de sang: de combien la TVC augmentera?

Pms-Pra = stressed volume / compliance veineuse
= 100 ml /compliance veineuse
= 100 ml / (1.4 X 70 kg)
= 0.3-1.0 mmHg

Donc l'augmentation des pressions de remplissage avec le volume est dépendante de ?

Quel est le « stressed » volume chez l'humain?

Jacobsohn J Can Anesth 1997

Methodology

Five patients undergoing hypothermic circulatory arrest for surgery on major vessels.

Magder CCM 1998;26:1061-1064

Methodology

We measured the volume that came out of patients undergoing this procedure for this volume represents stressed volume, that is, it is comparable with the volume above the hole on the side of the tub

Result

- We found that stressed vascular volume, as in animal studies [5-7], is only [similar]20% to 30% of the blood volume.
- The average stressed volume was 1290 +/- 296 mL or 20.2 +/- 1.0 mL/kg.
- If one assumes a normal blood volume of 65 mL/kg for women and 69 mL/kg for men [9], this estimate gives an average of 30 +/- 17% of the total predicted blood volume.

Retour veineux: points essentiels

Intensive Care Med (1998) 24: 651–653

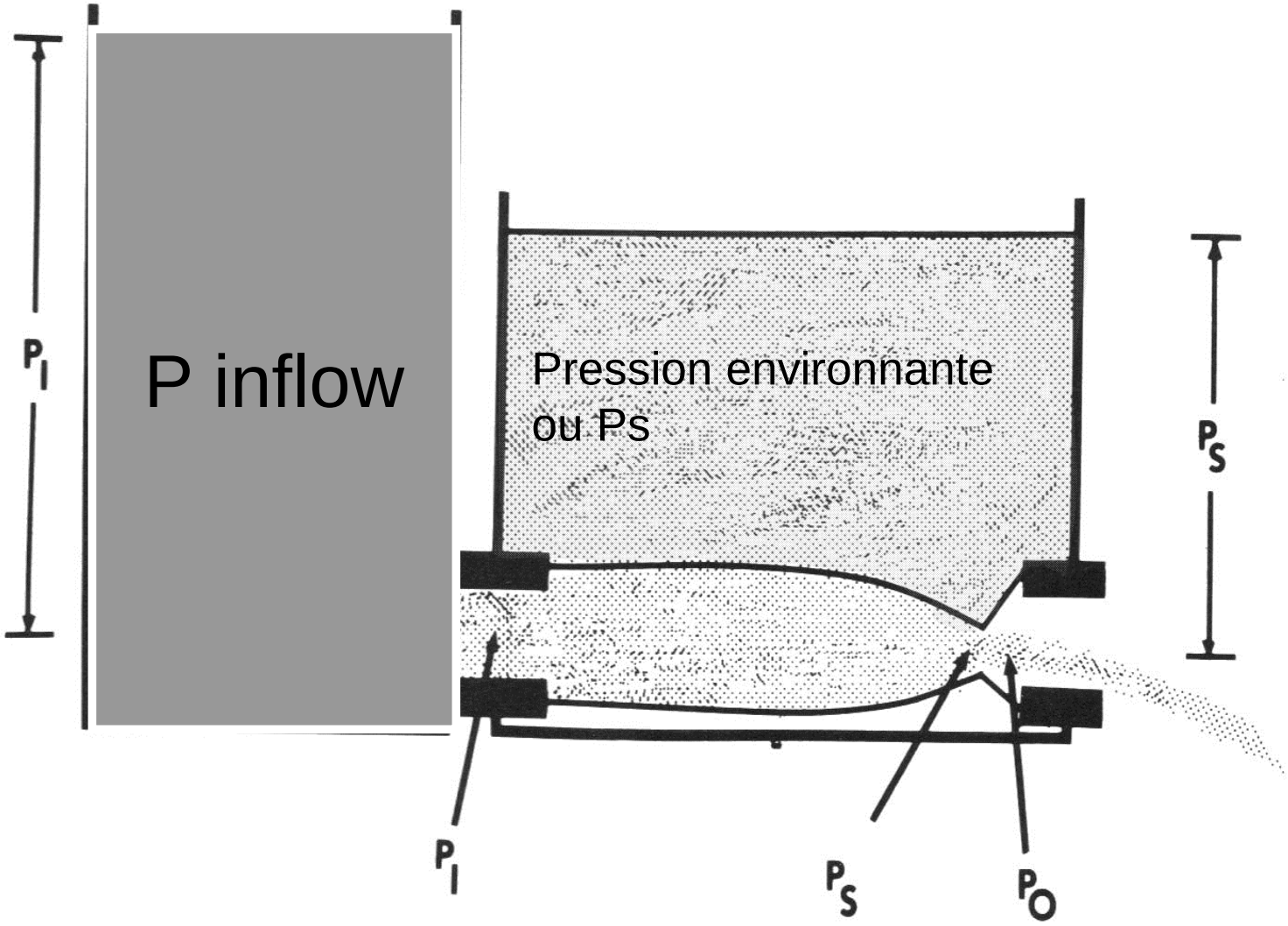
EDITORIAL

S. Magder

More respect for the CVP

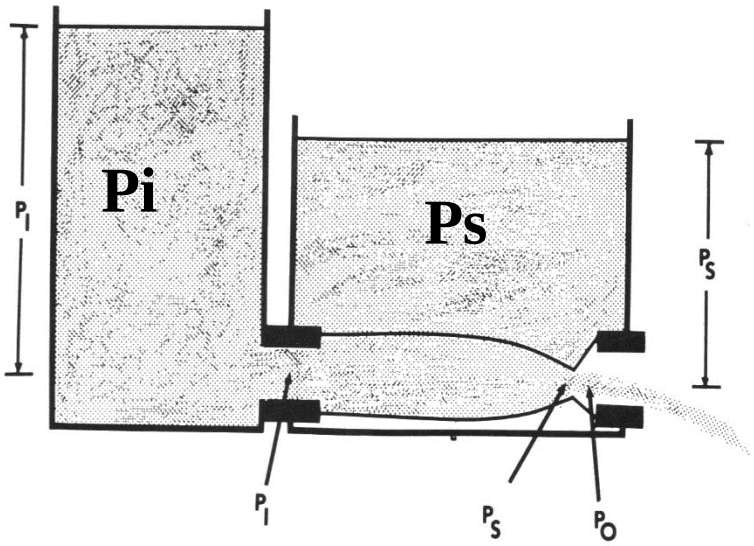
- Débit cardiaque = retour veineux
- Rôle du cî ur = vider le réservoir veineux en abaissant la pression de lôoreillette droite
- Limite ou plateau à lôaugmentation du retour veineux: « Starling resistor »

Concept du « Starling resistor »



Fundamental cardiovascular and pulmonary physiology JF Green

Concept du « Starling resistor »



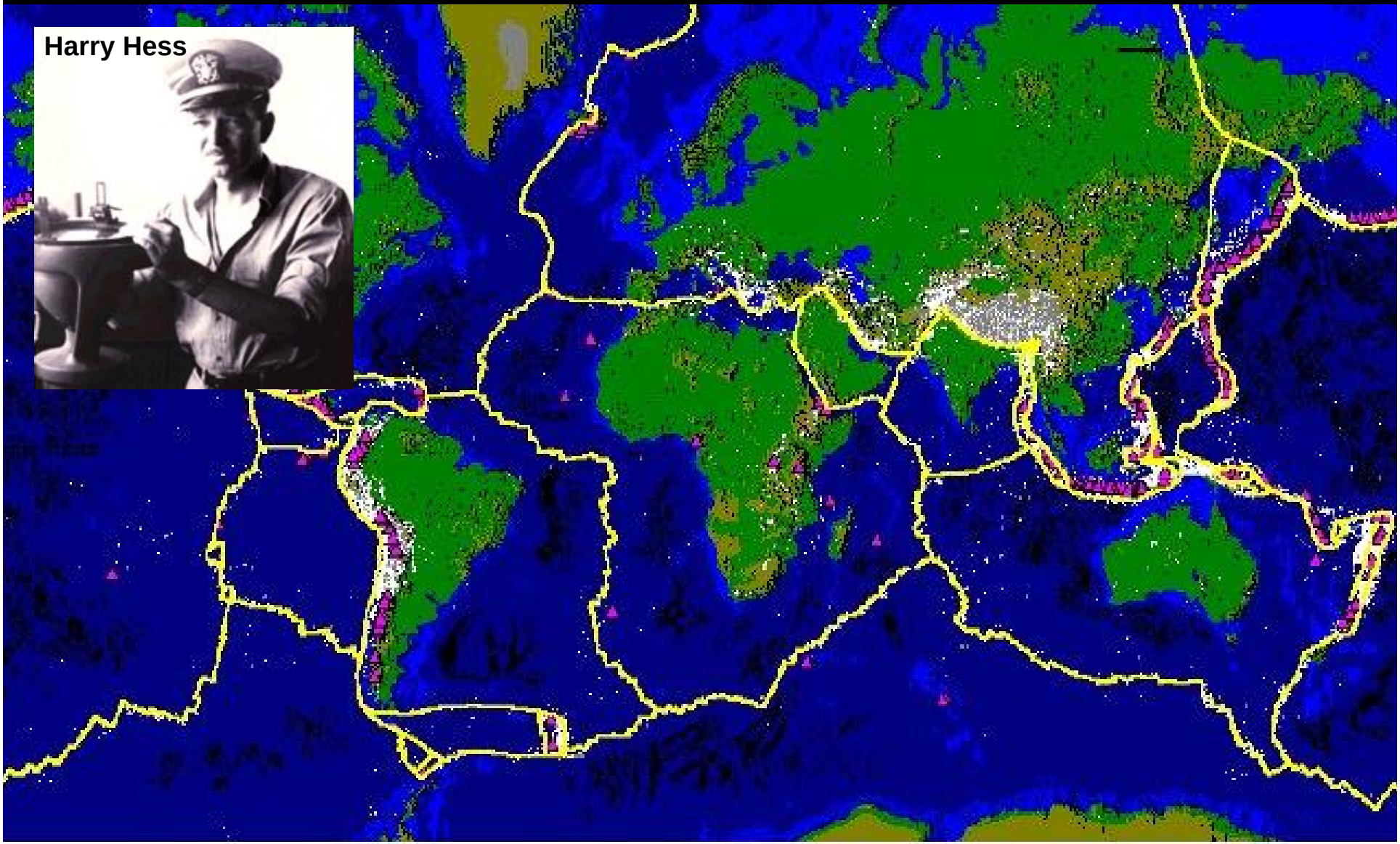
Si Ps > Pi > Po: débit = 0

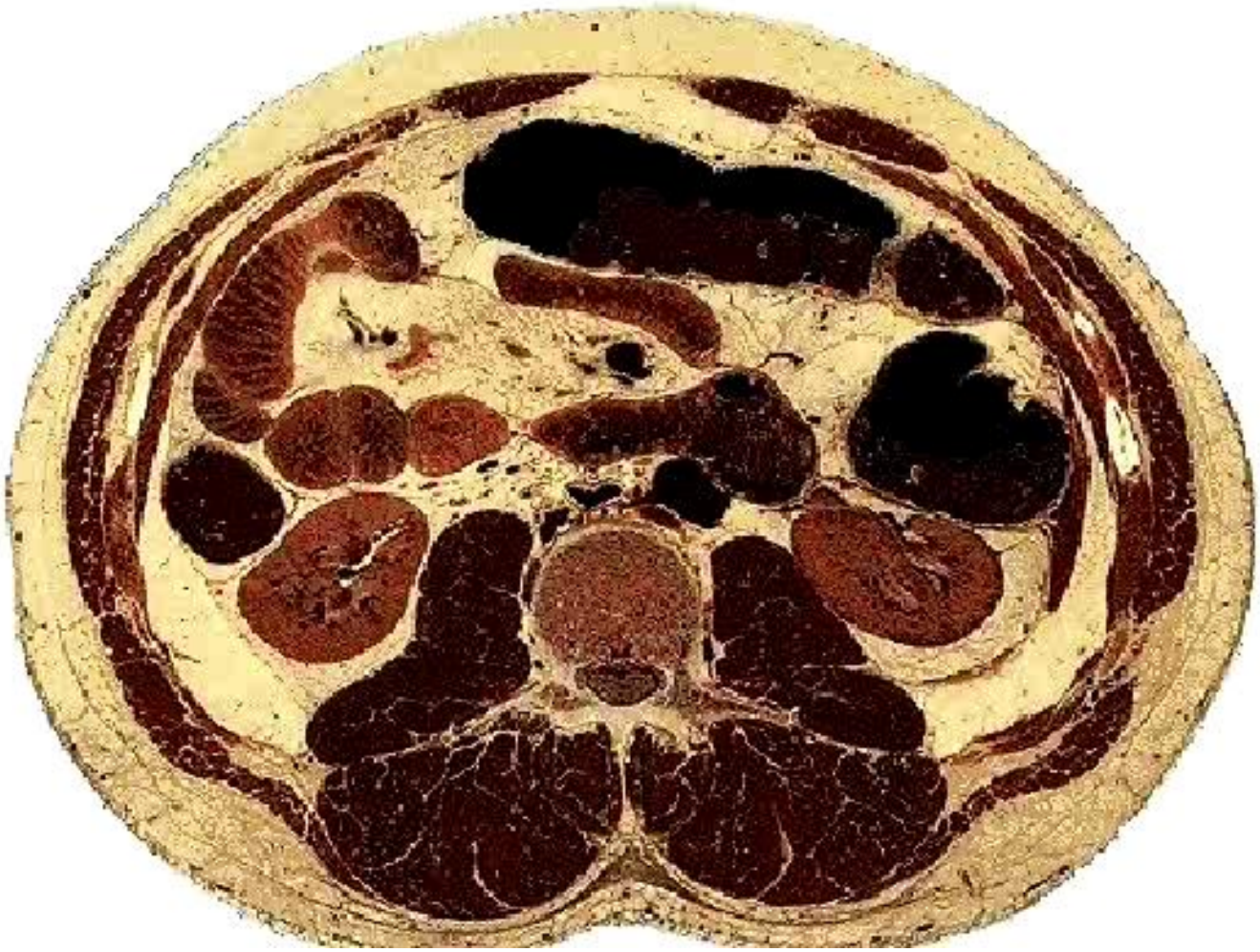
Si Pi > Ps > Po: débit selon Pi ï Ps

Si Pi > Po > Ps: débit selon Pi - Po

Lôinspiration augmente le retour veineux jusquà ce que
la pression de lôoreillette droite devienne sub-atmosphérique.
À ce moment, collapsus des veines extra-thoraciques

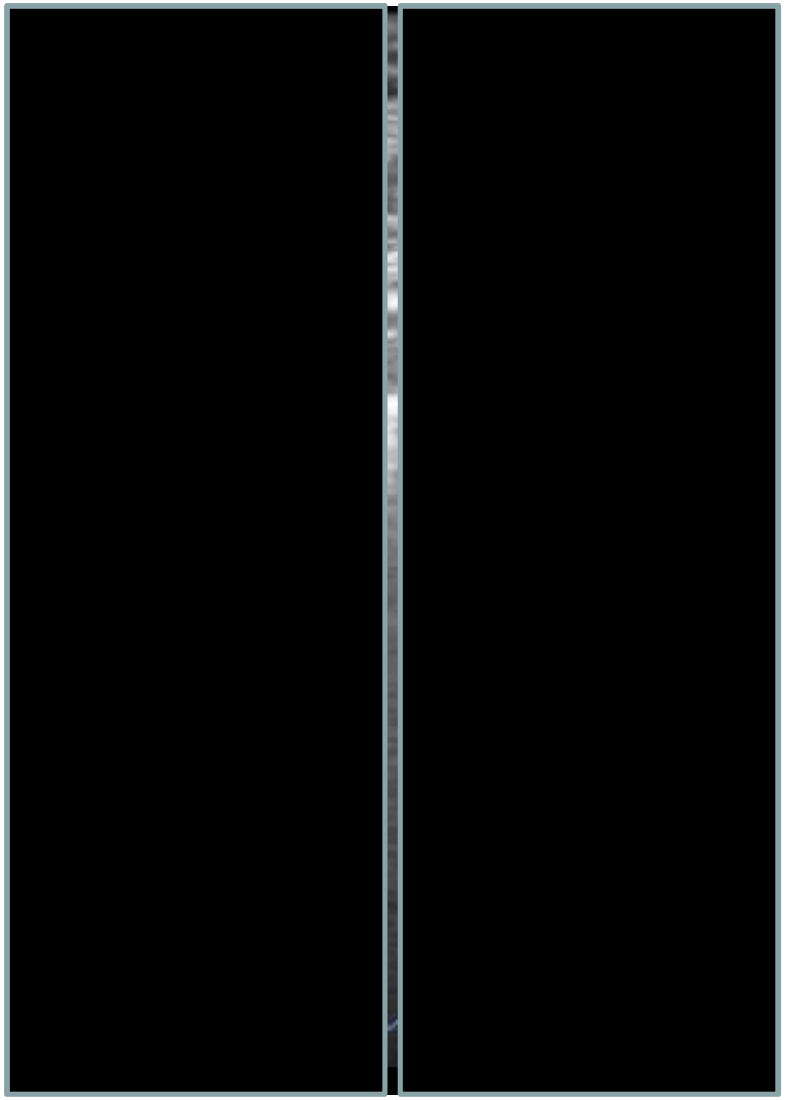
Fundamental cardiovascular and pulmonary physiology JF Green


Harry Hess
○: Séismes
▲: Eruption volcanique
Harry Hess

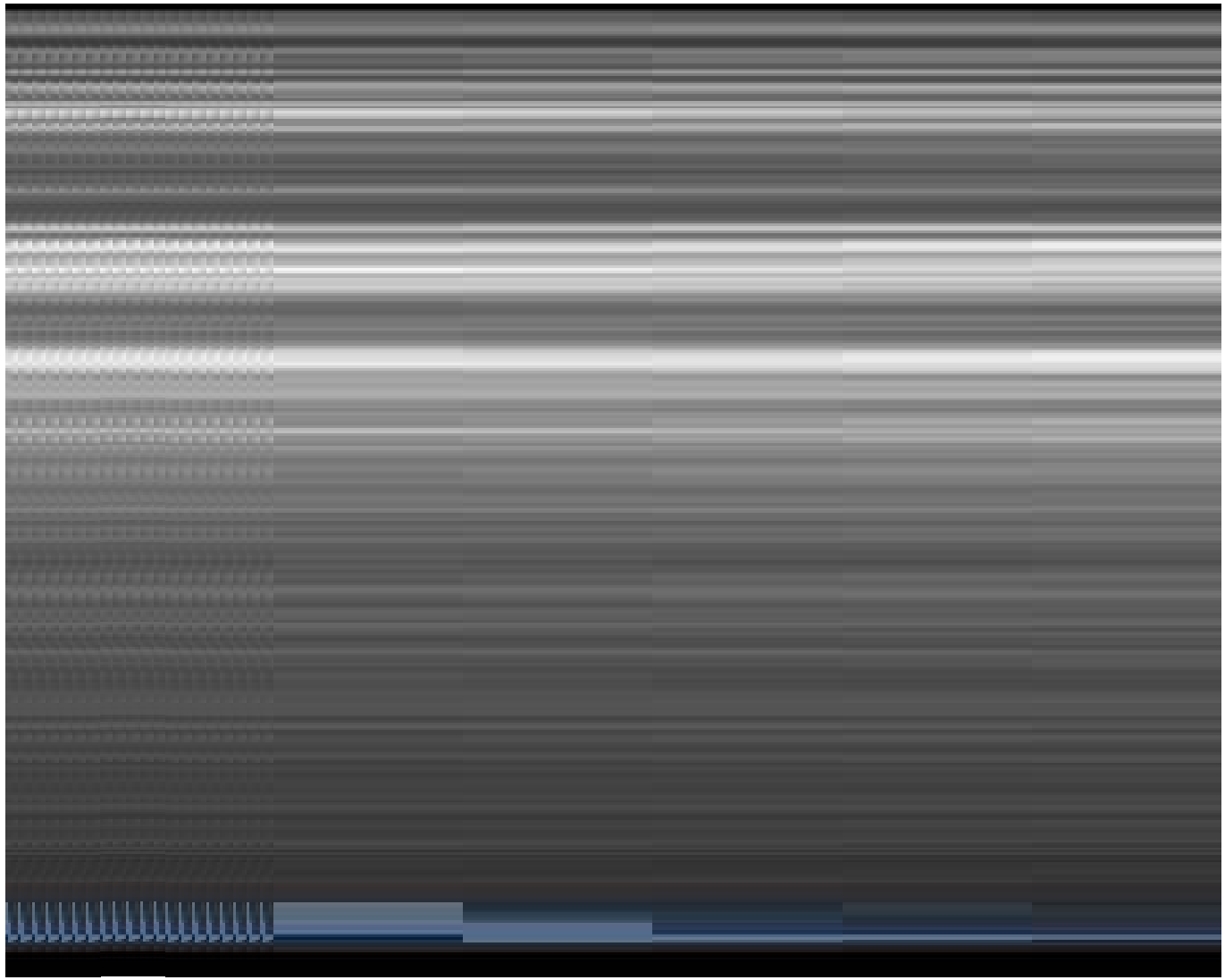


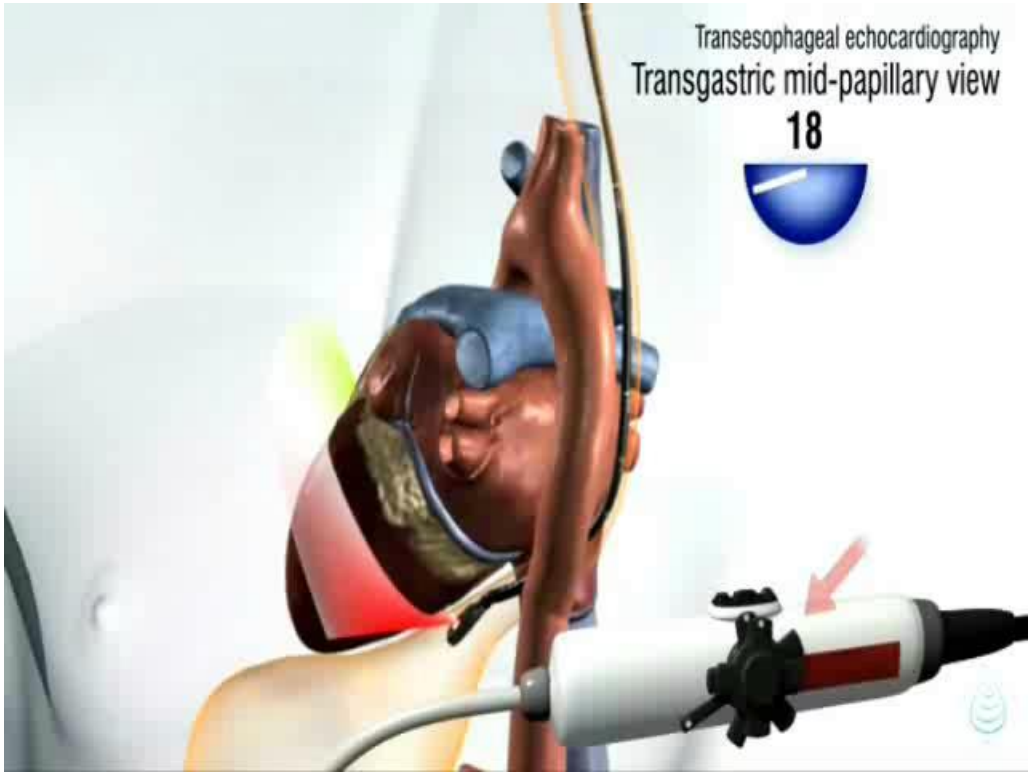
Courtoisie Alain Gauvin

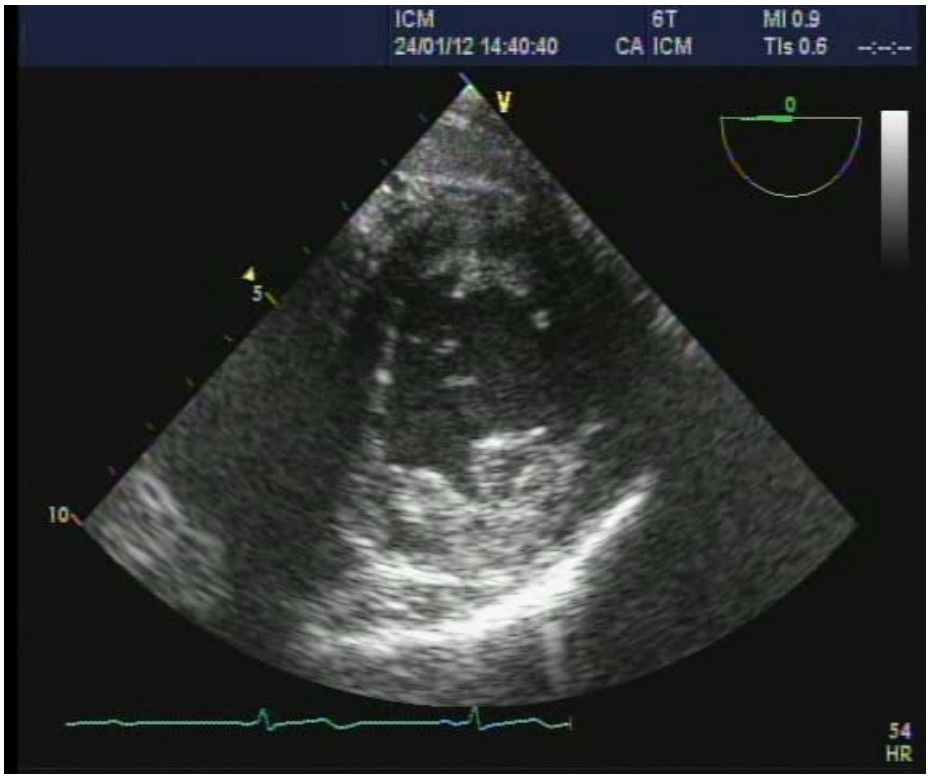
Mode 2D et mode M

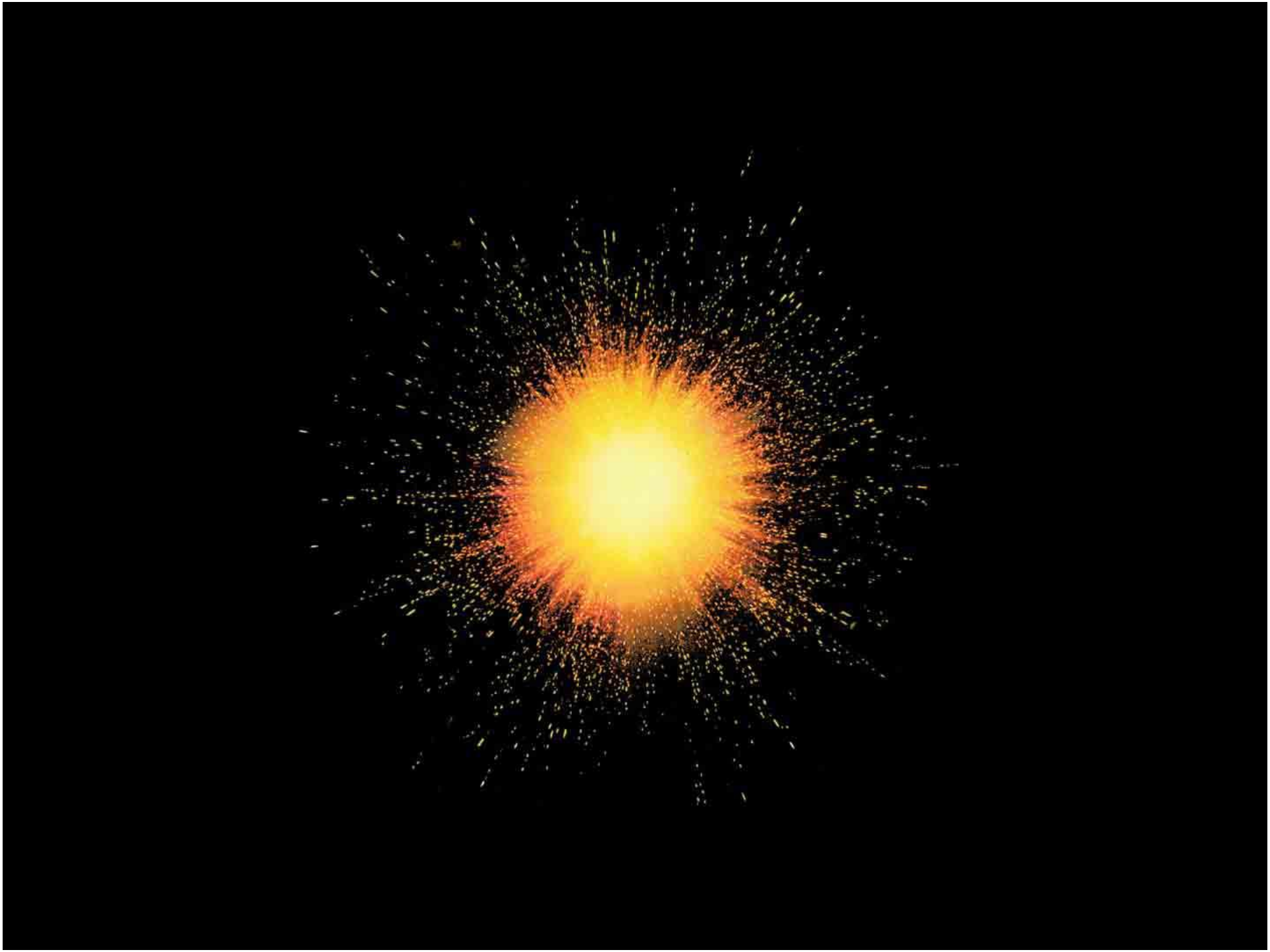


Mode 2D et mode M




Transesophageal echocardiography
Transgastric mid-papillary view
18

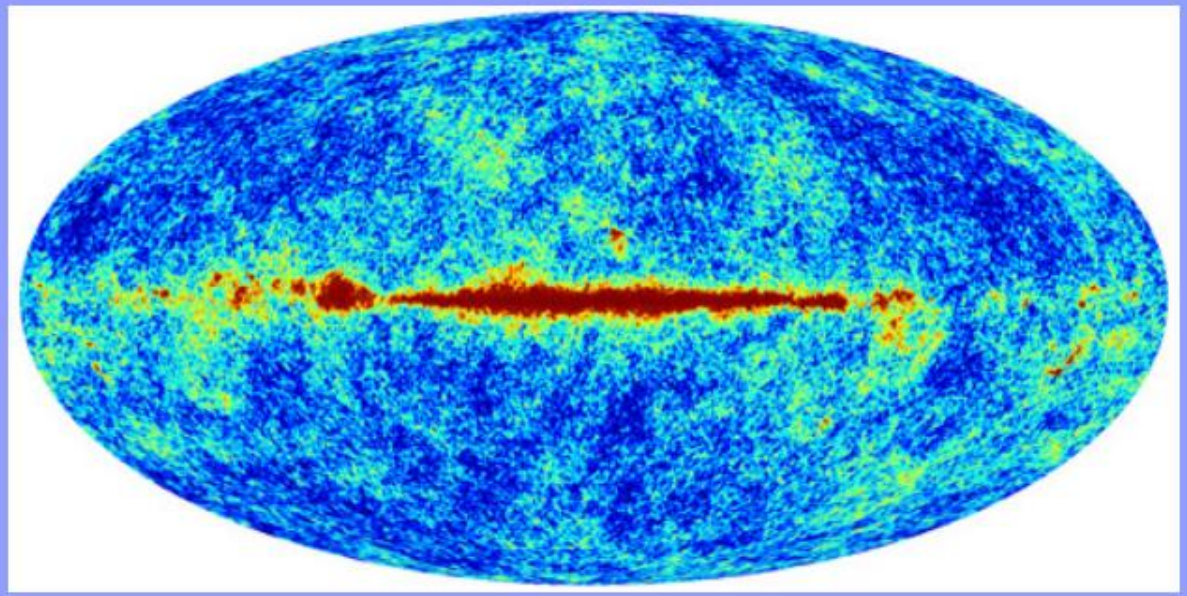

ICM
24/01/12 14:40:40
6T
CA ICM
MI 0.9
TIs 0.6
--:--:--
V
0
5
10
54
HR

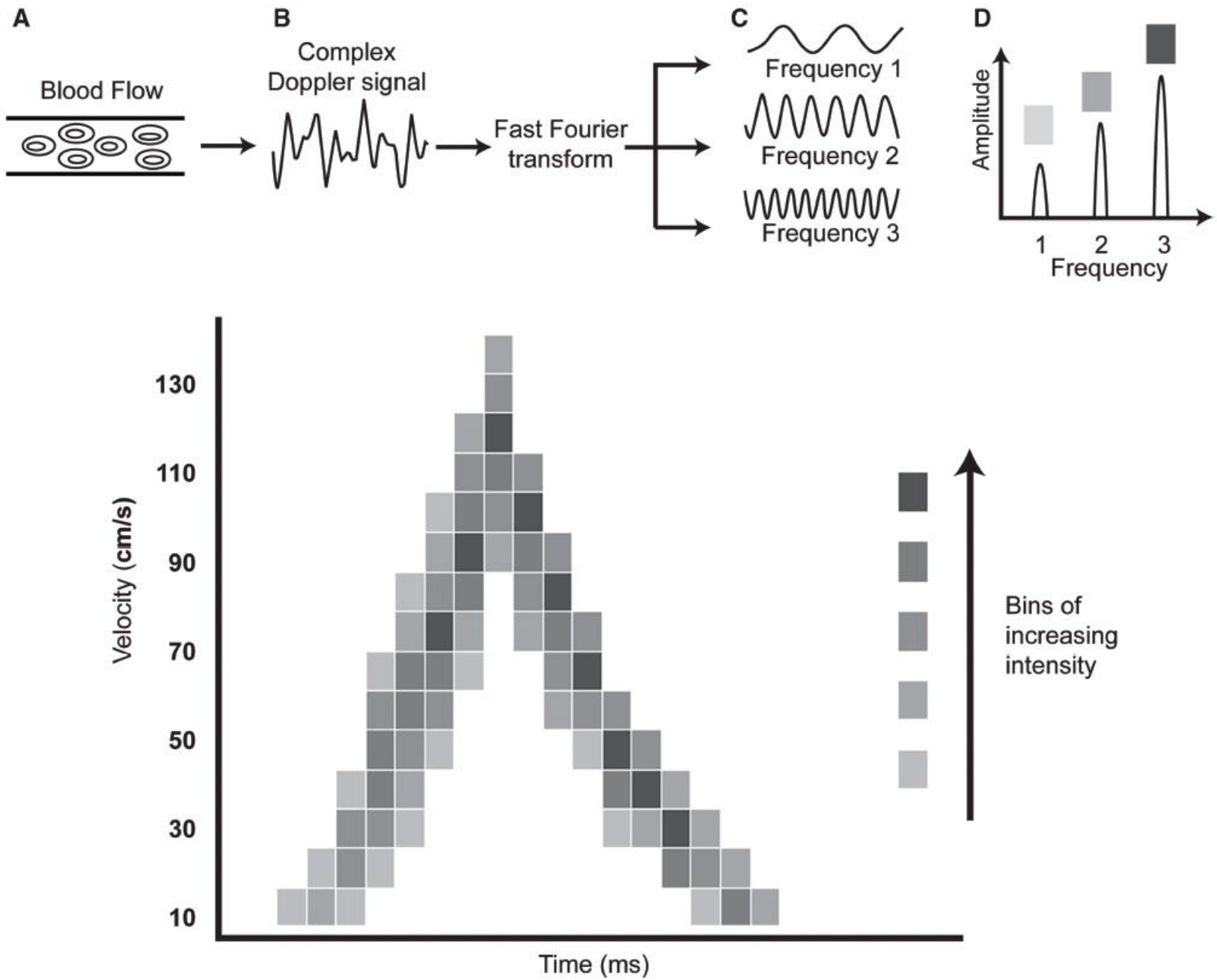


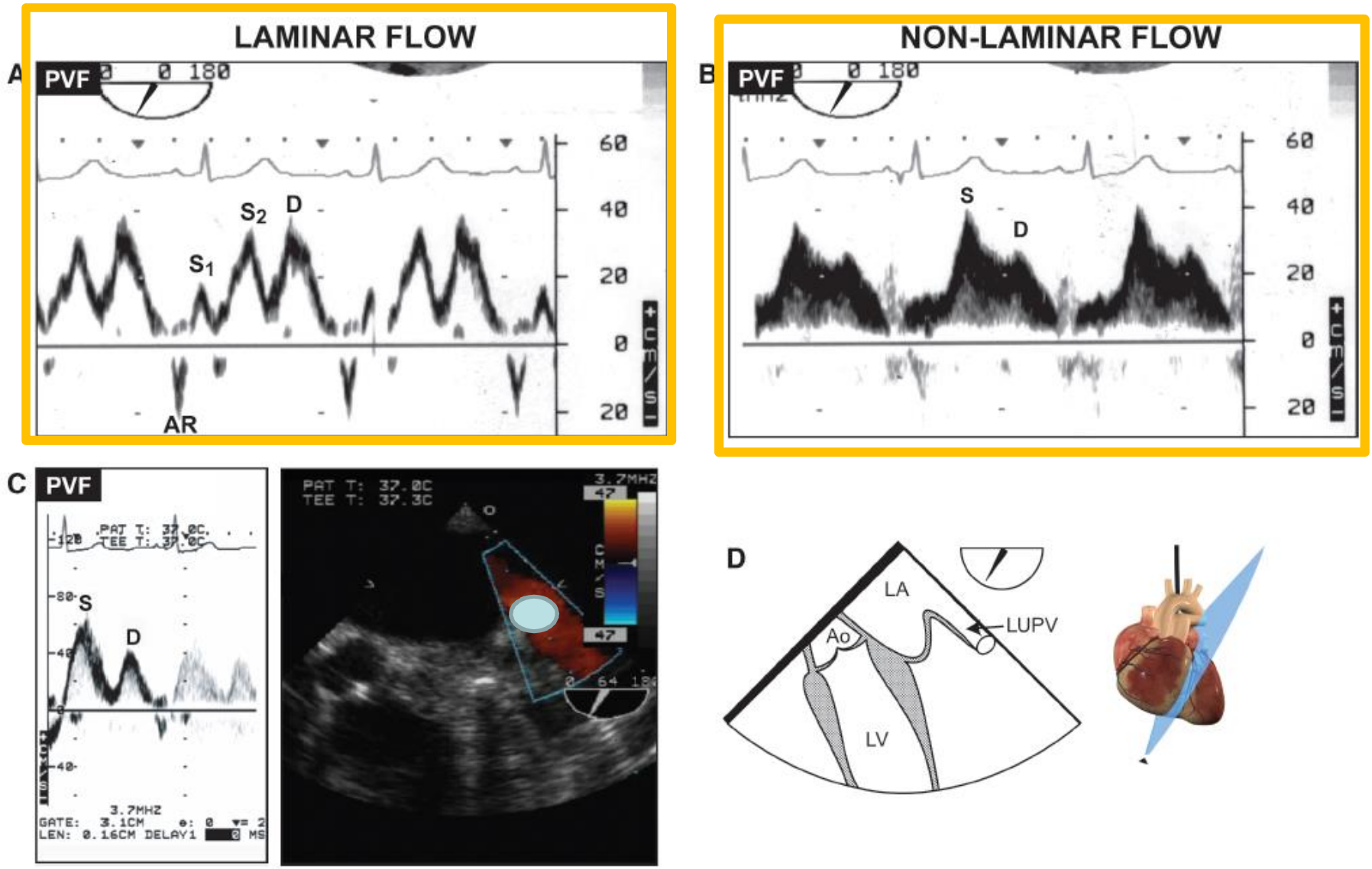
Fond diffus cosmologique :

Reliquat de chaleur issu du Big Bang qui s' est refroidi au fil du temps par effet Doppler due à l' expansion de l' Univers.

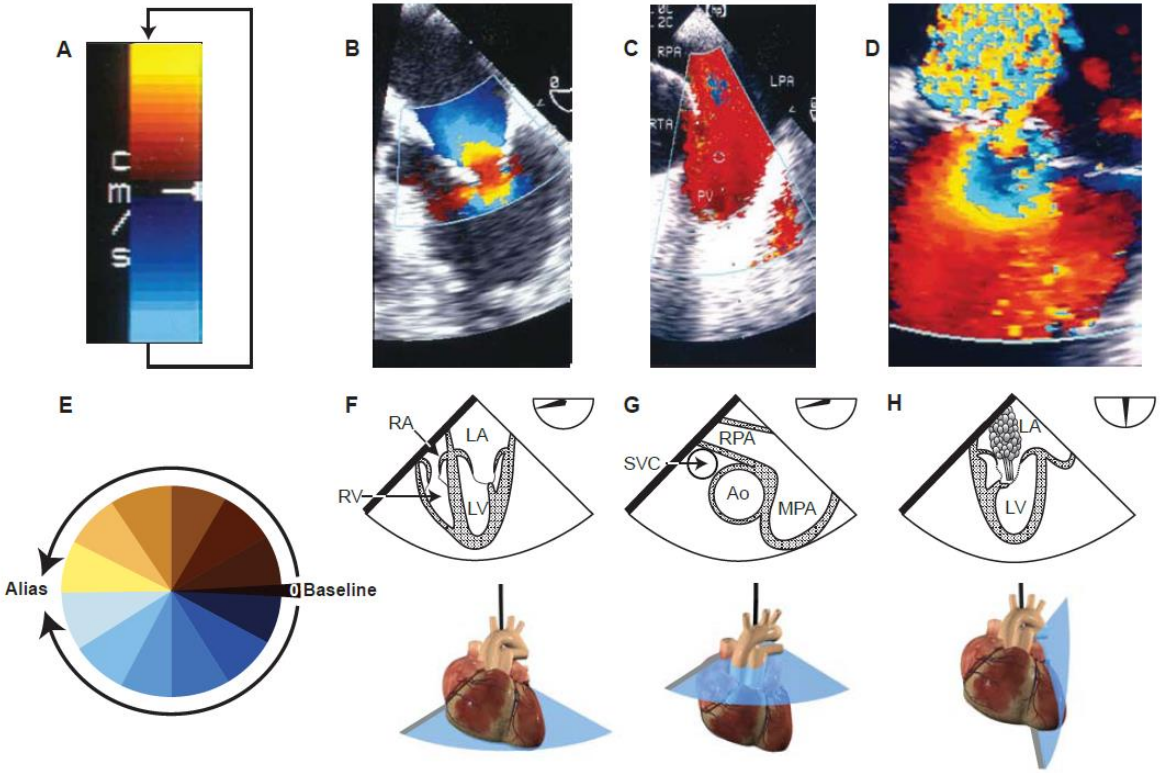
Edwin Hubble




A
Blood Flow
B
Complex
Doppler signal
Fast Fourier
transform
C
Frequency 1
Frequency 2
Frequency 3
D
Amplitude
1
2
3
Frequency
130
110
90
70
50
30
10
Velocity (cm/s)
Time (ms)
Bins of
increasing
intensity


LAMINAR FLOW
A
PVF
S2
D
S1
AR
60
40
20
0
20
NON-LAMINAR FLOW
B
PVF
S
D
60
40
20
0
20
C
PVF
S
D
3.7MHZ
GATE: 3.1CM
LEN: 0.16CM DELAY1
PAT T: 37.0C
TEE T: 37.3C
3.7MHZ
D
LA
LUPV
Ao
LV

Color Doppler: BART



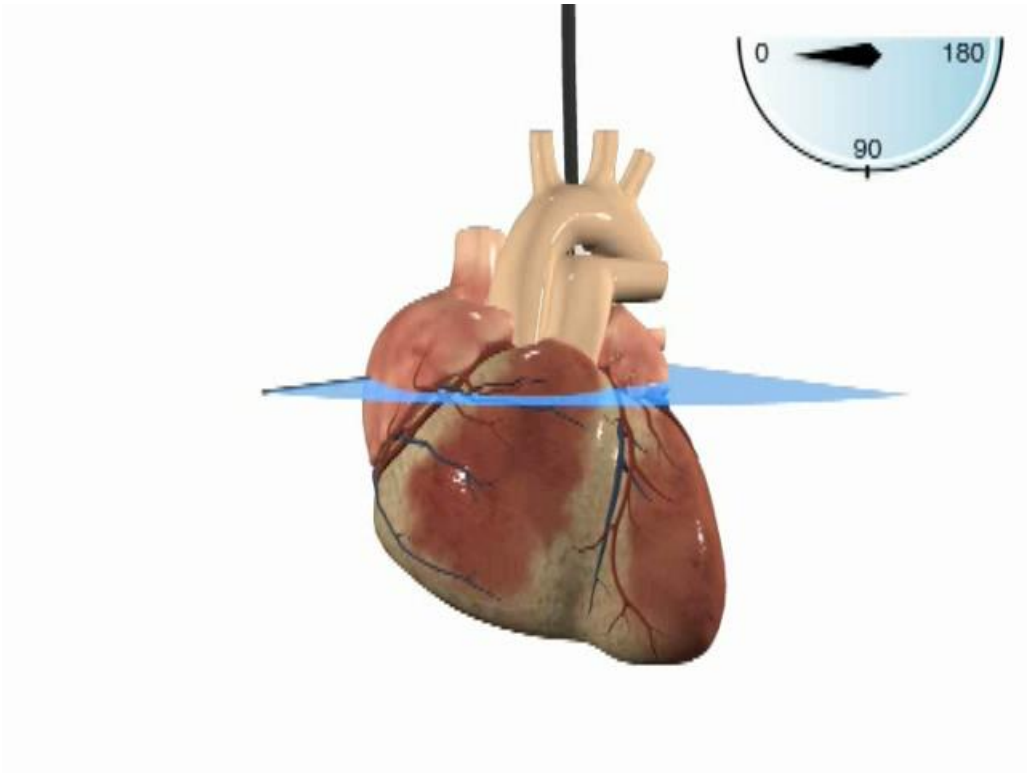
Rôle du Doppler

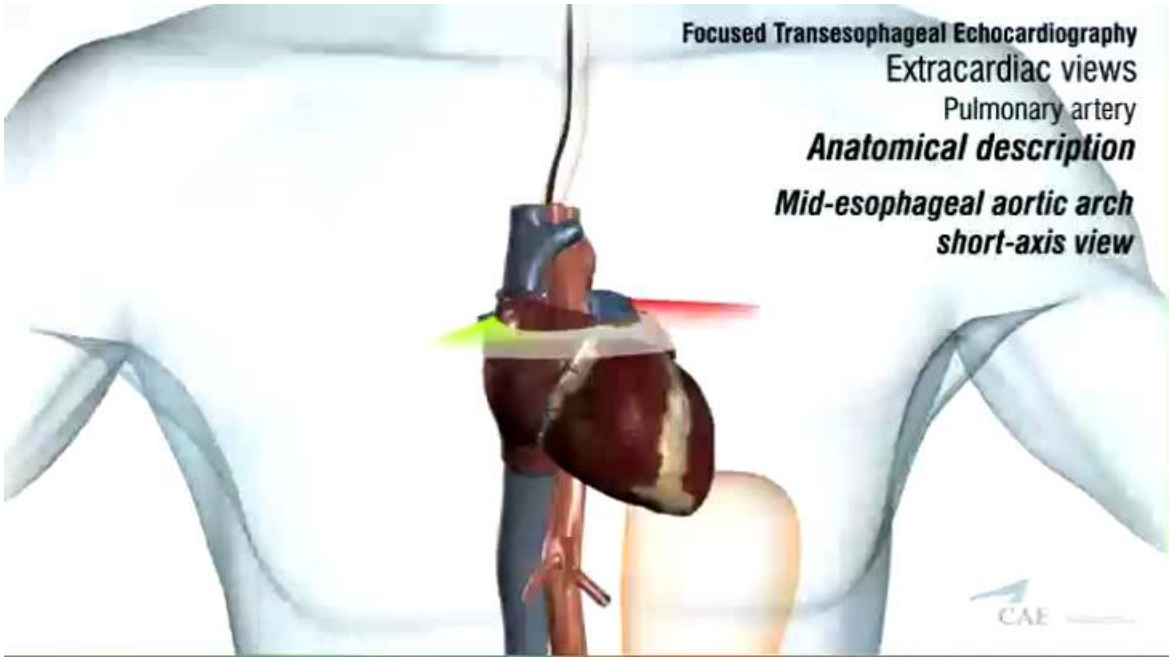
- Mesure du débit cardiaque
- Détection des vélocités anormales: régurgitation et sténose valvulaires
- Classification des fonction diastolique
- Estimation des pressions de remplissage

Anesthesiology 2001; 95:1083–8

Influence of Superior Vena Caval Zone Condition on Cyclic Changes in Right Ventricular Outflow during Respiratory Support

Antoine Vieillard-Baron, M.D., Roch Augarde, M.D.,† Sebastien Prin, M.D.,† Bernard Page, M.D.,‡ Alain Beauchet, M.D.,§ François Jardin, M.D.‖*




Focused Transesophageal Echocardiography
Extracardiac views
Pulmonary artery
Anatomical description
Mid-esophageal aortic arch
short-axis view
CAE

Focused Transesophageal Echocardiography

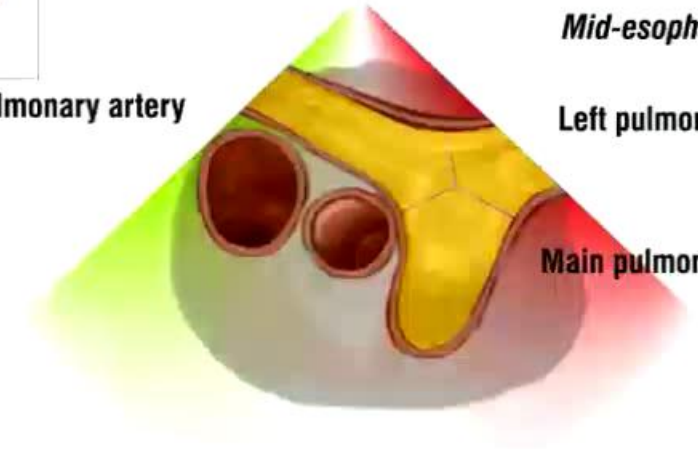
Extracardiac views

Pulmonary artery

Anatomical description

Right pulmonary artery

Mid-esophageal aortic arch short-axis view



Left pulmonary artery

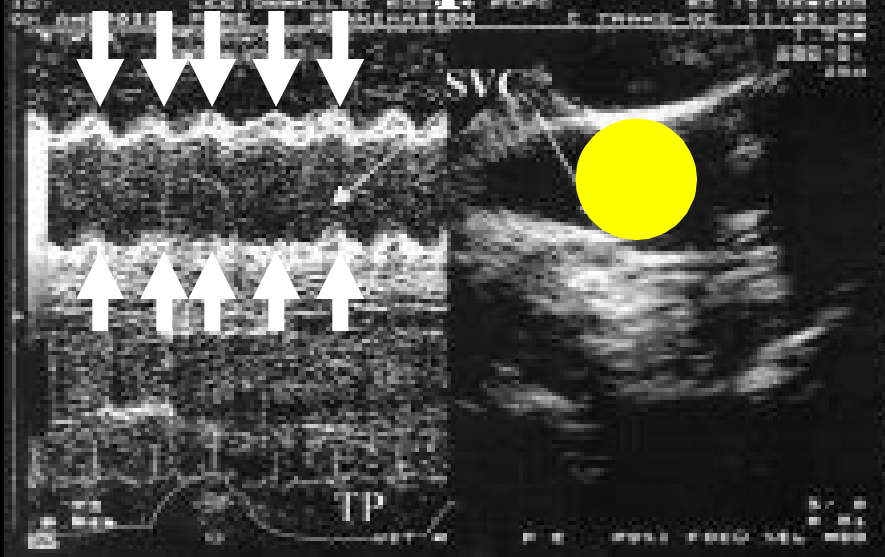
Main pulmonary artery

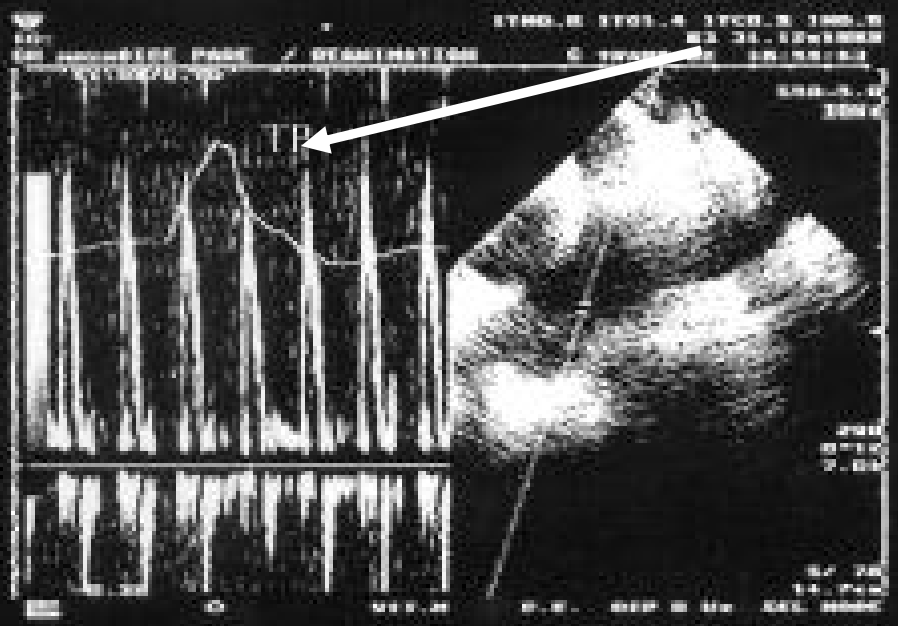
CAE

Methods

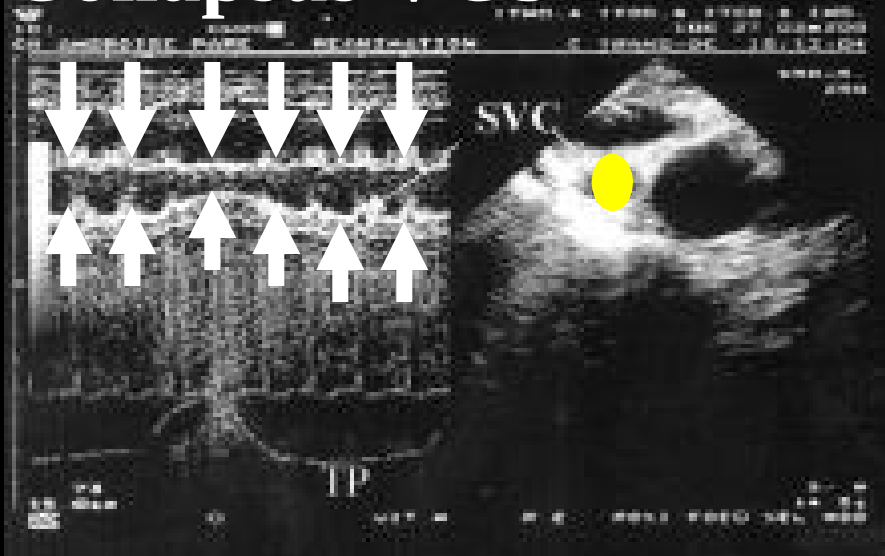
- 22 patients with circulatory failure on mechanical ventilation
- The superior vena cava was examined from a short- or long-axis view, using the two-dimensional view to direct the M-mode beam across the maximal diameter. From this view, we measured SVC diameter during the respiratory cycle.
- The collapsibility index of the superior vena cava, *i.e.*, the inspiratory decrease in SVC diameter,was determined as (maximal diameter on expiration - minimal diameter on inspiration)/maximal diameter on expiration, and was expressed as a percentage.7

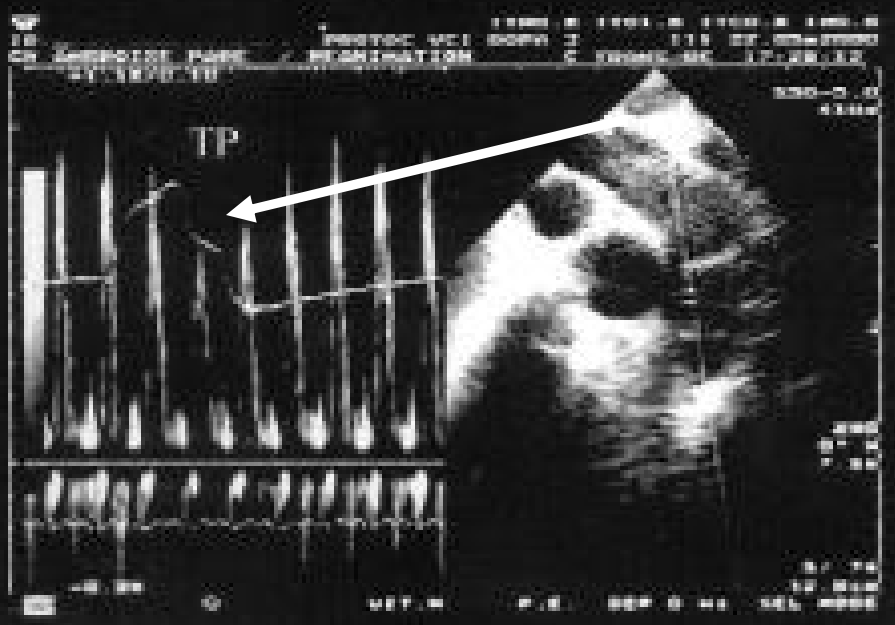
Pas de collapsus VCS



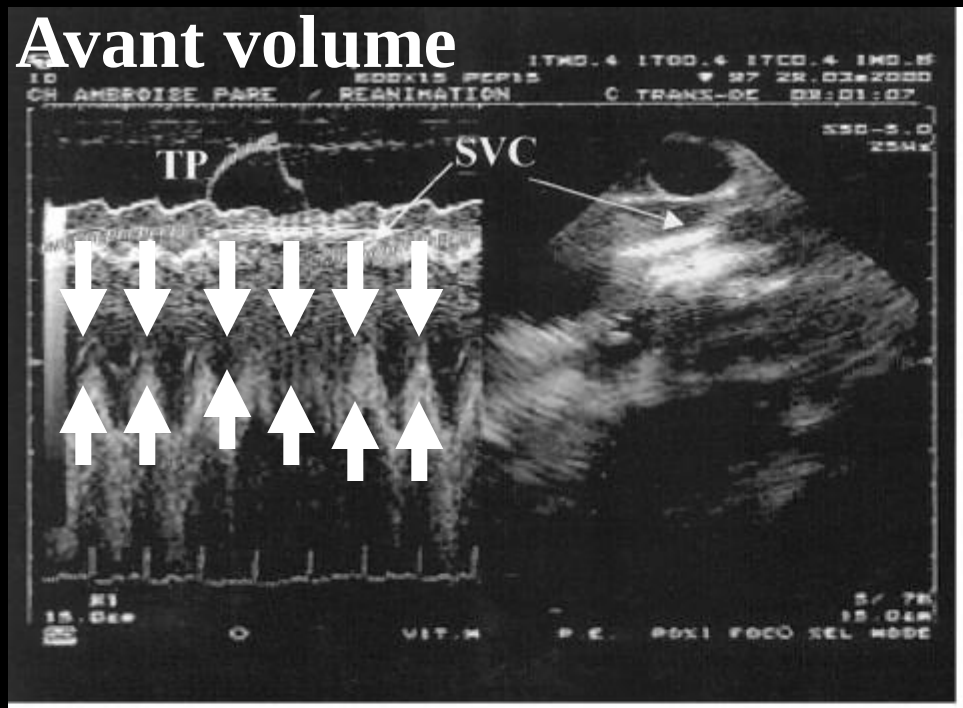


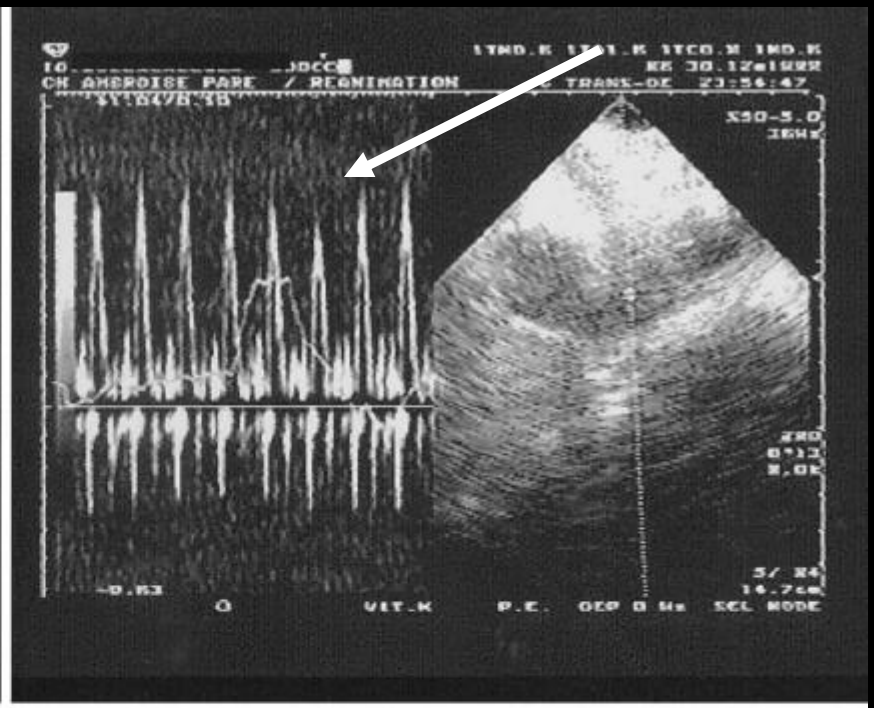
Collapsus VCS



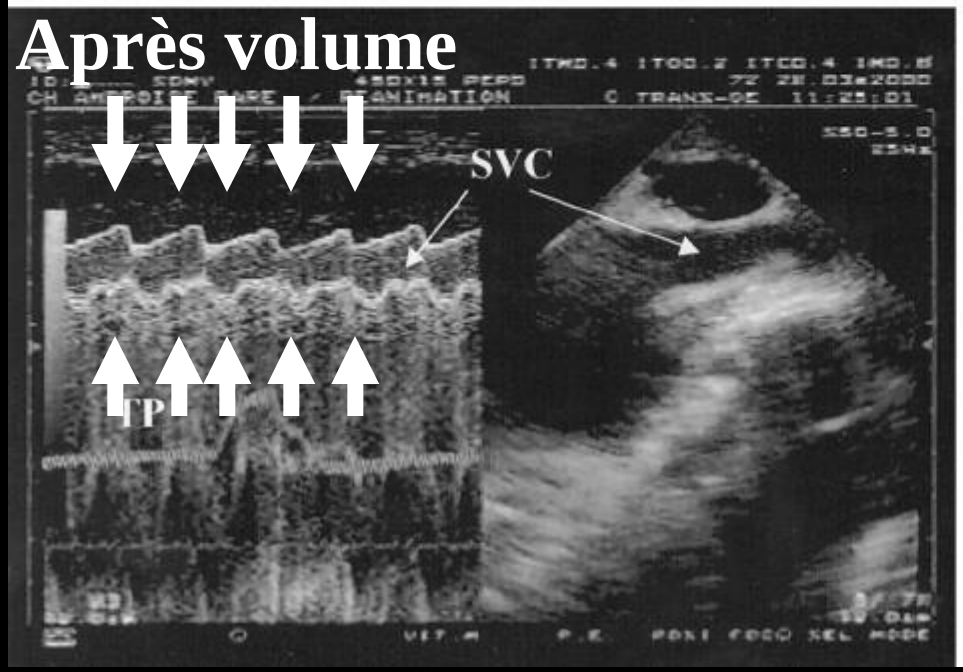


Avant volume





Après volume



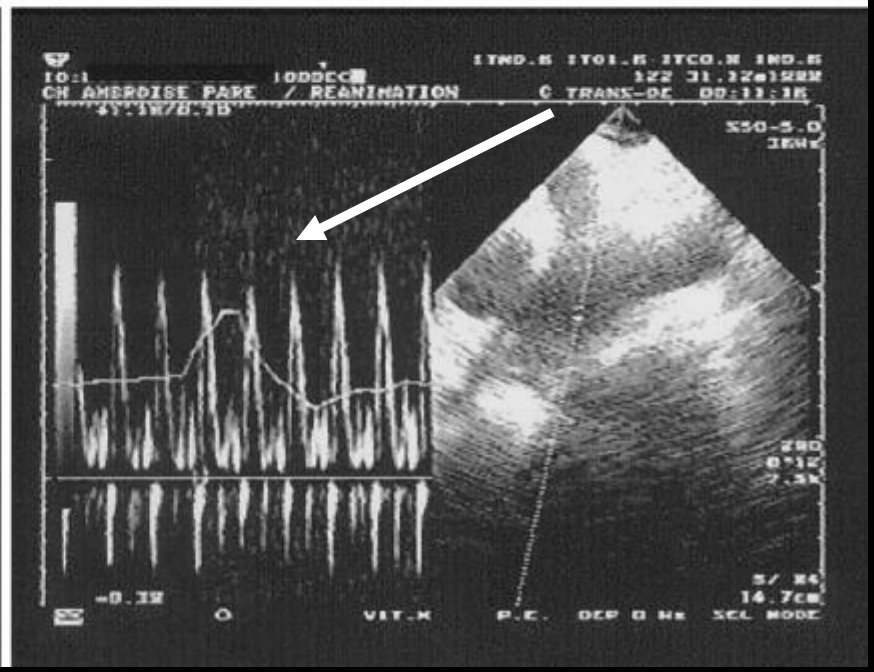
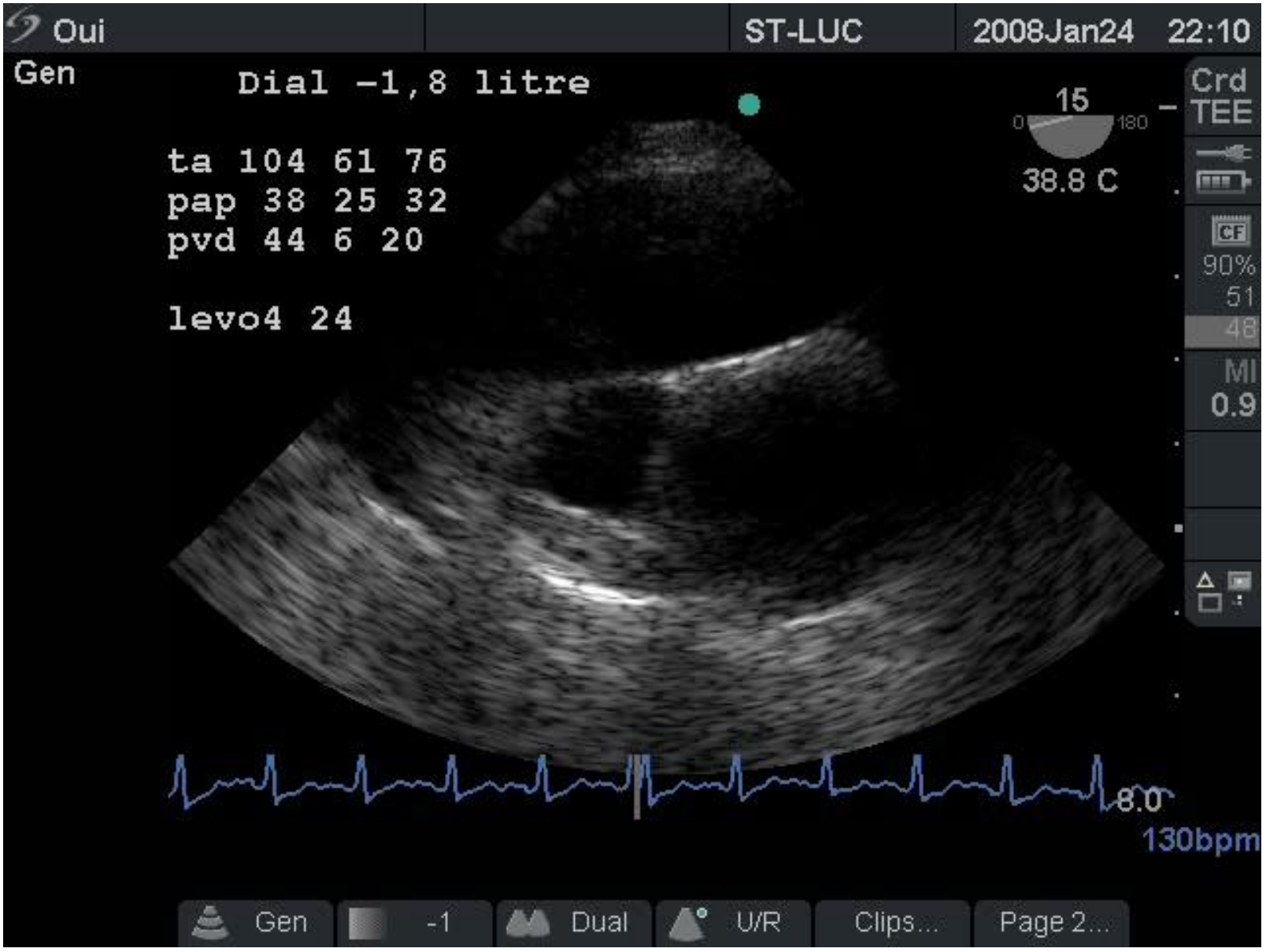


Table 1. Comparison among Hemodynamic Data at Baseline and after Volume Expansion

	Group 1	Group 2A (before BVE)	Group 2B (after BVE)
HR (beats/min)	91 ± 13	114 ± 14*	105 ± 16†
SAP (mmHg)	114 ± 23	91 ± 14*	105 ± 20†
CVP (mmHg)	12 ± 2 (9–16)	7 ± 2* (5–9)	12 ± 12† (10–15)
SI (cm^3/m^2)	24 ± 7	20 ± 6*	24 ± 8†
CI ($l \cdot min^{-1} \cdot m^{-2}$)	2.2 ± 0.6	2.3 ± 0.7	2.9 ± 0.8†
V_{MAX} (m/s)	0.66 ± 0.18	0.83 ± 18*	0.79 ± 0.19
AC_{mean} (m/s)	7.2 ± 3.1	9.2 ± 5.7	9.2 ± 3.3
FP (ms)	254 ± 46	208 ± 107*	213 ± 42
PA_{VTI} (cm)	10.5 ± 3.4	7.1 ± 3.4*	9.6 ± 3.3†


Oui
ST-LUC
2008Jan24 22:10
Gen
Dial -1,8 litre
ta 104 61 76
pap 38 25 32
pvd 44 6 20
levo4 24
15
0
180
38.8 C
Crd
TEE
CF
90%
51
48
MI
0.9
8.0
130bpm
Gen
-1
Dual
U/R
Clips...
Page 2...

En résumé

- Le collapsus des VCS signifie qu'en expiration le retour veineux se retrouve en condition de zone où le Ps > Pi
- Dans ces conditions, on observe une réponse positive au volume
- Le collapsus des VCS + VCI est une méthode non-invasive d'évaluation de la réponse au volume

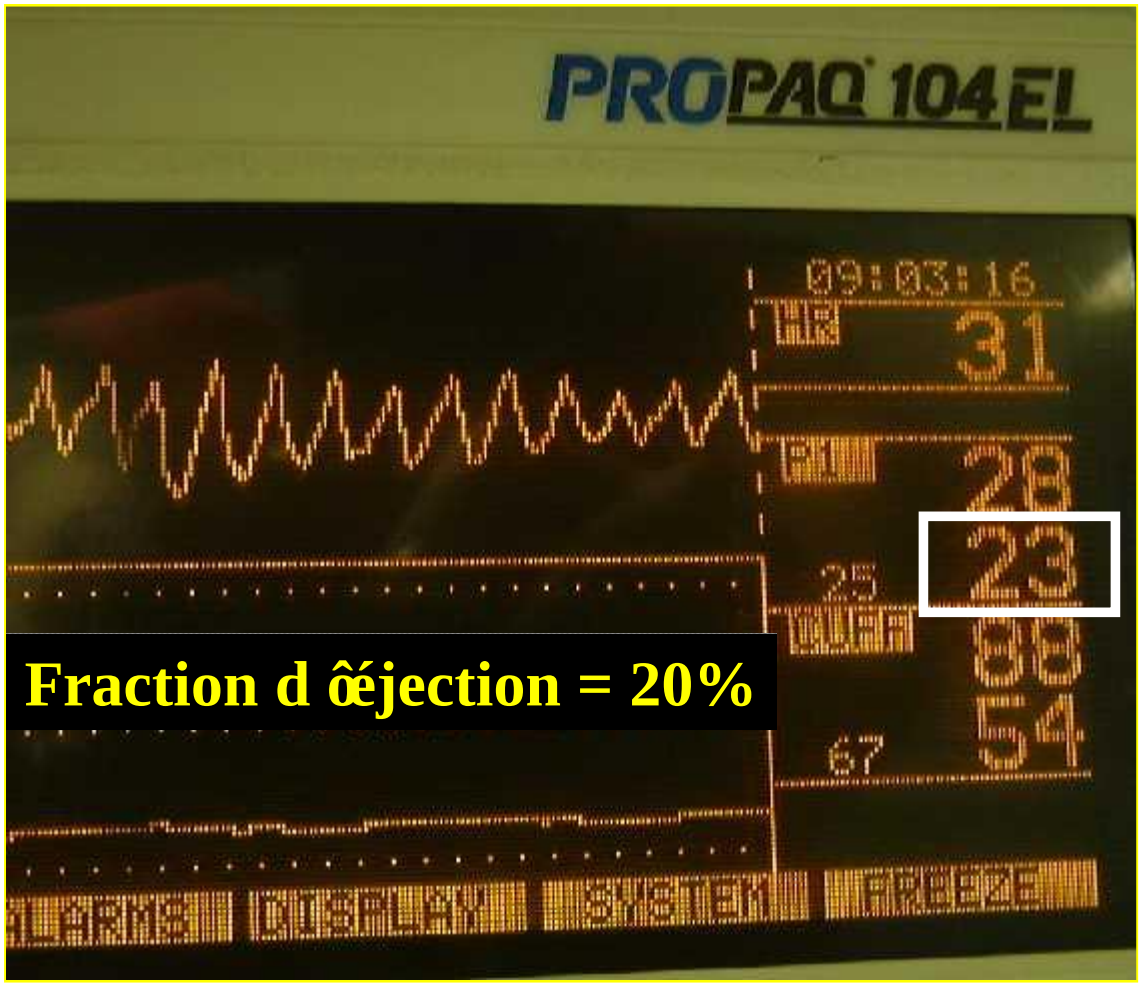
Concepts

- Le stressed volume contribue à la pression veineuse systémique (30 ml/kg)
- Le retour veineux est limité par le collapsus veineux extra-thoracique
- Quel est la valeur de la pression veineuse systémique?

Lors de l œarrêt cardiaque chez un patient avec une fraction d œéjection à 20%:
lequel est vrai:

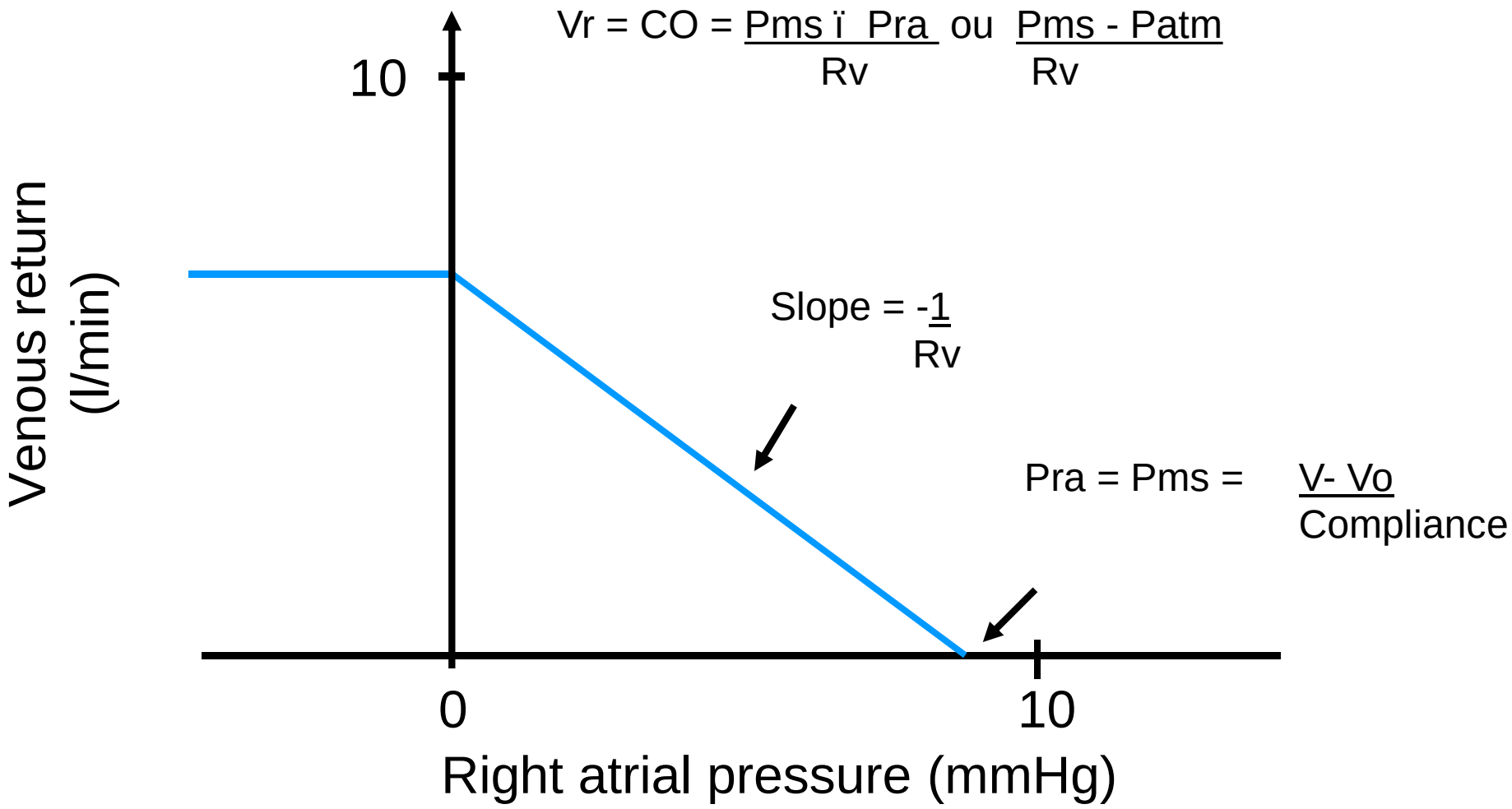
1-TAM = 0 mmHg et TVC = 0 mmHg
2-TAM = 10 mmHg et TVC = 0 mmHg
3-TAM = 20 mmHg et TVC = 20 mmHg
4-TAM = 0 mmHg et TVC = 20 mmHg
5-Ça dépendsé ..

Femme de 70 ans, implantation de pace-défibrillateur



P1 = pression artérielle

La fonction cardiaque se situe un point de cette courbe



Adapated from: Jacobsohn et al Can J Anesth 1997 44:8 849-67

Déterminants du retour veineux

$$RV = \frac{\text{Pression motrice}}{\text{Résistance au RV}} = \frac{\text{Pms ï Pra}}{\text{Rrv}}$$

Ź Retour veineux si

1-Ź Pms: hypovolémie, vasodilatation

2-ŷ Pra: défaillance cardiaque

3-ŷ Rrv: syndrome de compartiment

Déterminants du retour veineux

RV = Pression motrice = Pms ï Pra
Résistance au RV Rrv

RV = (V-Vo)/C ï Pra
Rrv

Retour veineux diminue seulement si:

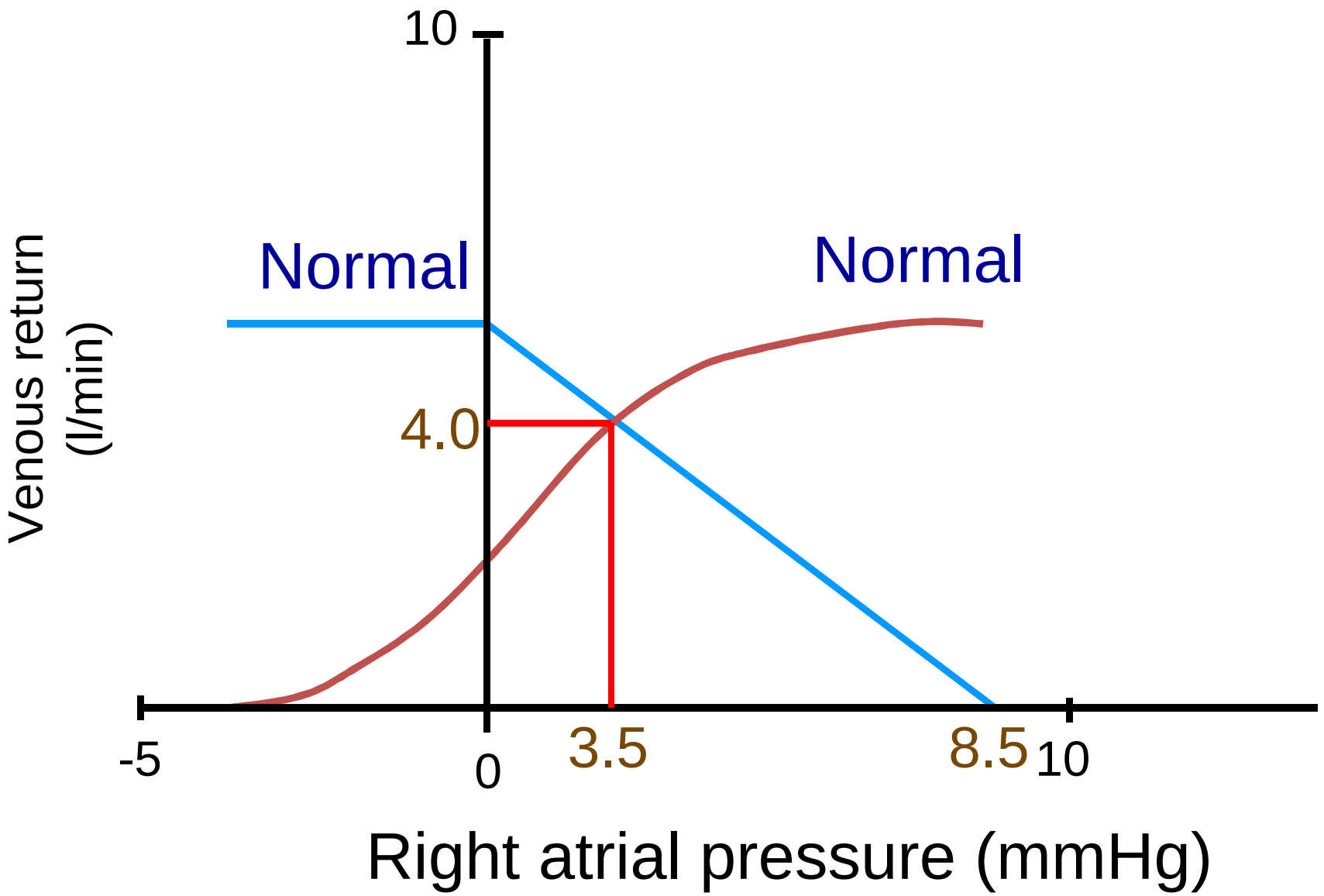
1- Volume total Ź (hypovolémie)

2- Vo ou volume non-constraint ŷ (vasodilatation)

3- Compliance veineuse ŷ (vasodilatation)

4- Pression de lôoreillette droite ŷ (ins DŽ

5- Résistance au retour veineux ŷ (syndrome de compartiment, polycythémie, redistribution des lit vasculaire avec cte de temps Űlente)



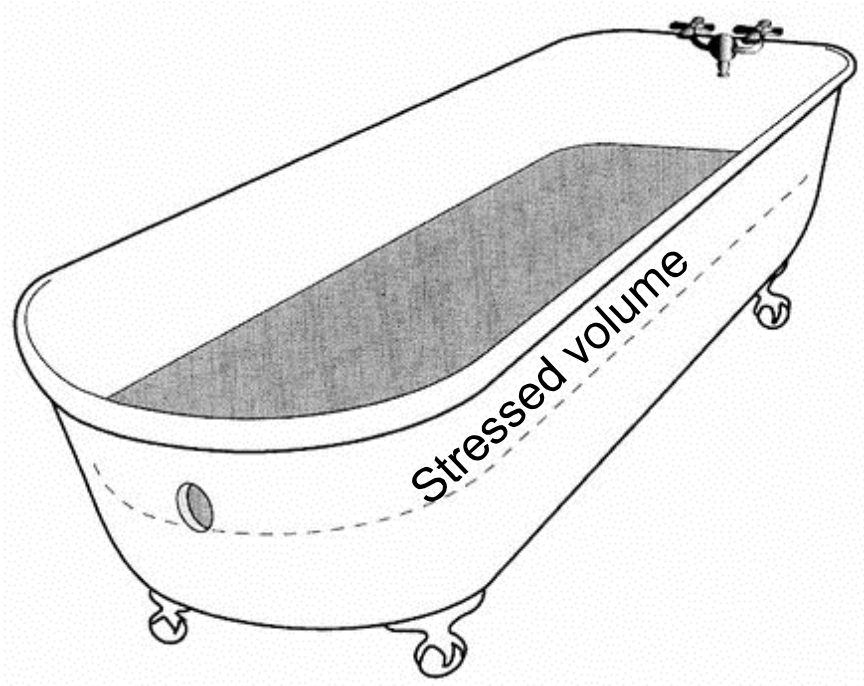
Adapated from: Jacobsohn et al Can J Anesth 1997 44:8 849-67

Intensive Care Med (1998) 24: 651–653

EDITORIAL

S. Magder

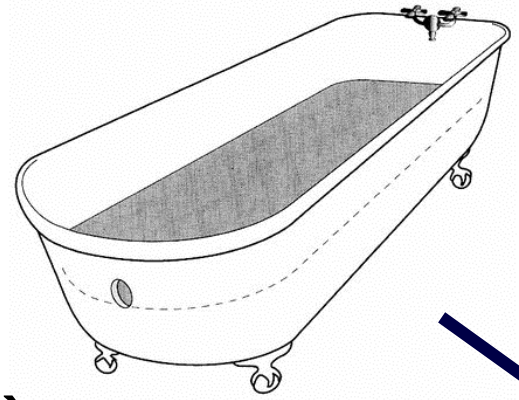
More respect for the CVP



Déterminants du retour veineux

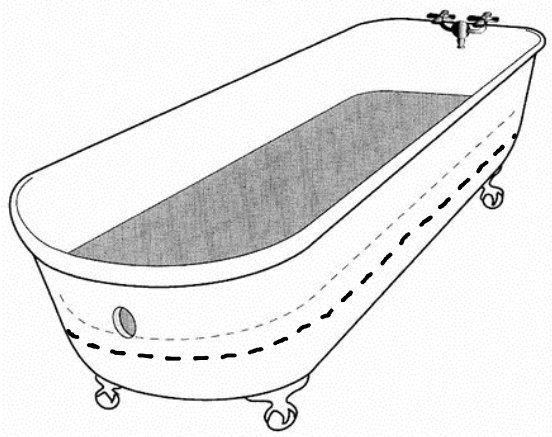
- Pression à la sortie du drain (pression de l'oreillette droite)
- Quantité de volume au-dessus du drain (stressed volume)
- Robinet (débit du cî ur gauche)
- Volume résiduel sous le drain (unstressed volume)
- Pression exercée par le volume au-dessus du drain ou « stressed » volume (pression veineuse systémique)
- Taille du bain (capacitance veineuse)
- Quantité d'eau dans le bain: stressed et unstressed volume
- Taille d'ouverture du drain (caractéristiques des Zone 2 ou 3)
- Hauteur du drain selon la fonction cardiaque droite

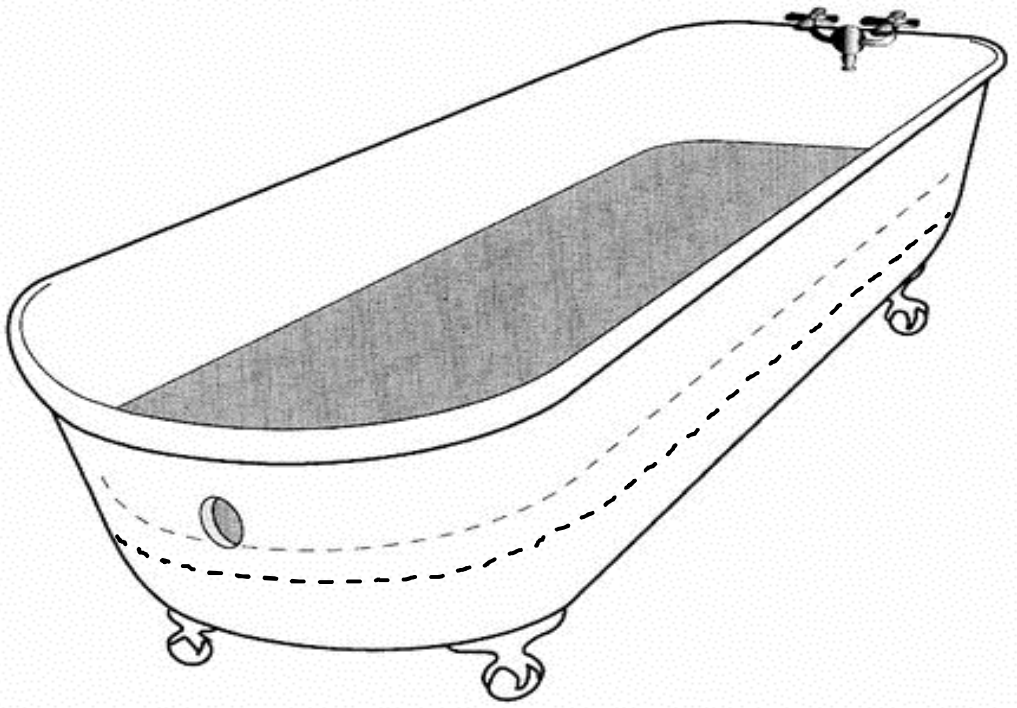
Pms = $\frac{\text{Stress volume}}{\text{Compliance}}$



Loss of ñstress volumeò

Increase in ñunstress volumeò or compliance





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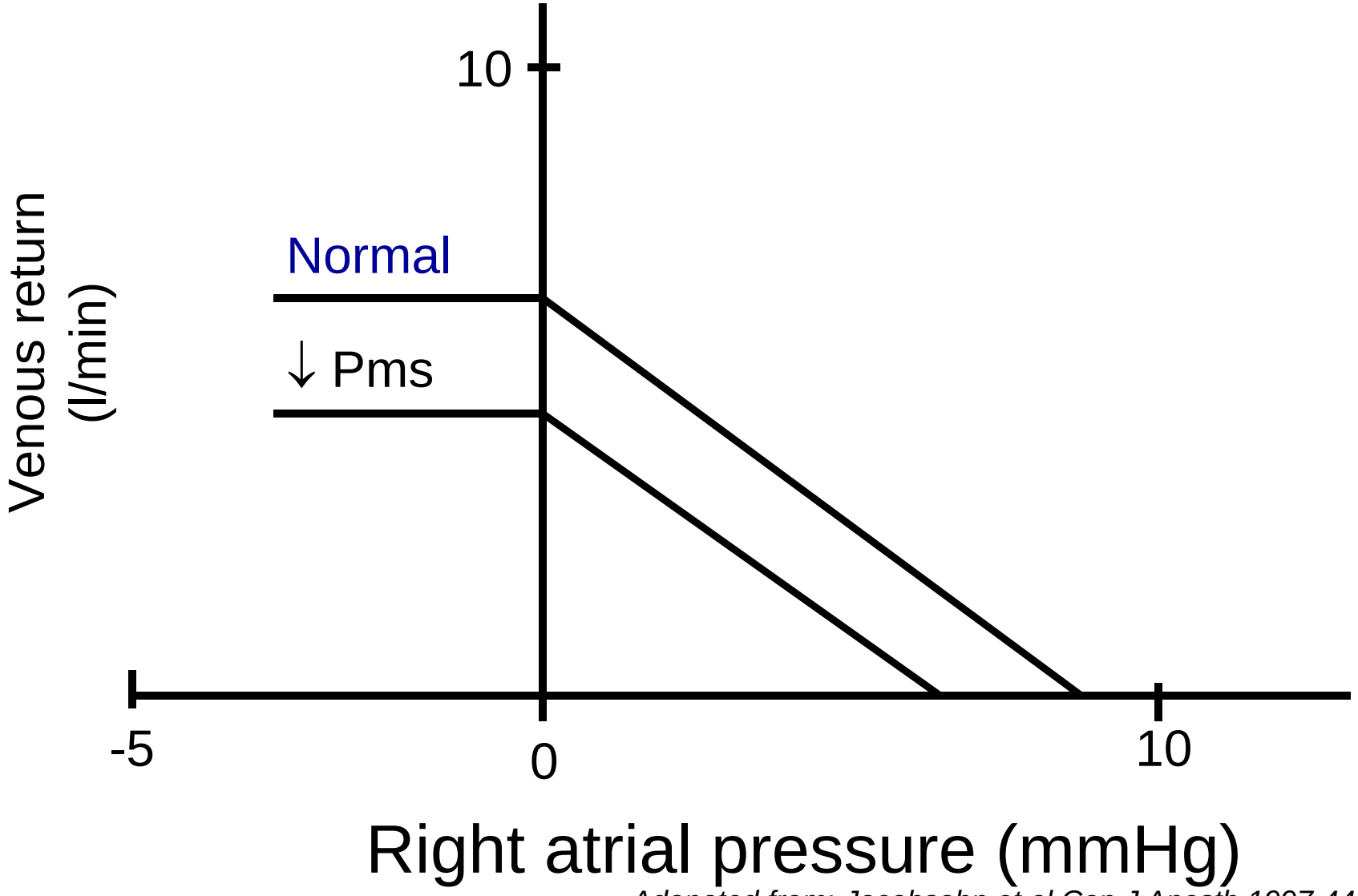
Hypovolemia



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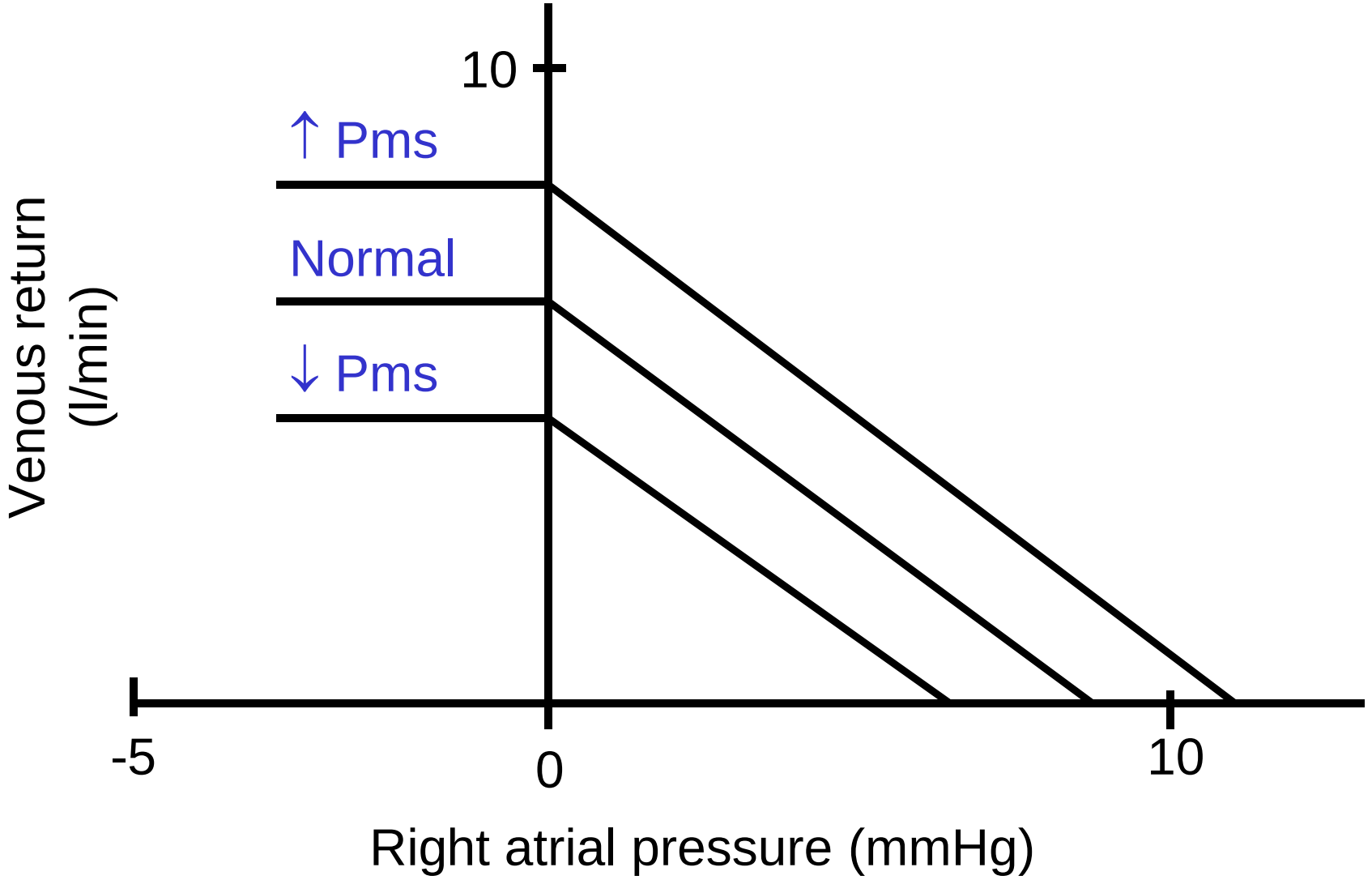
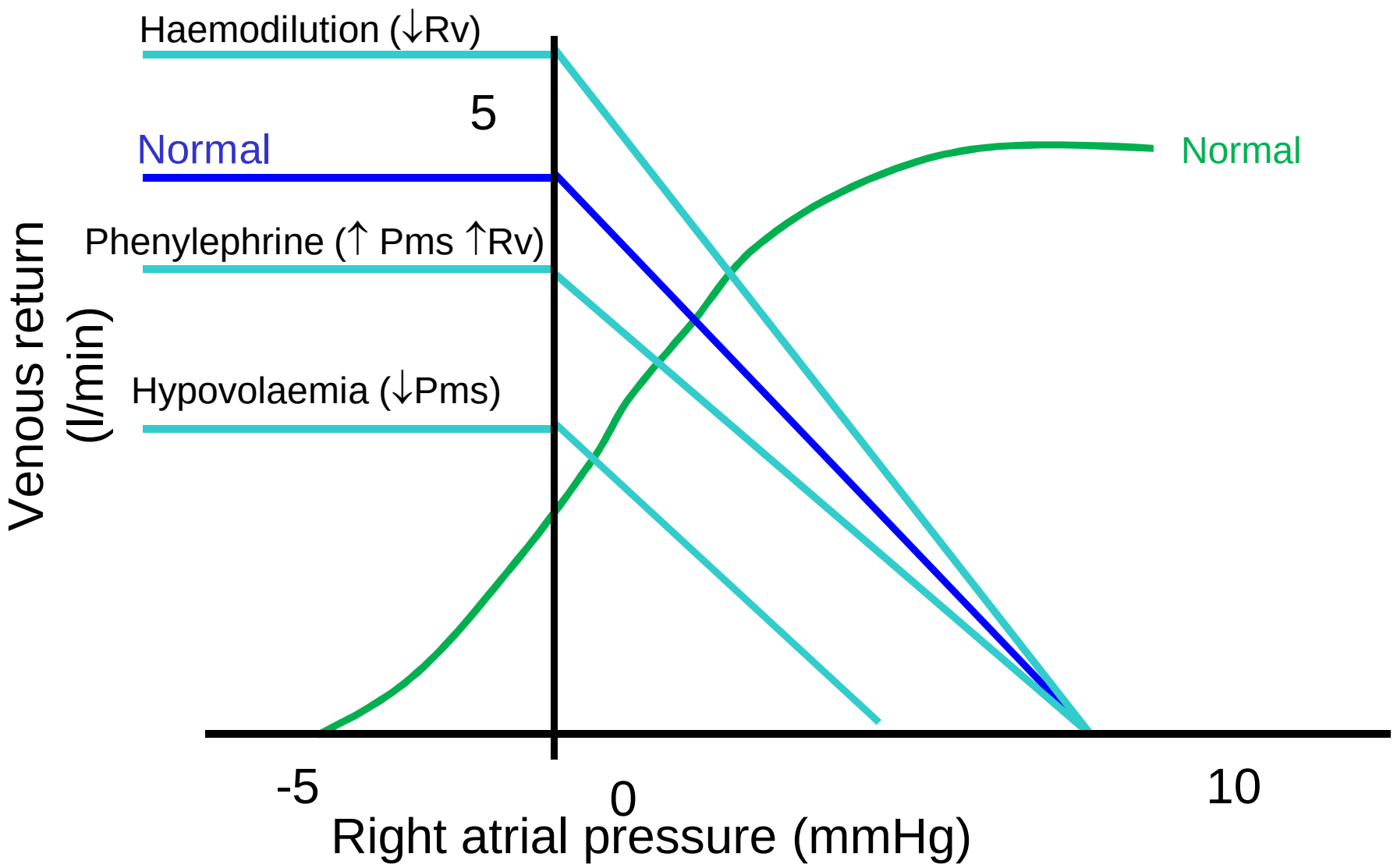


Adapated from: Jacobsohn et al Can J Anesth 1997 44:8 849-67

Choc hypovolémique et néosynéphrine



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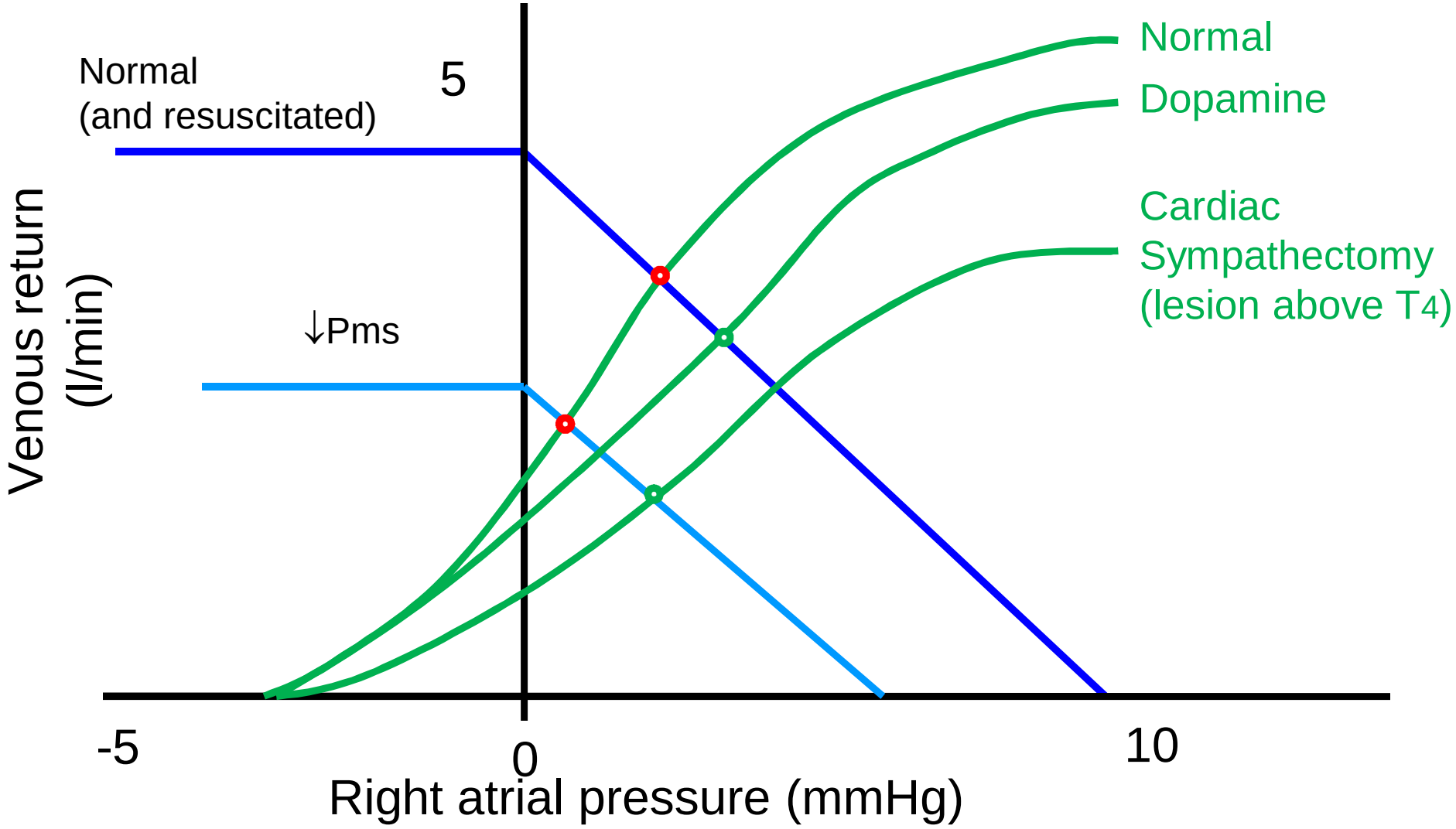
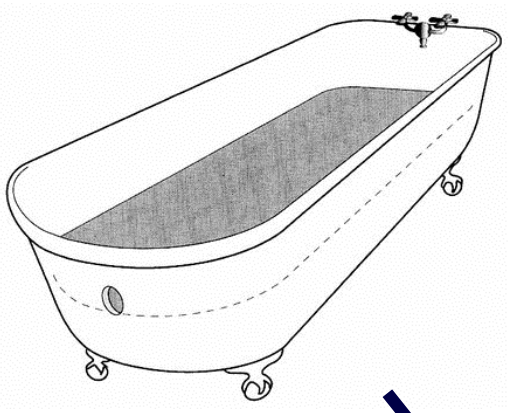
Choc spinal

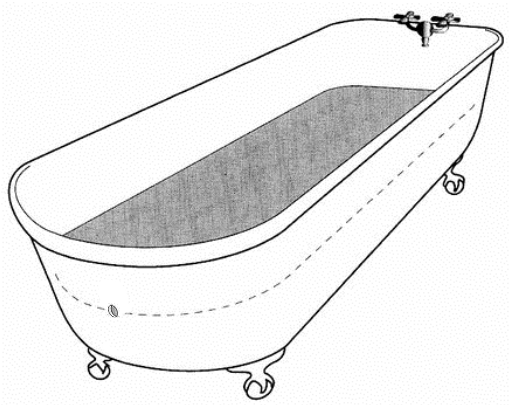


Adapated from: Jacobsohn et al Can J Anesth 1997 44:8 849-67

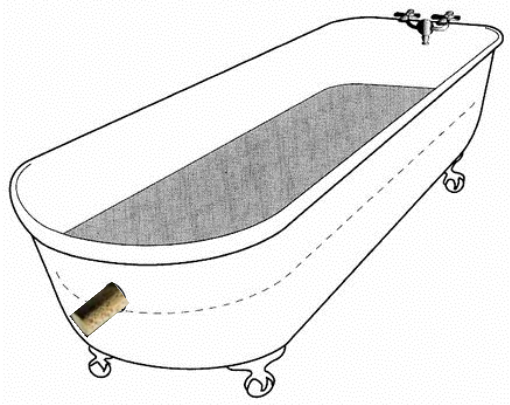
Rrv



Ź size of the opening



Obstruction of the opening



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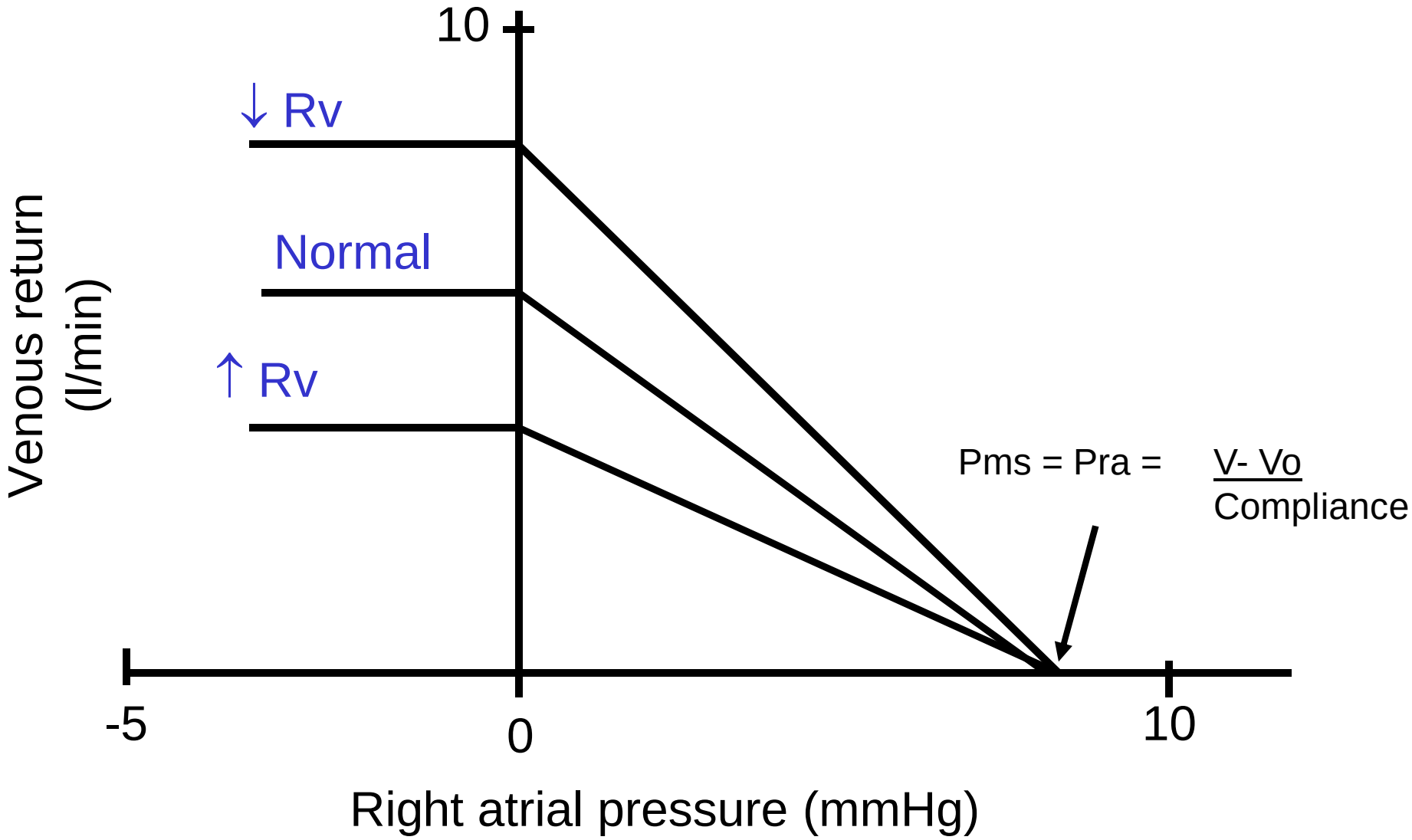
Syndrome du compartiment Abdominal va ↑ Rv



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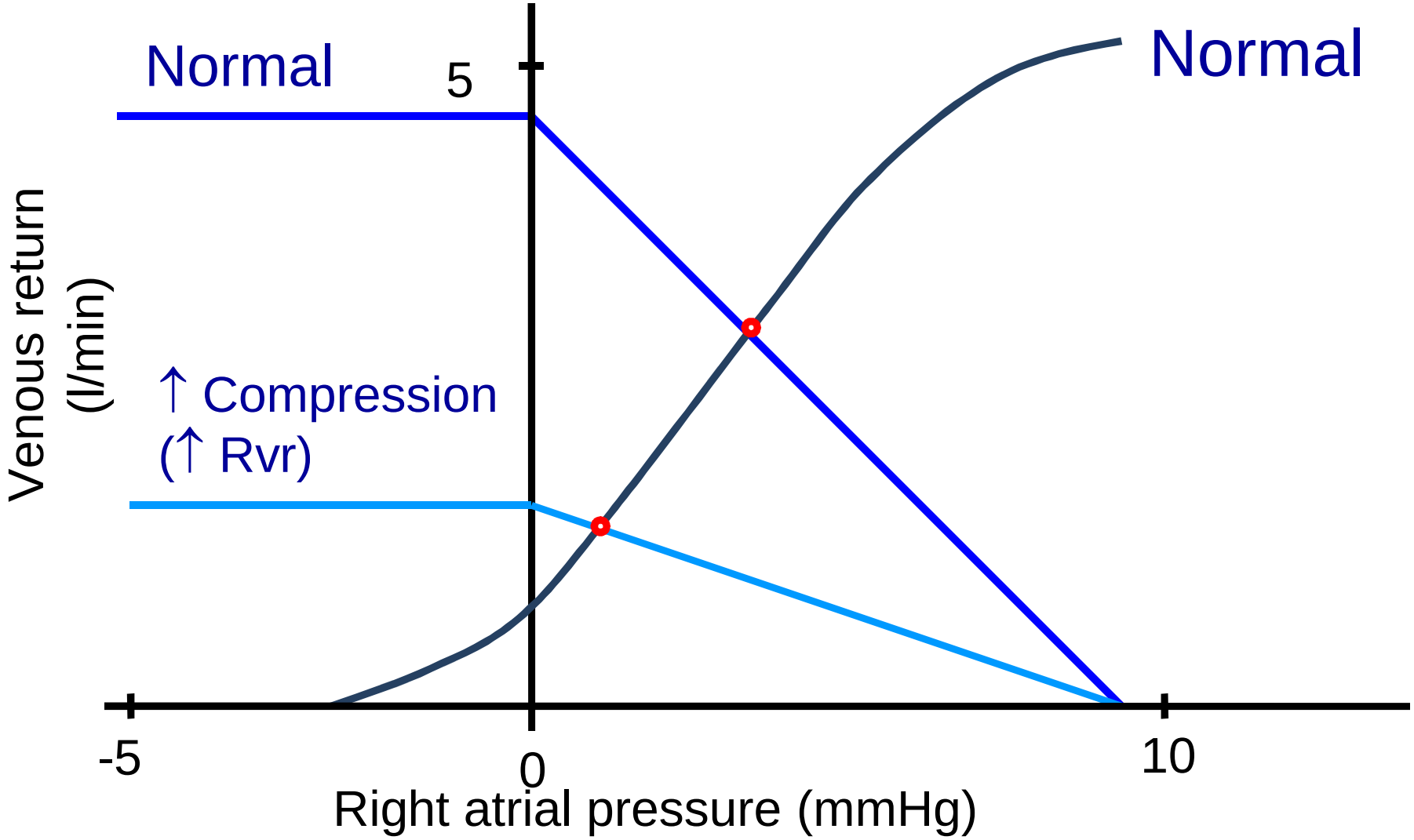
Obstructive shock: IVC compression



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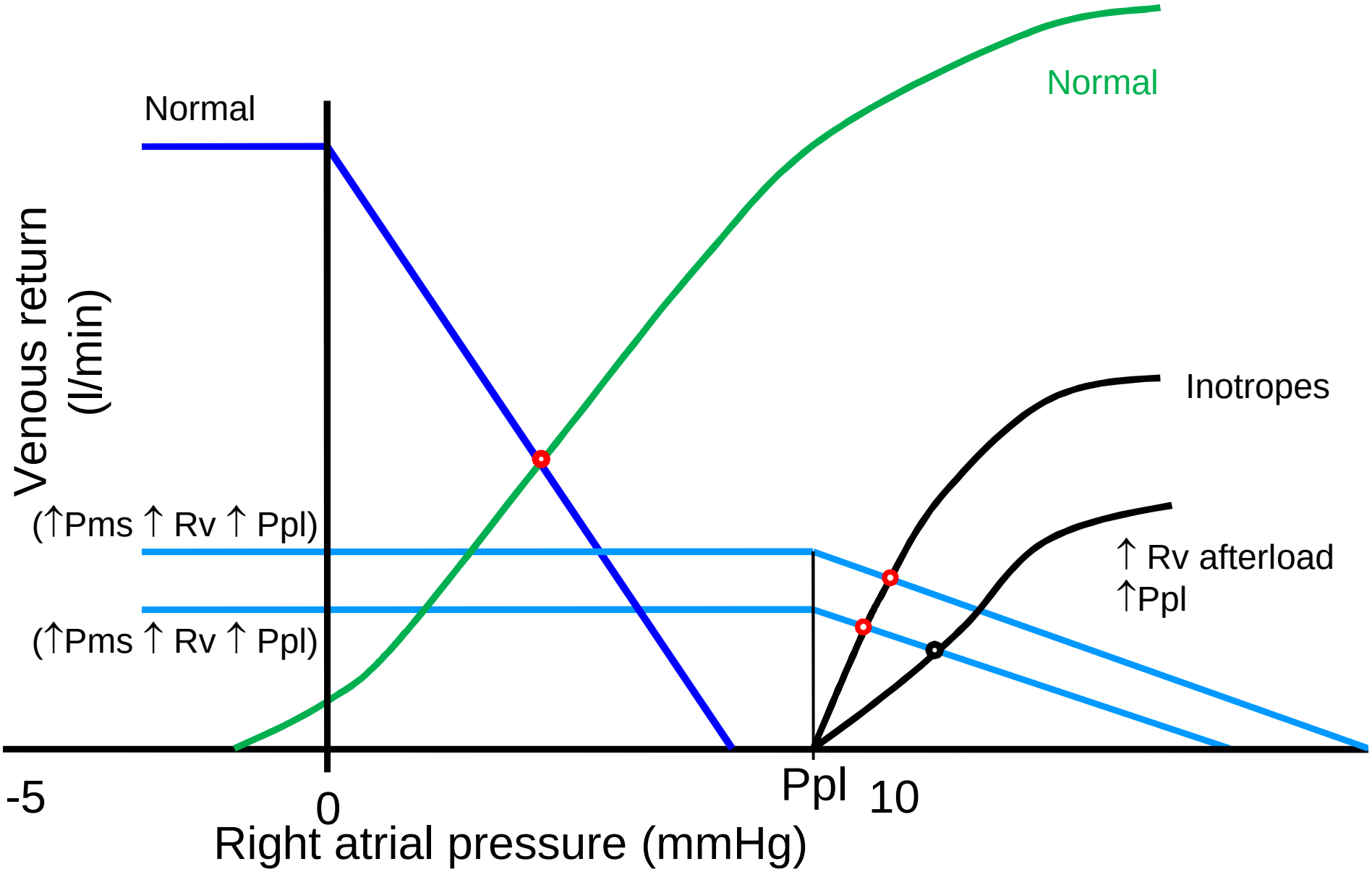
Choc obstructif: pneumothorax



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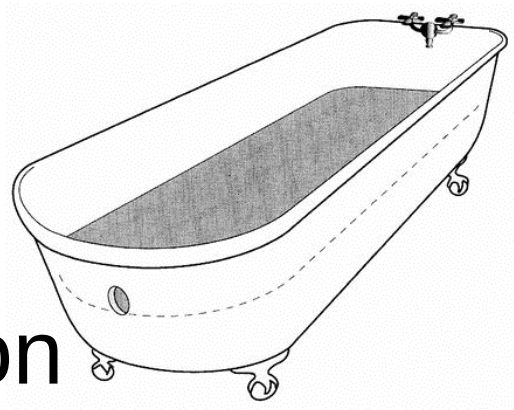
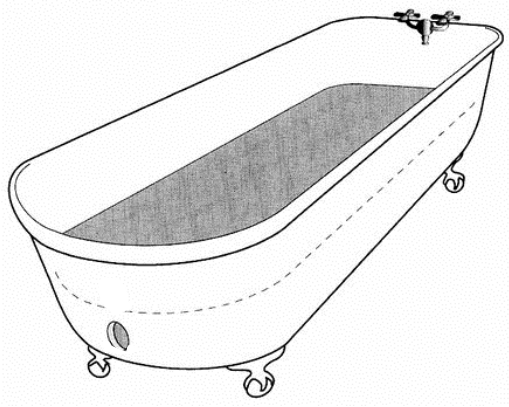
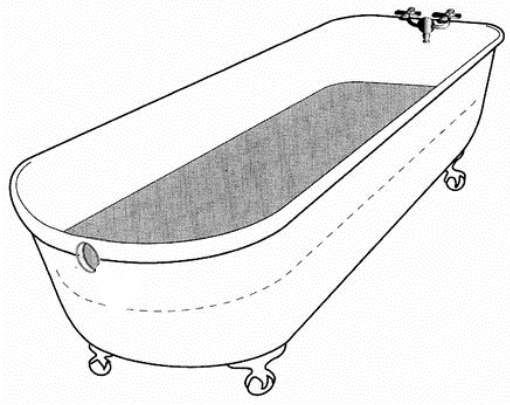
Pra



ŷ Cardiac function

ŕ Cardiac function:
ŷ Right atrial pressure





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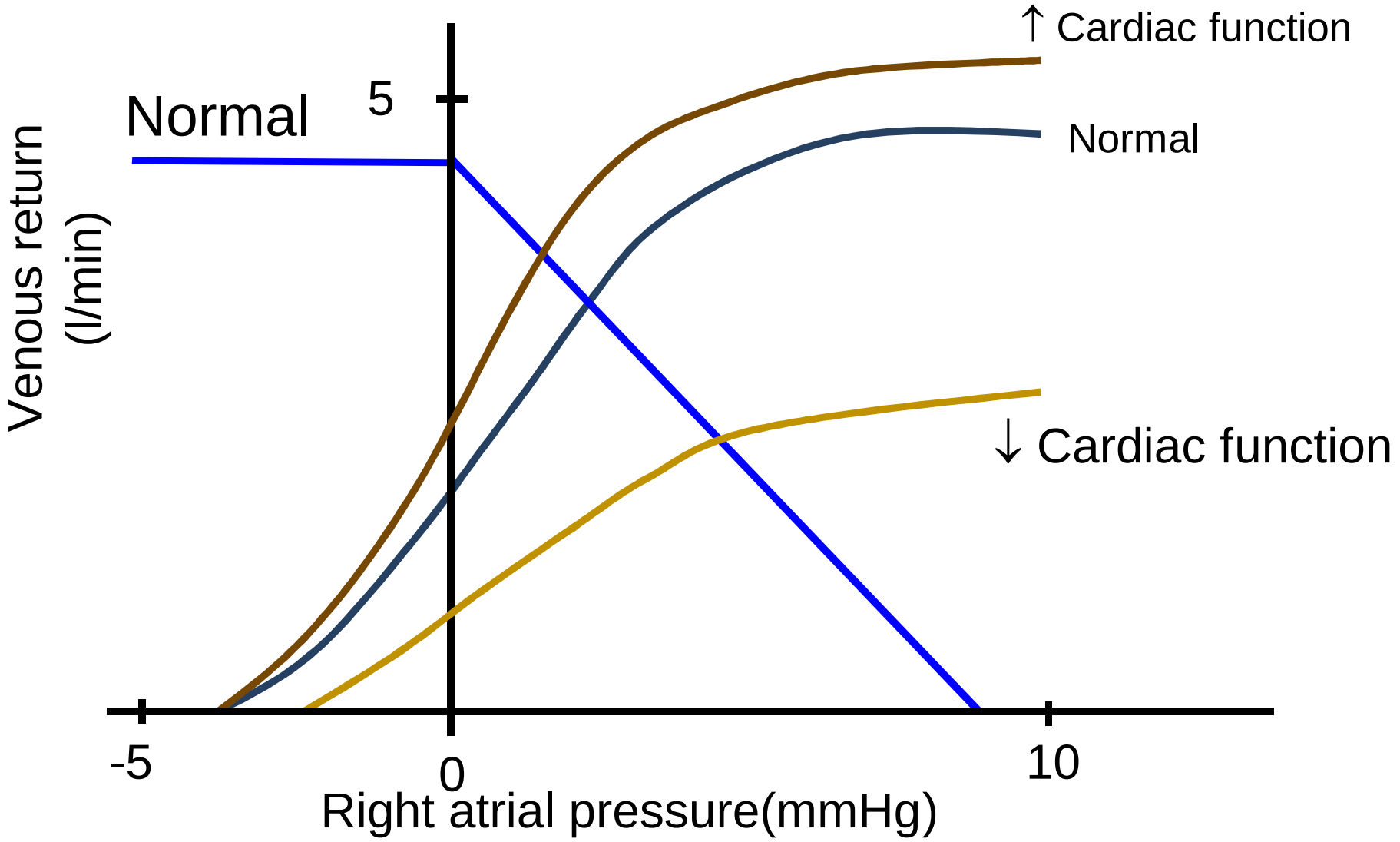
Cardiogenic shock



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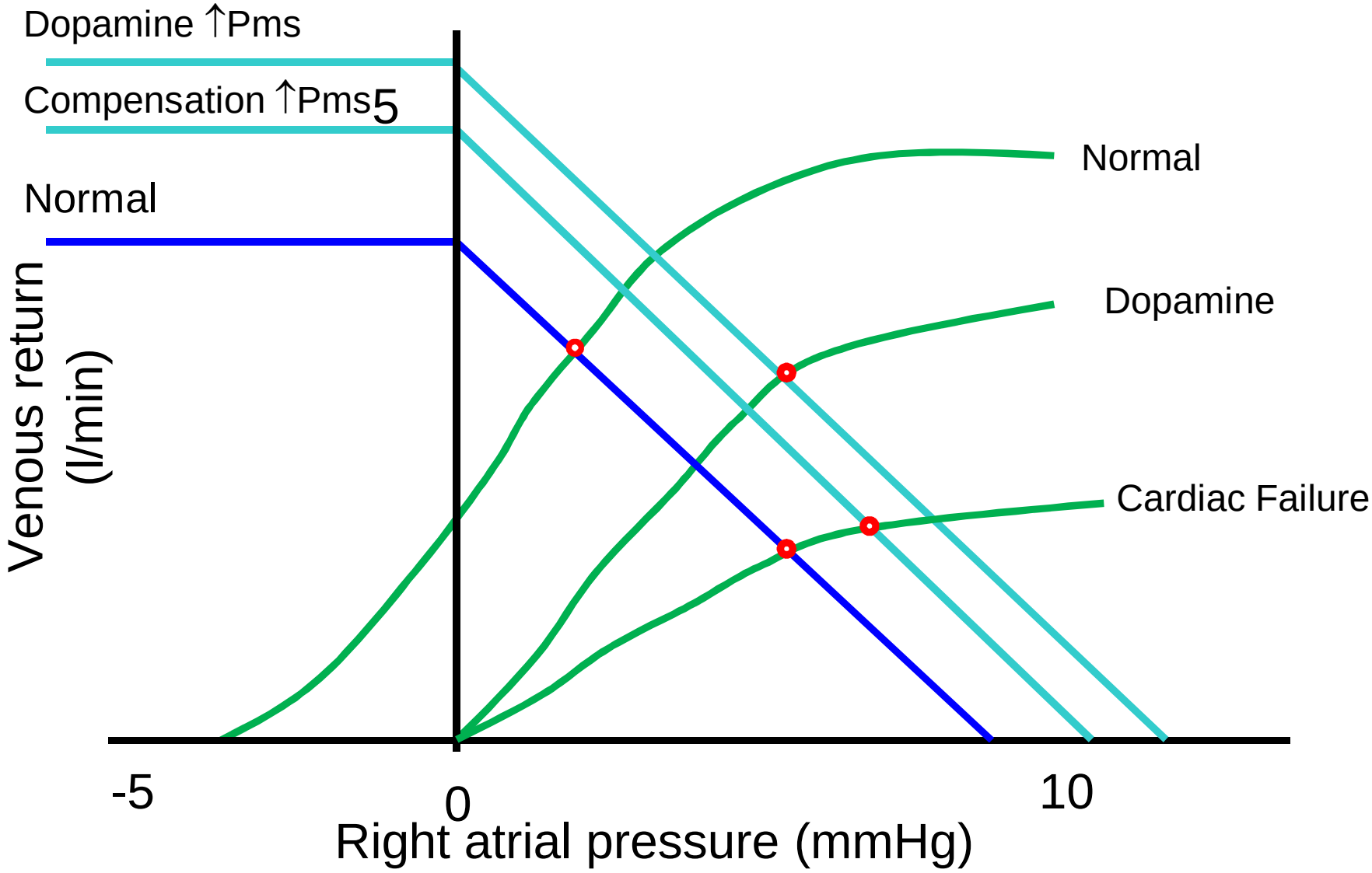
Choc cardiogénique et dopamine



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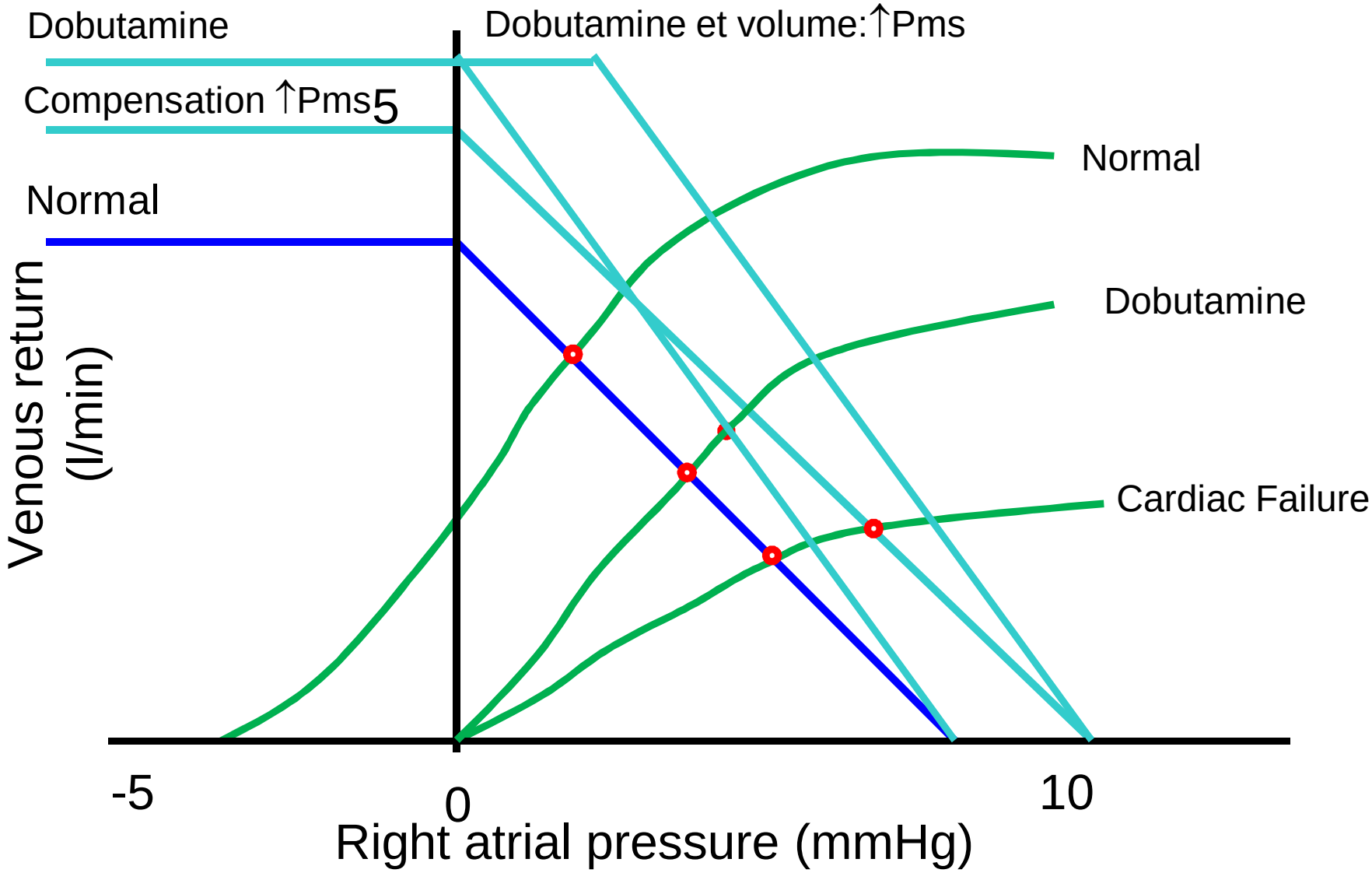
Choc cardiogénique et dobutamin



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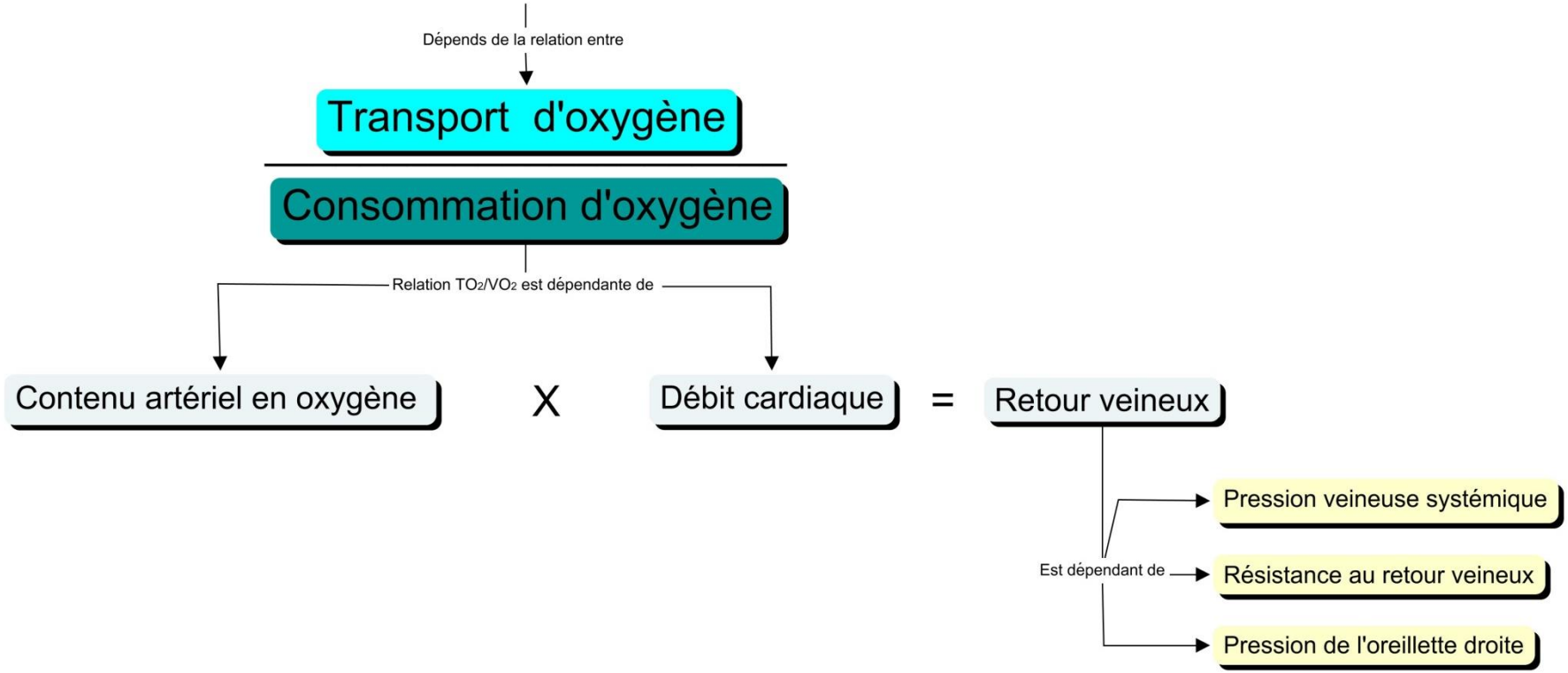
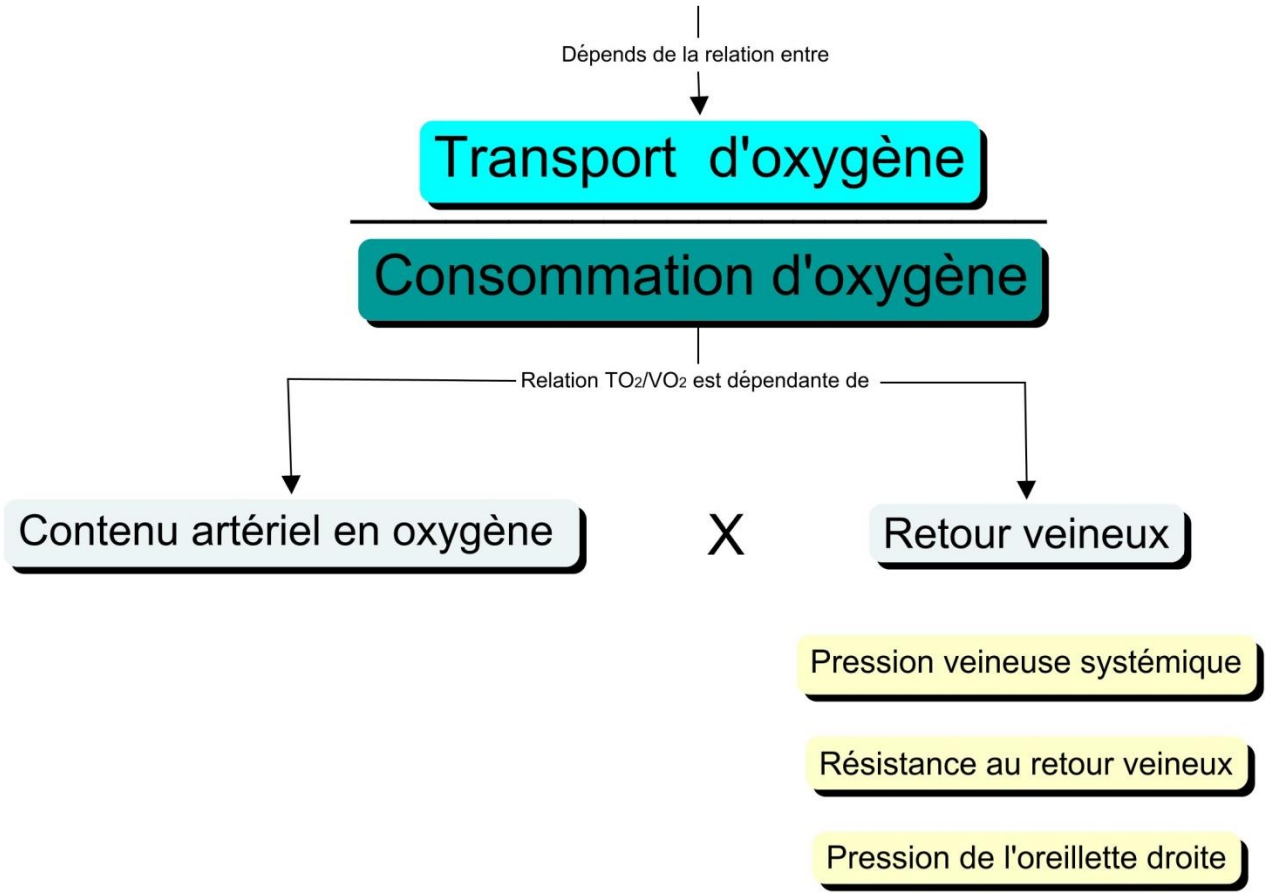
Instabilité hémodynamique et hypoxémie



Instabilité hémodynamique et hypoxémie



Instabilité hémodynamique et hypoxémie

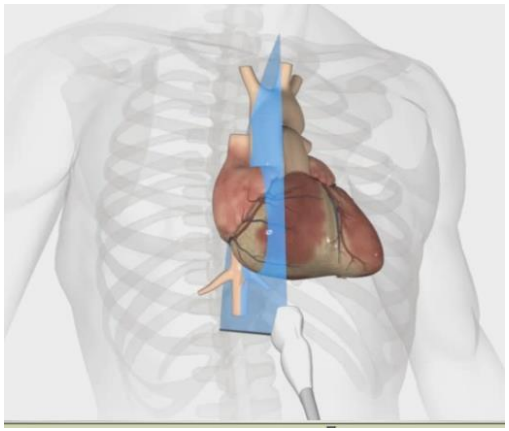
Dépends de la relation entre

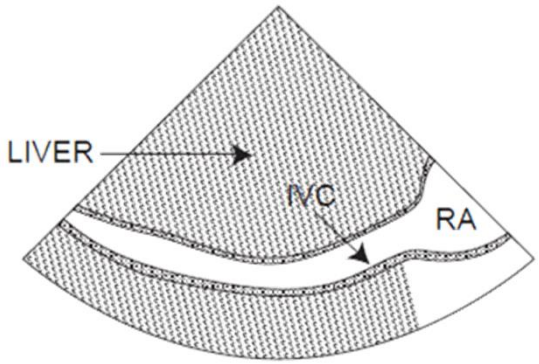
Transport d'oxygène

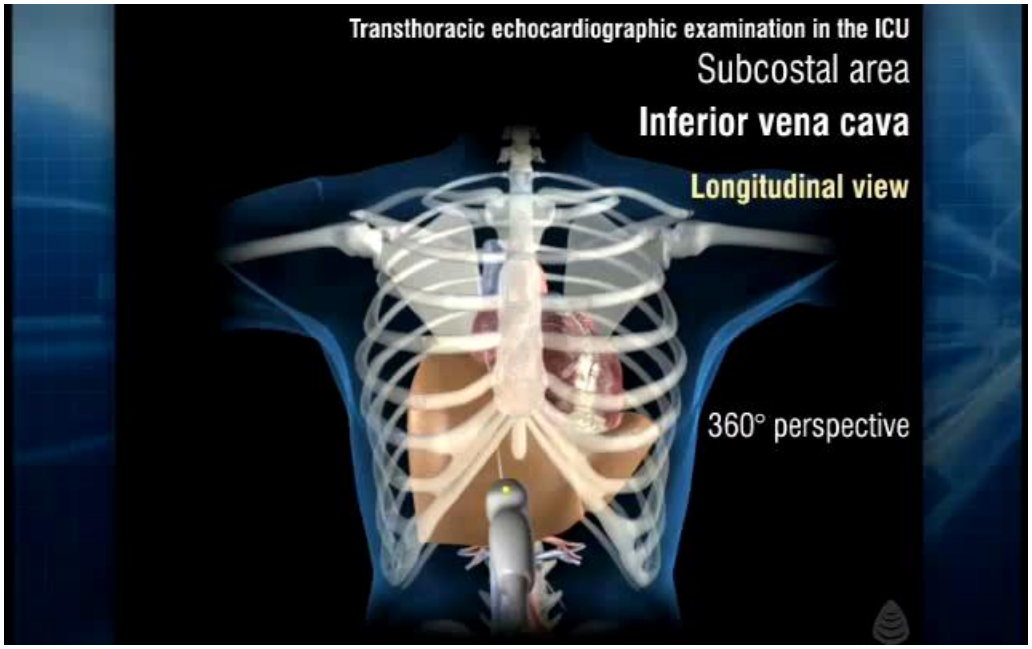
Consommation d'oxygène

Relation TO_2/VO_2 est dépendante de

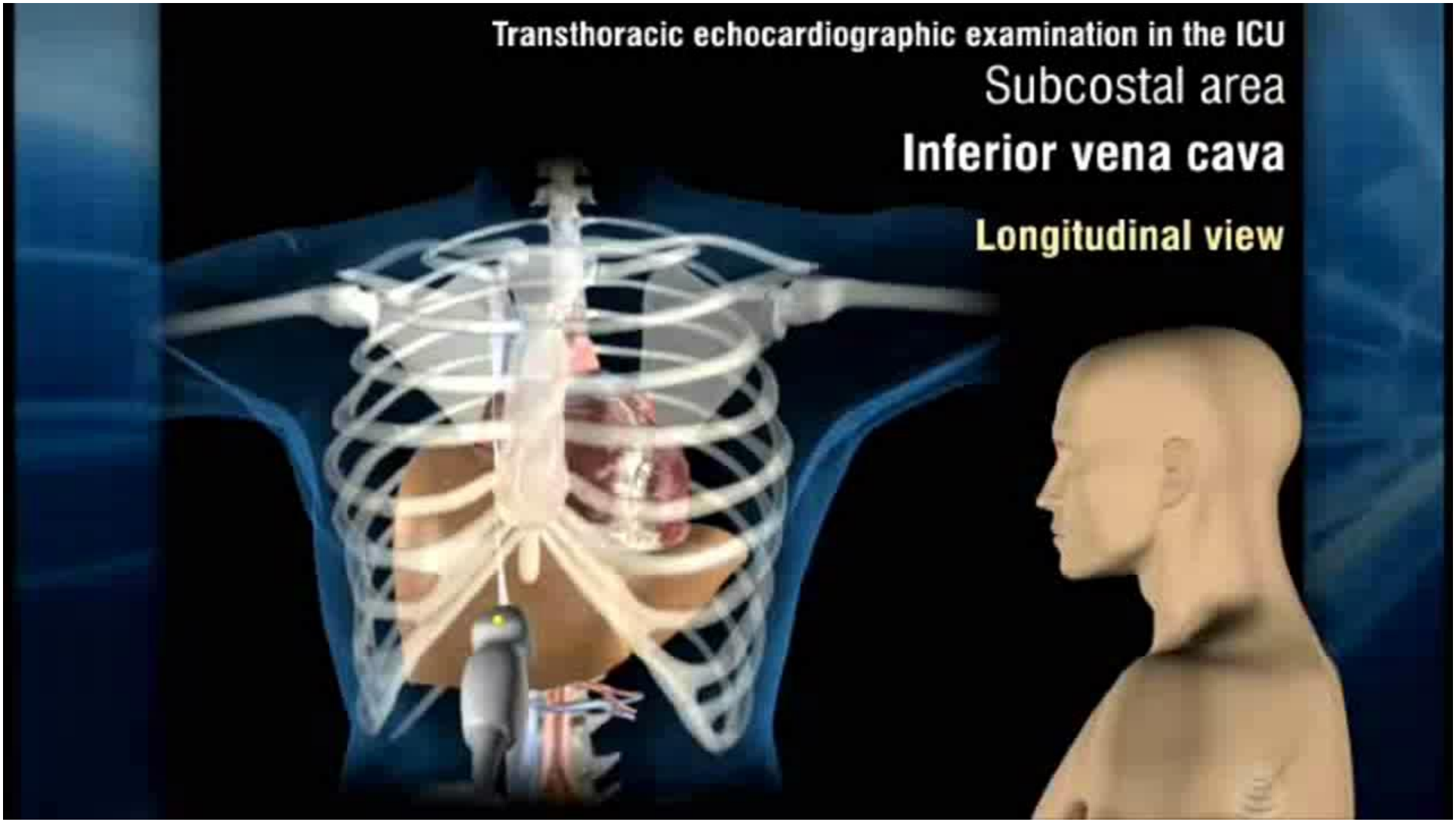
Contenu artériel en oxygène X **Retour veineux**





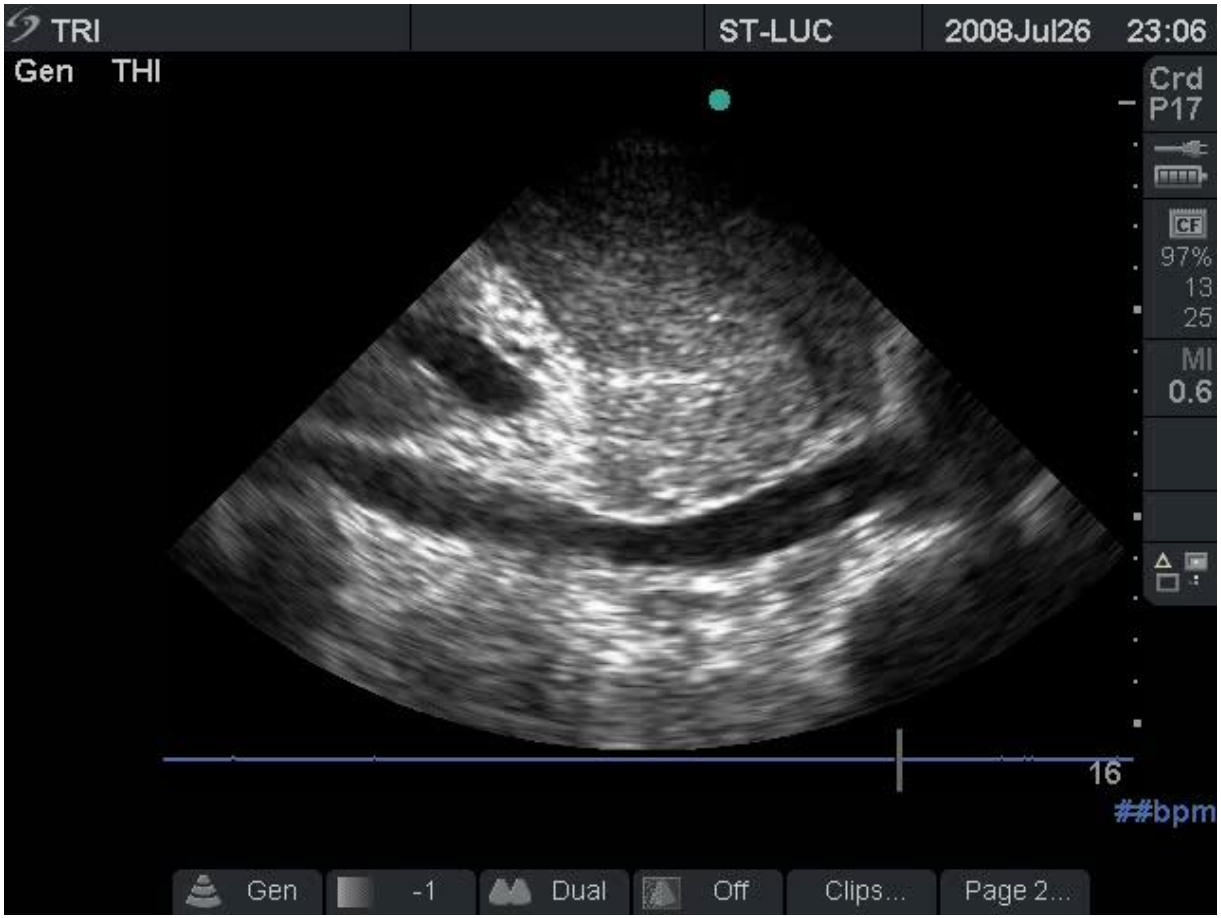

Transthoracic echocardiographic examination in the ICU
Subcostal area
Inferior vena cava
Longitudinal view
360° perspective

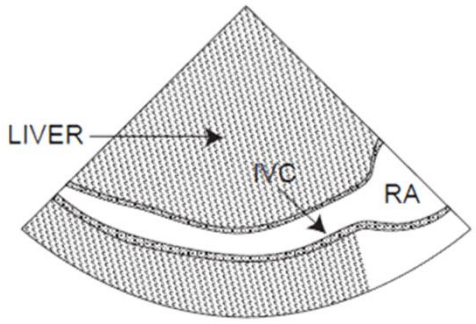
Vue sous-xyphoïdienne 90°

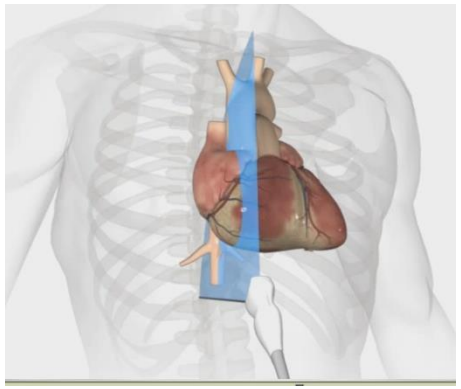


Courtoisie de CAE Healthcare

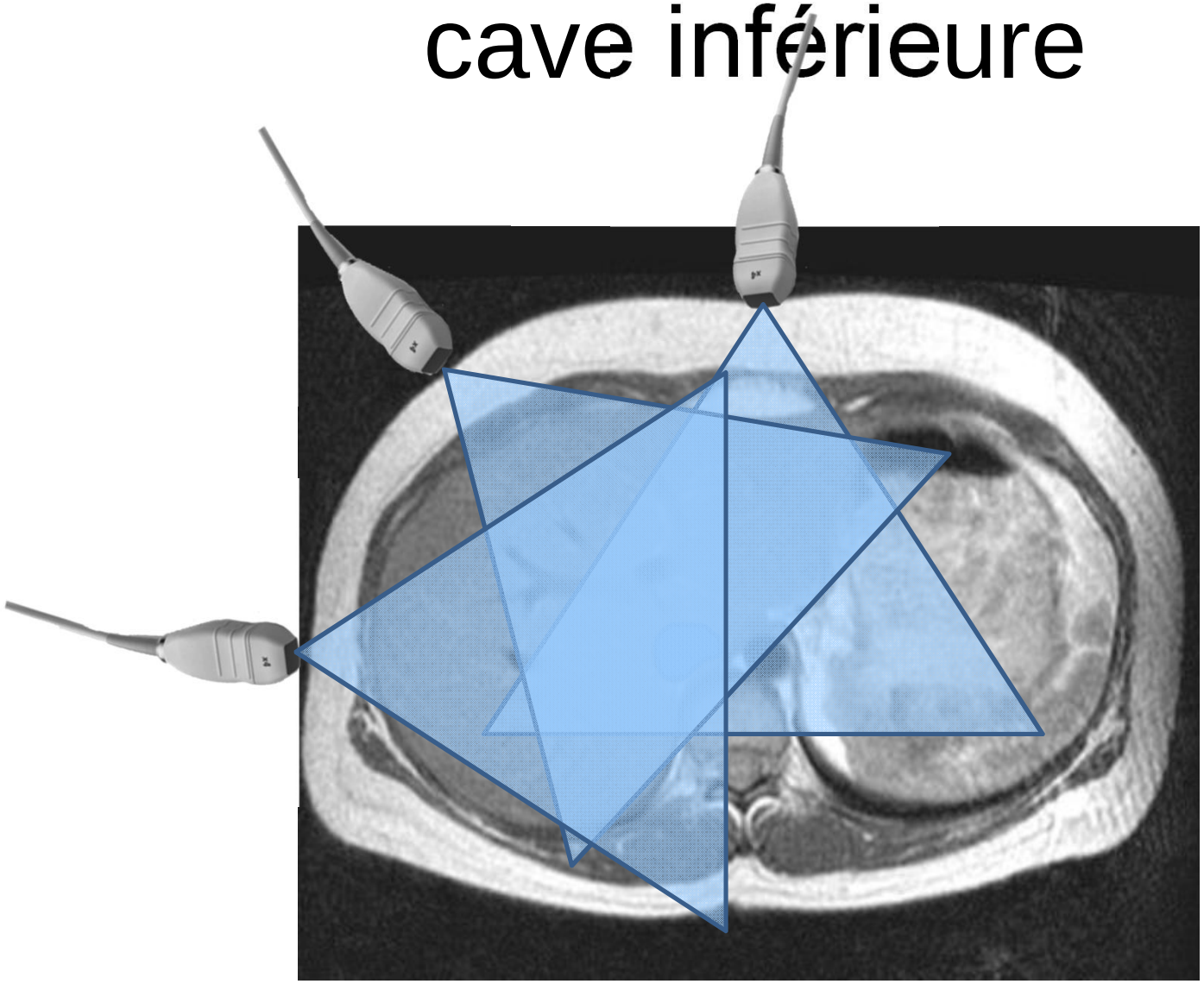
Réponse au volume +





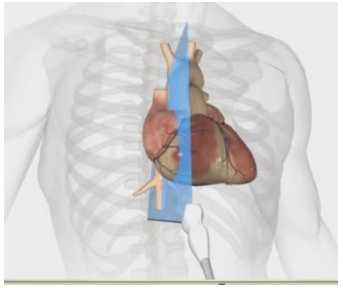


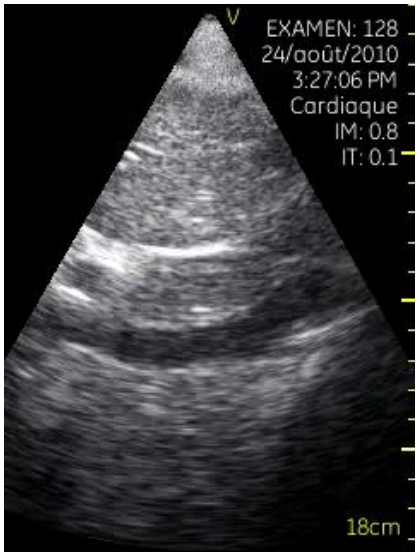
Vues alternatives de la veine cave inférieure



État de choc

Hypotension
Oligurie
Extrémités froides
Altération neurologue
Acidose





État de choc

Hypotension
Oligurie
Extrémités froides
Altération neurologue
Acidose

Choc hypovolémique

Pertes sanguines

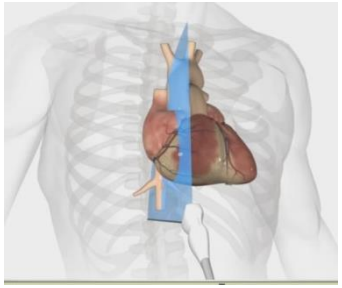
Pertes non-sanguines

↓Pvs

Choc distributif

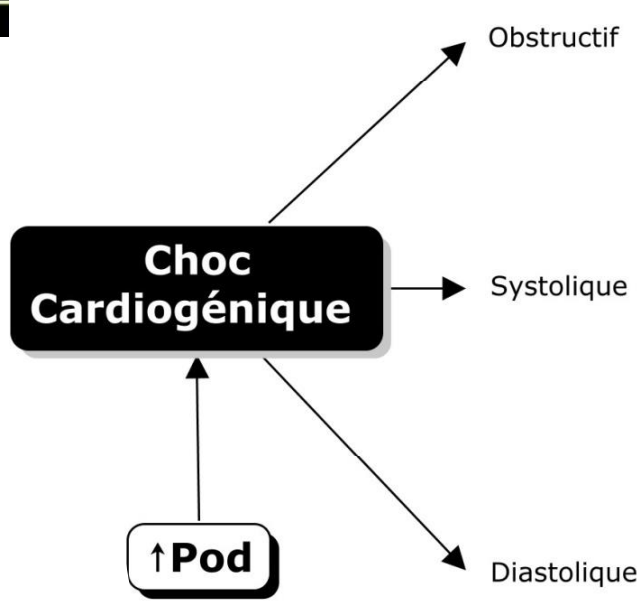
Septique

Non-septique

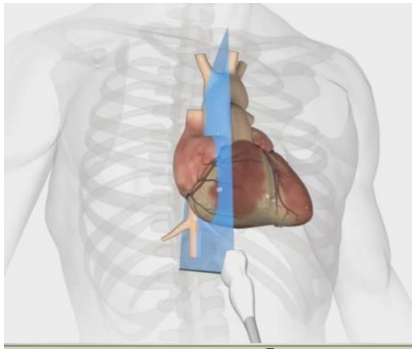


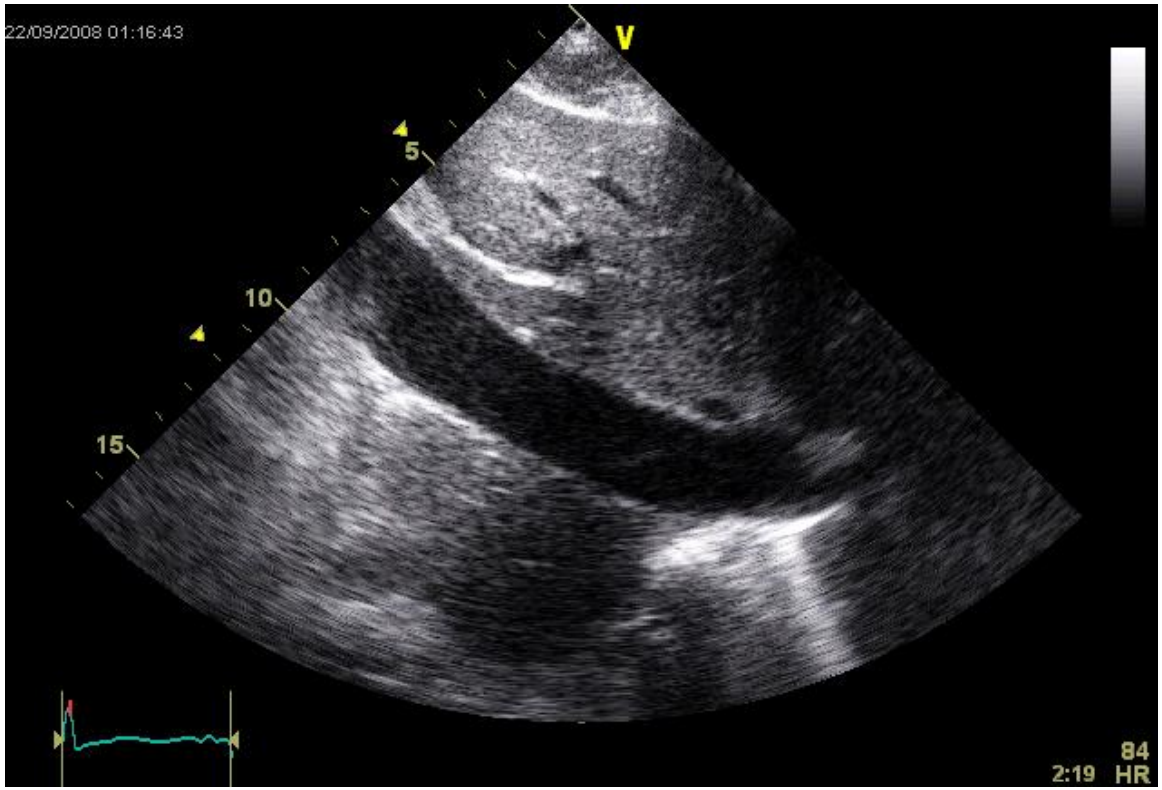
État de choc

Hypotension
Oligurie
Extrémités froides
Altération neurologue
Acidose



‖ 19 ans donneur d'organe: volume ou vasopresseur?



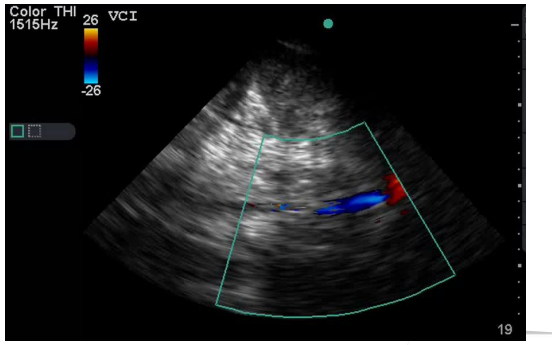


Limitations

Intrinsèque

Extrinsèque

↑Rrv → **Choc obstructif**

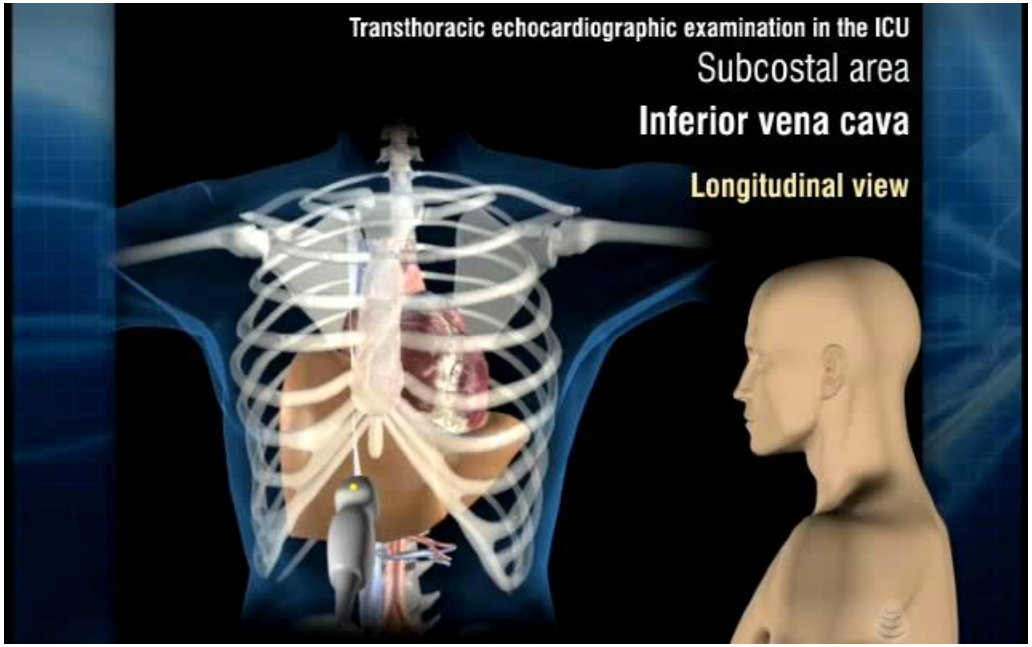


État de choc

Hypotension
Oligurie
Extrémités froides
Altération neurologue
Acidose

Infra-diaphragmatique

Supra-diaphragmatique


Transthoracic echocardiographic examination in the ICU
Subcostal area
Inferior vena cava
Longitudinal view

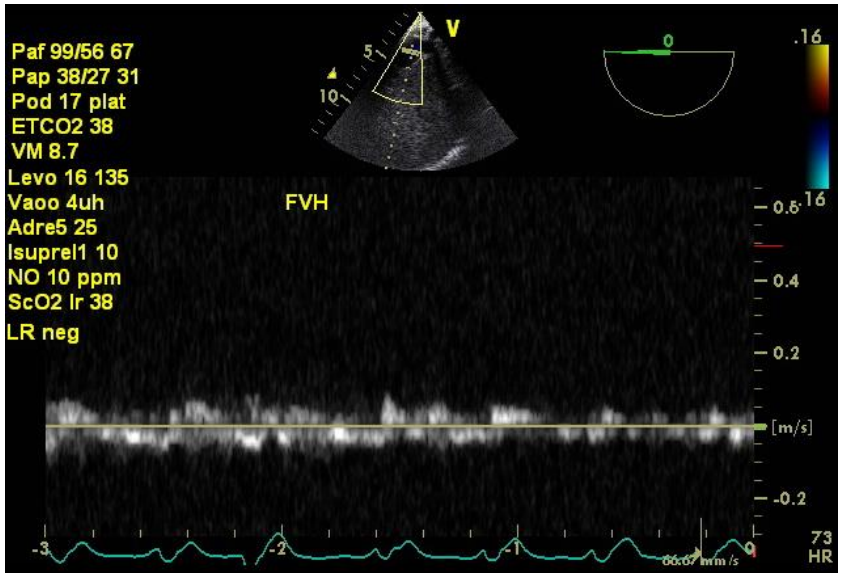
Comment diagnostiquer un problème de résistance au retour veineux?

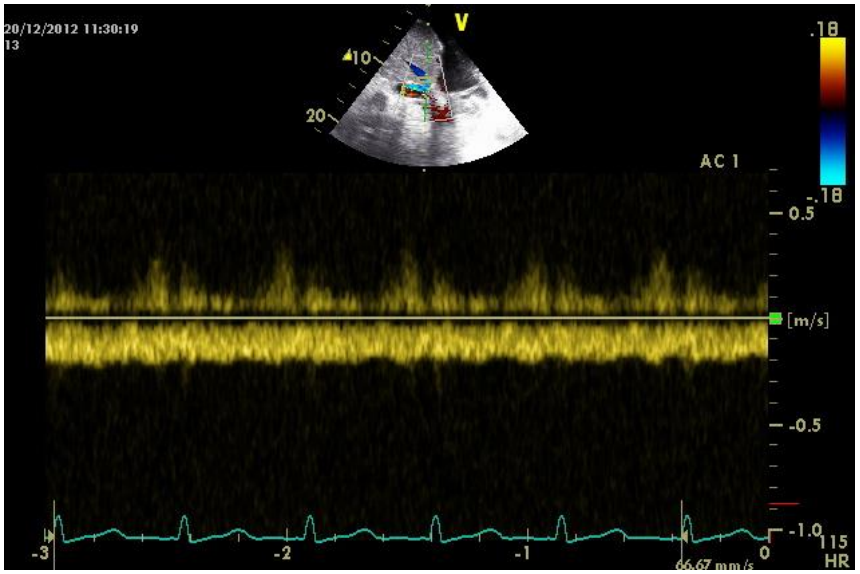
..\2013 Septembre 08 HVF Case study\HVF_Montpellier 2013.pptx

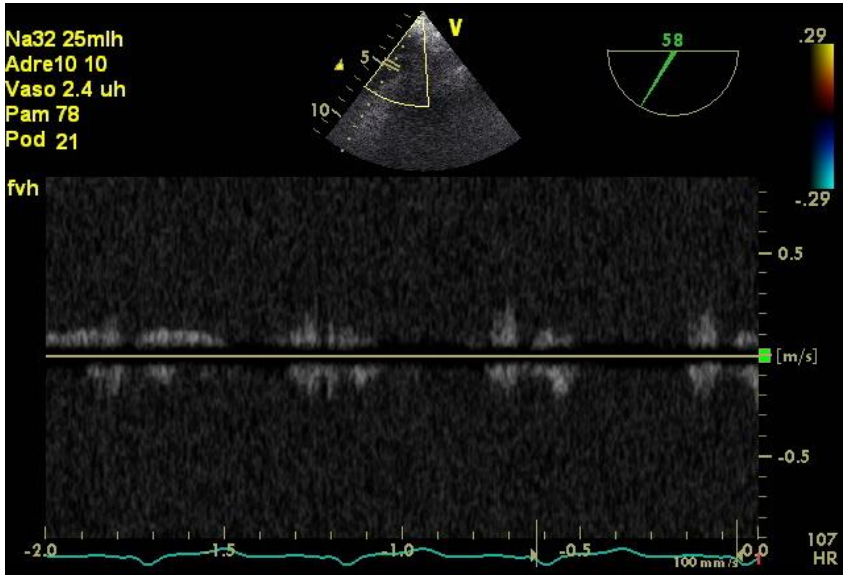
The hepatic venous blood flow in hemodynamically unstable patients

Hulin Jonathan, MD
Fellow in cardiac anesthesia
André Denault MD PhD
Professor anesthesia and critical care
Montréal Heart Institute

No disclosures

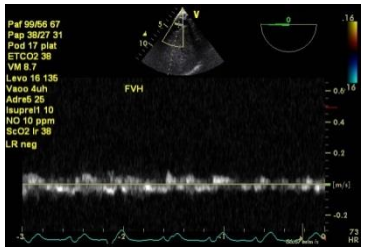

Paf 99/56 67
Pap 38/27 31
Pod 17 plat
ETCO2 38
VM 8.7
Levo 16 135
Vaoo 4uh
Adre5 25
Isuprel1 10
NO 10 ppm
ScO2 lr 38
LR neg
FVH
[m/s]
73
HR

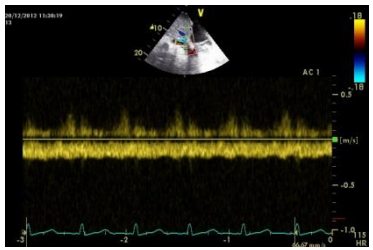

20/12/2012 11:30:19
AC 1
[m/s]
115
HR

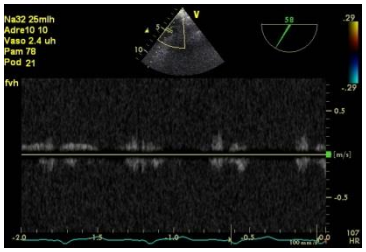

Na32 25mlh
Adre10 10
Vaso 2.4 uh
Pam 78
Pod 21
fvh
[m/s]
107
HR

What is the etiology of these hepatic venous flow?

- 1-Abdominal compartment syndrome
- 2-External compression of the inferior vena cava
- 3-Mediastinal tamponade
- 4-Inferior vena cava stenosis
- 5-All of these





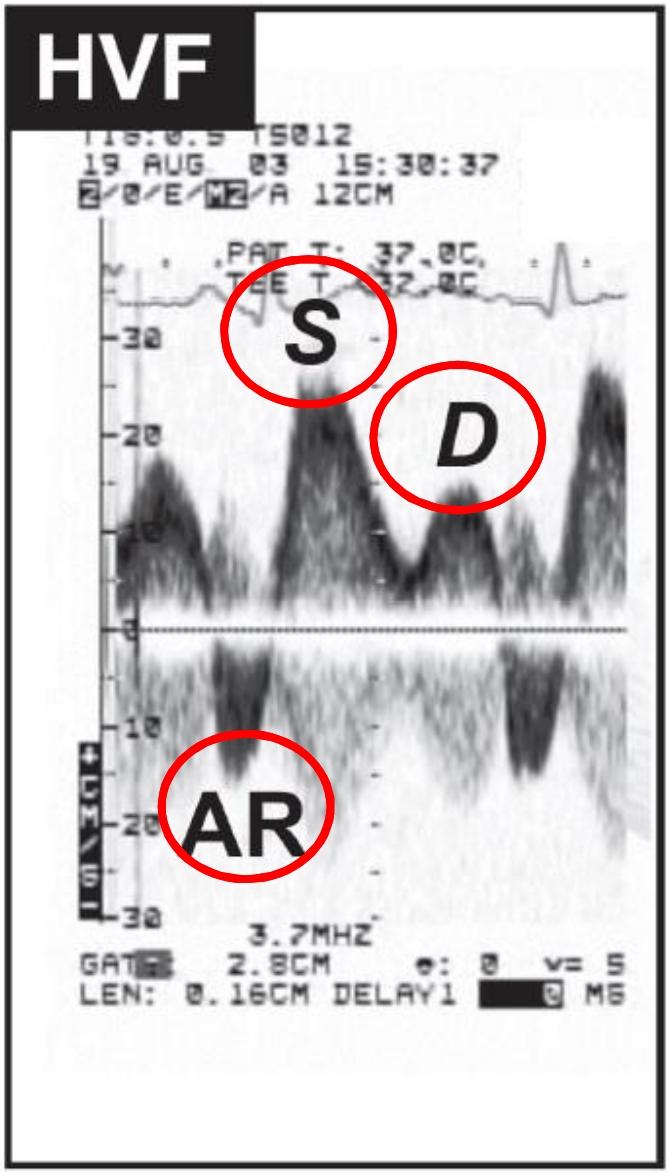


Understanding the Spectral Doppler Waveform of the Hepatic Veins in Health and Disease[1]

Meir H. Scheinfeld, MD, PhD • Ardiana Bilali, ARDMS • Mordecai Koenigsberg, MD

RadioGraphics 2009; 29:2081–2098

HVF


19 AUG 03 15:30:37
S
D
AR
30
20
10
0
10
20
30
3.7MHZ
2.8CM
LEN: 0.16CM DELAY1

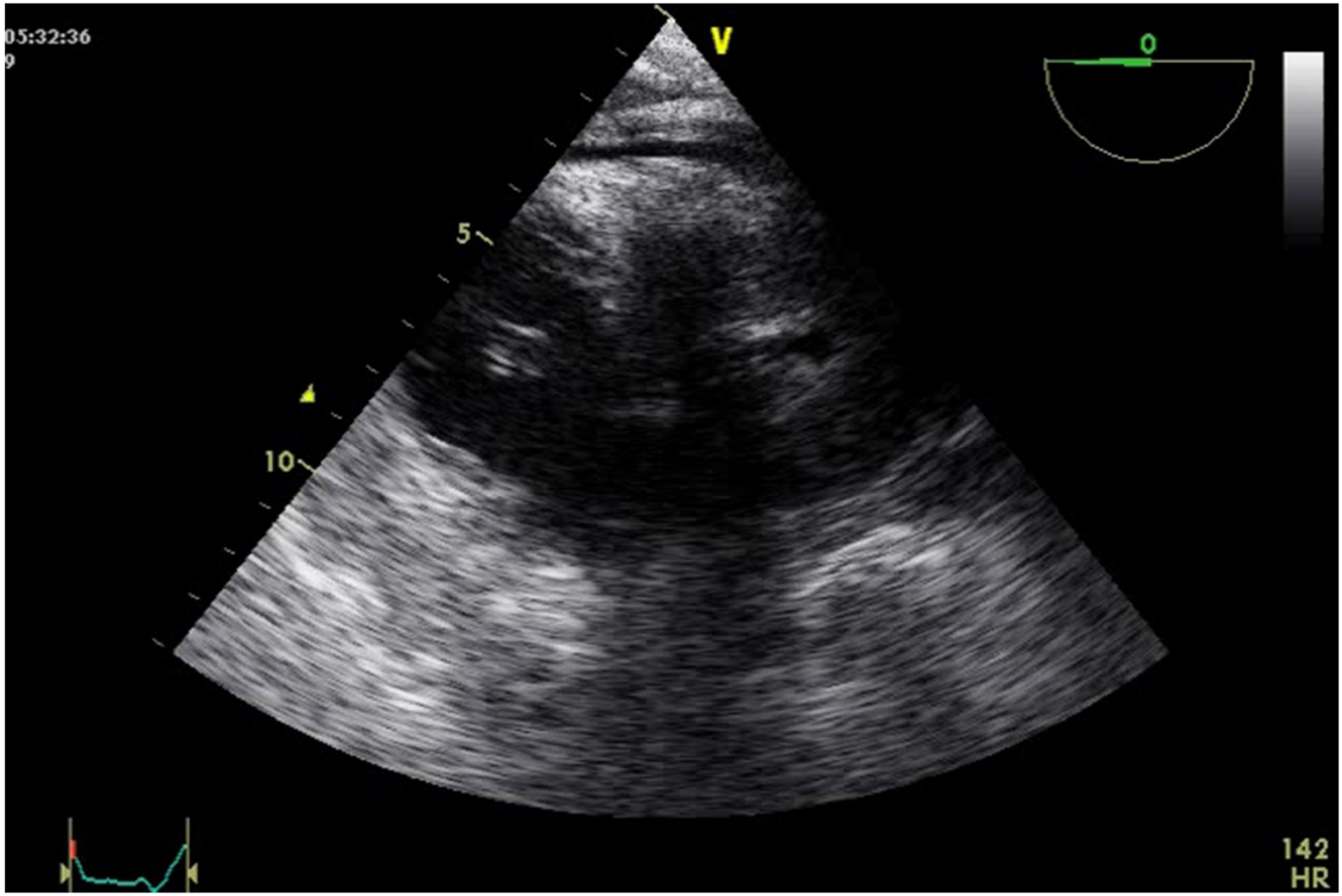
Hepatic venous blood flow

- Easy to obtain with intercostal, transabdominal or TEE
- Normal aspect: triphasic with four components (A,S,V,D)
- A: atrial contraction, blood from heart towards IVC
- S: right ventricule systole, blood towards the right atrium
- V: atrial overfilling, all directions possible
- D: tricuspid closure, blood towards the right heart
- An anormal aspect can be the reflect of abdominal, liver or cardiac pathologies

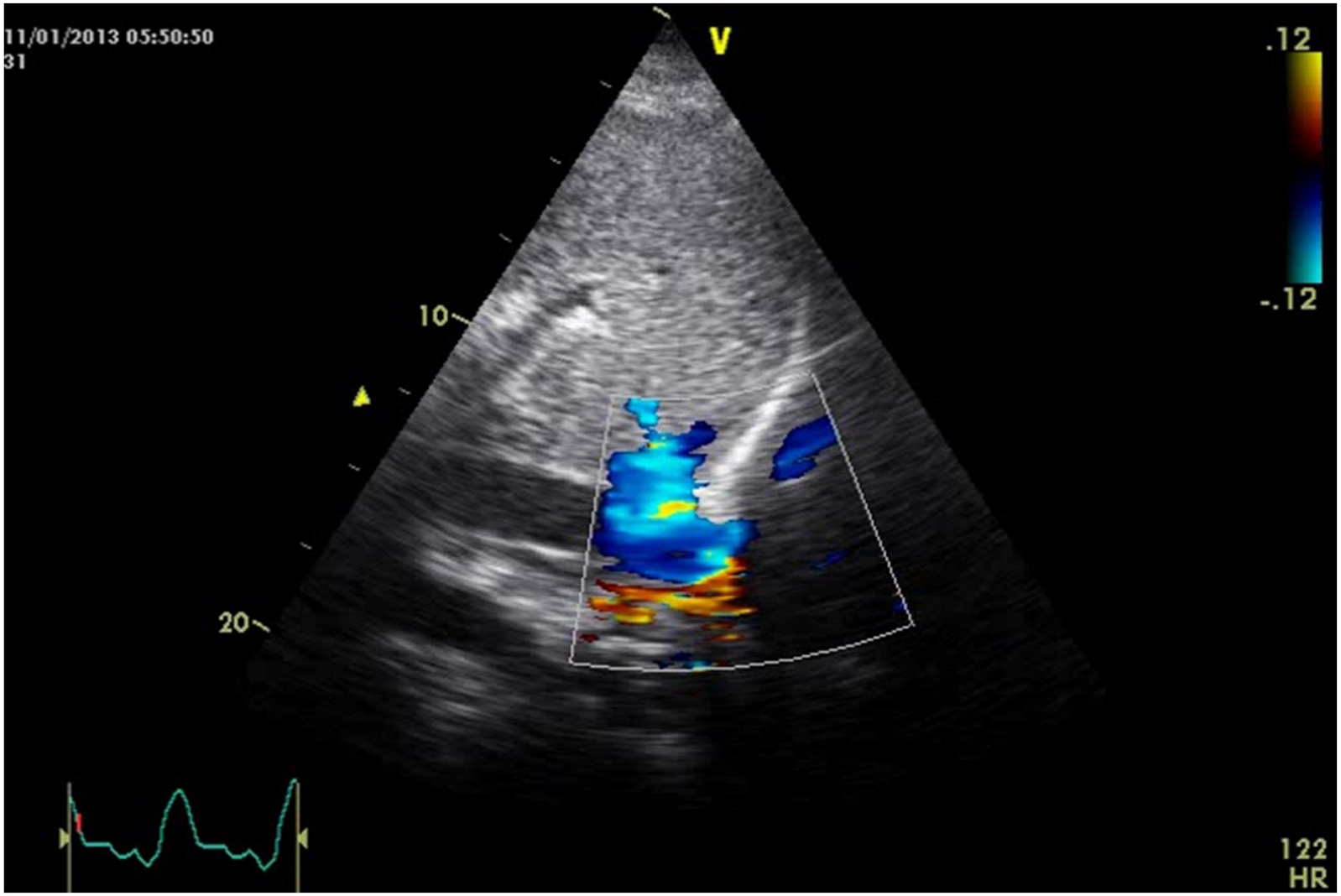
Case #1 Cardiac transplantation

- Mr S., 69 years old.
- Heart transplant (Dilated cardiomyopathy)
- Bleeding difficult to control in the OR
- Packed with dressings in the OR and transfer to ICU
- Chest remained open
- After 6 hours ICU admittance, hemodynamic instability despite huge inotropic, vasoconstricive and right heart support (NA, Adre, NO, Vasopressin, isoprenaline)
- 23% reduction in NIRS (61 to 38)
- TTE and TEE

Mid-papillary transgastric view

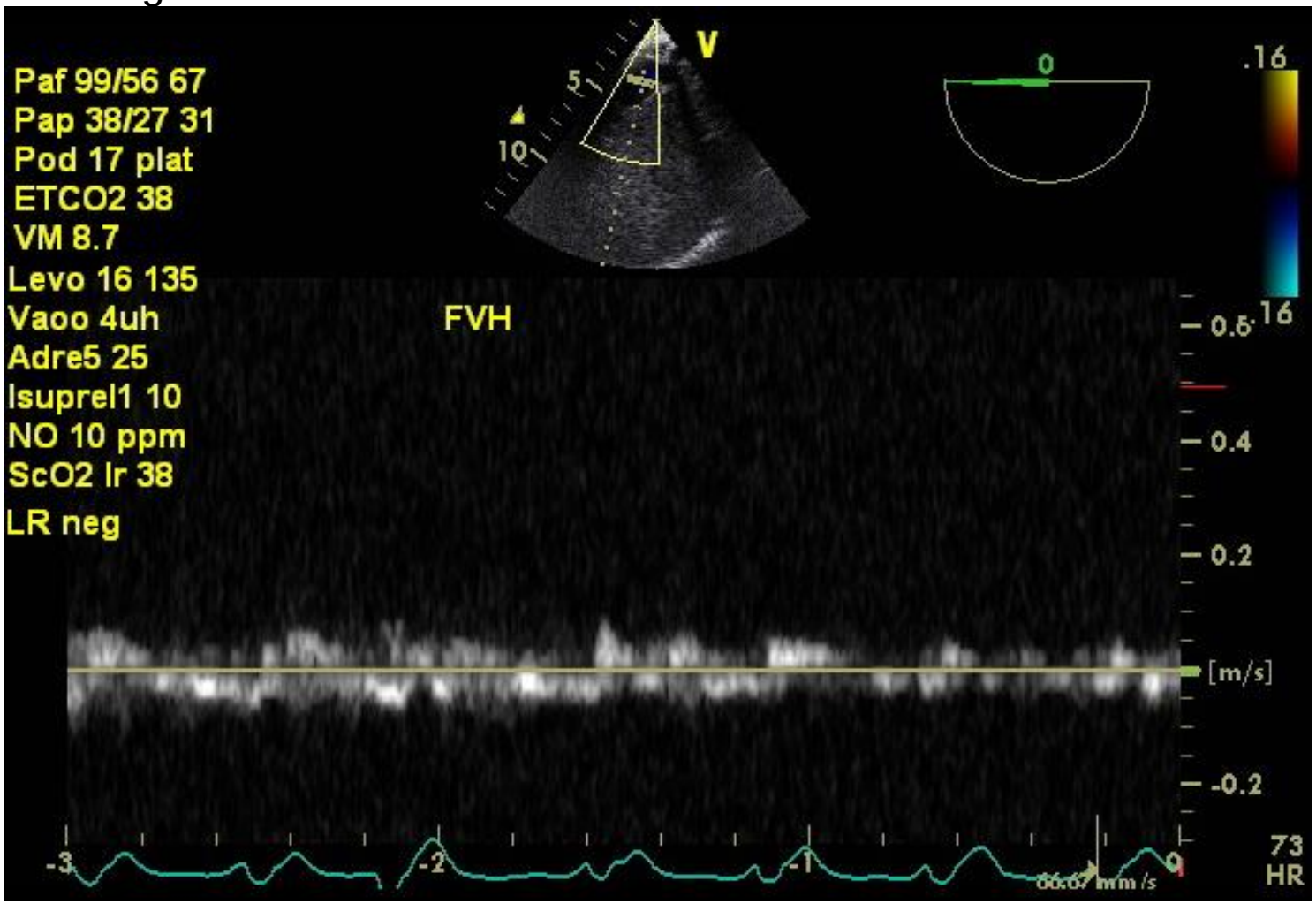


Subcostal view 90^0



Hepatic venous blood flow

PVF High but HVF



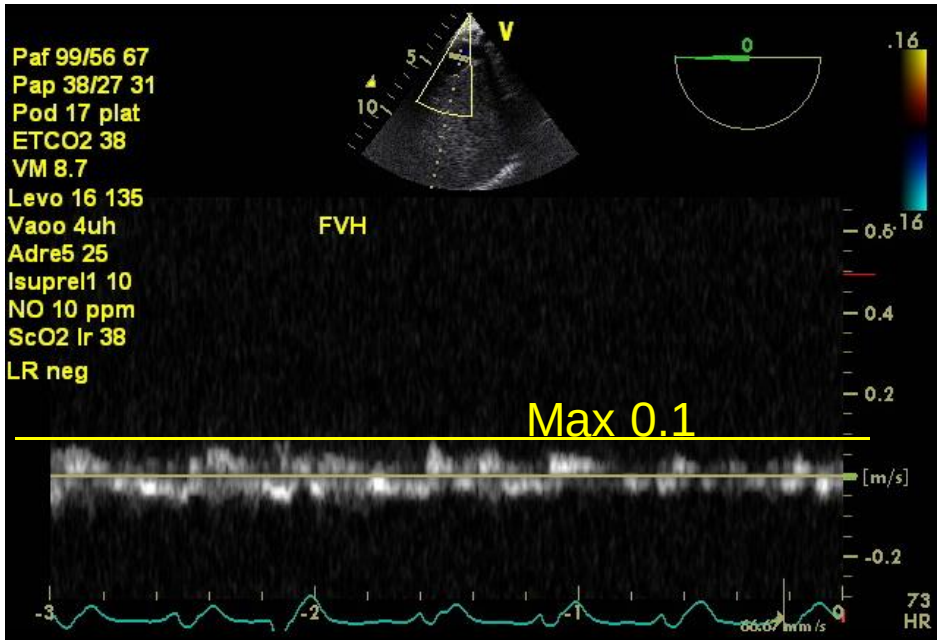
Case #1

- After that findings, chest reopened and a dressing was found to compress the junction between right atrium and IVC
- After removal, stabilisation of hemodynamics and rapid decrease in inotropic needs
- NIRS up to 47 but then went in RV failure and required ECMO: survived discharge

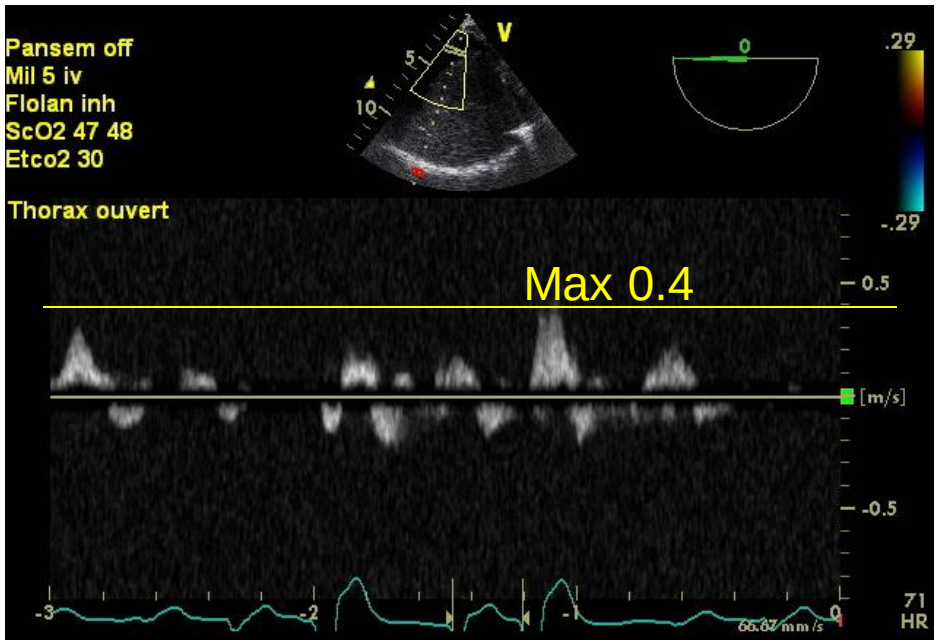
Case #1

Hepatic venous blood flow

Before



After

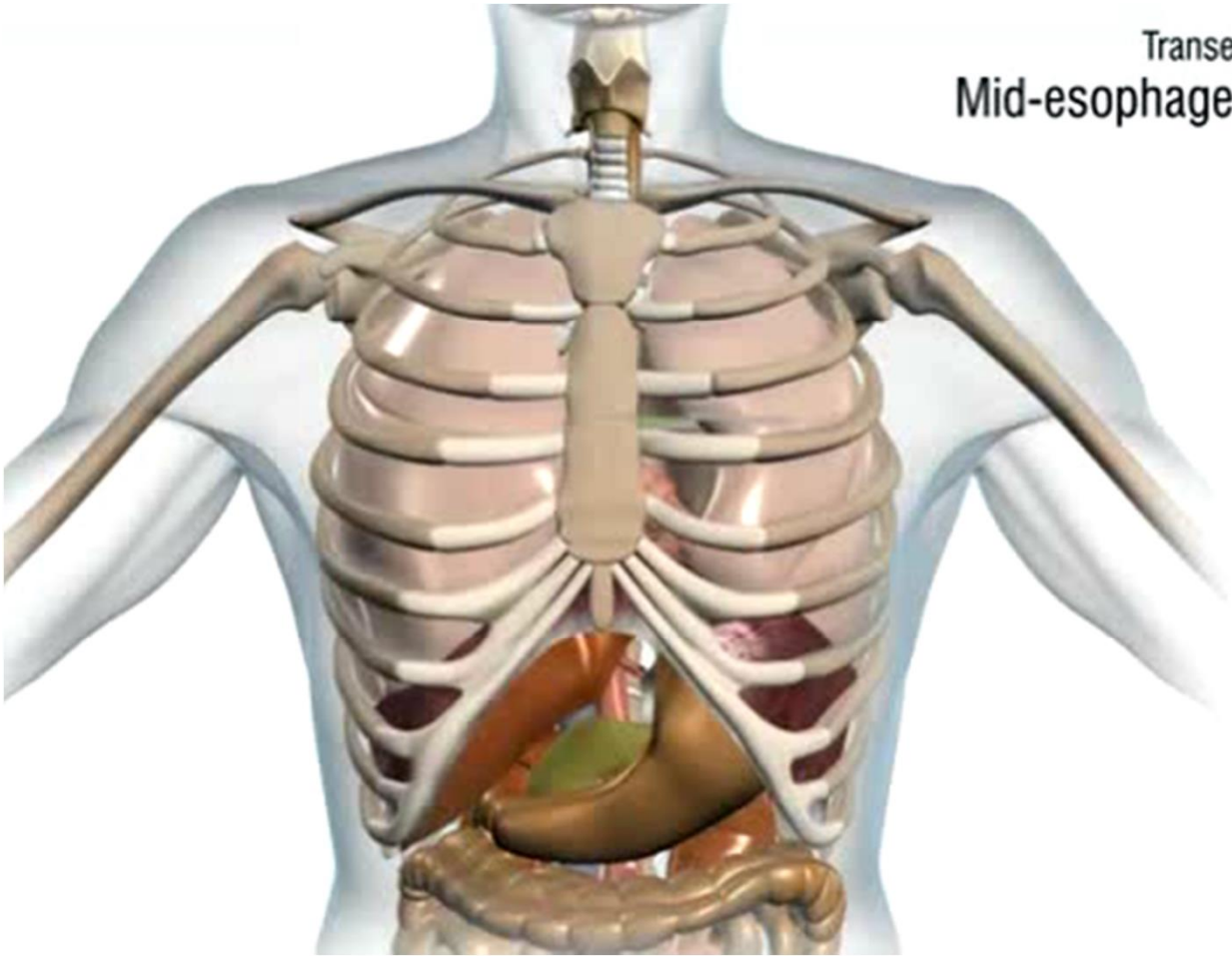


Case #2: Liver transplantation

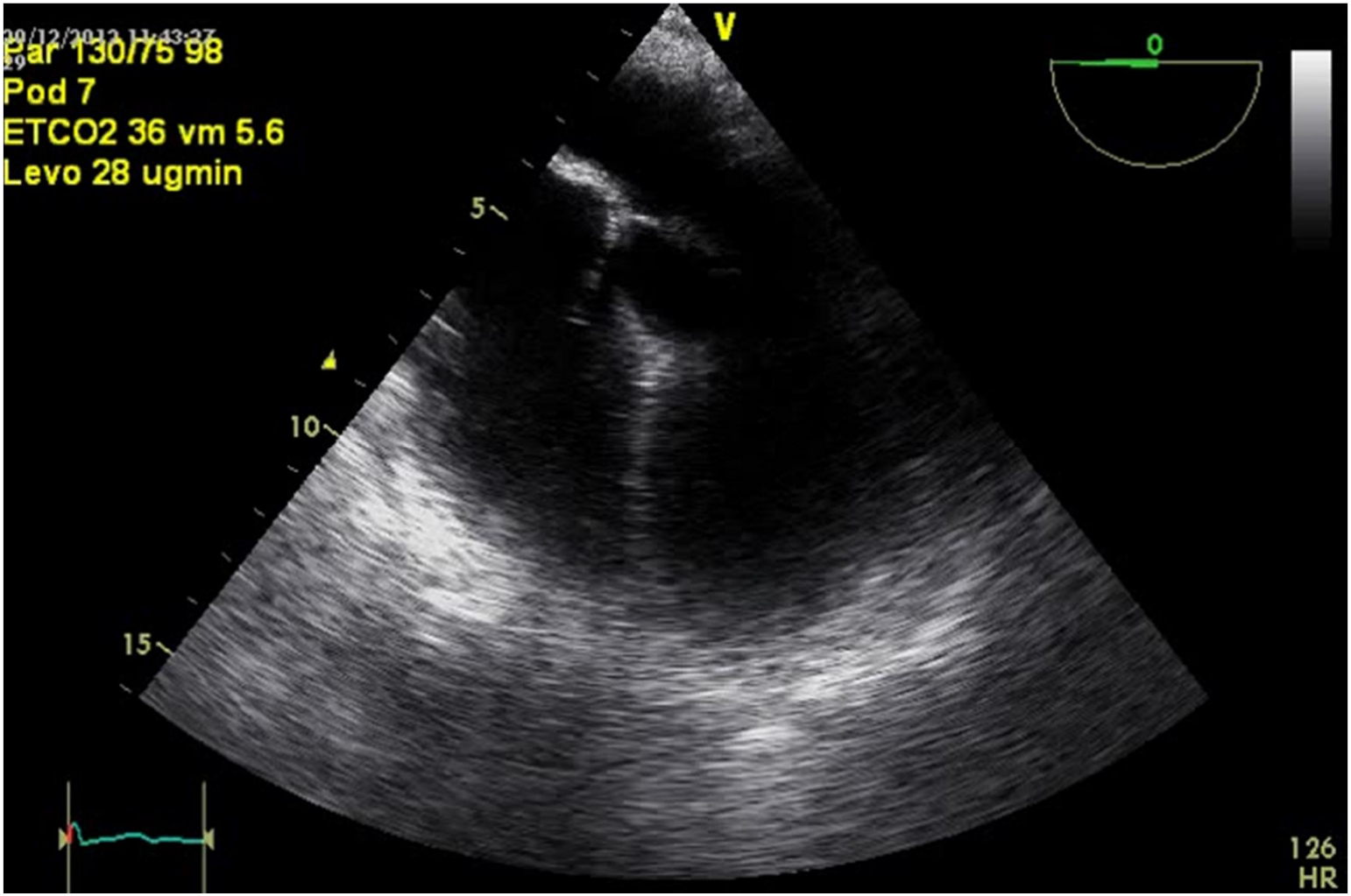
- Mr V., Liver transplantion.
- Rapidly unstable after ICU admittance with good inotropic support (norepinephrine 40 mcg/min).
- Vasoplegic?
- TTE and TEE evaluation.

Transesophageal echocardiography

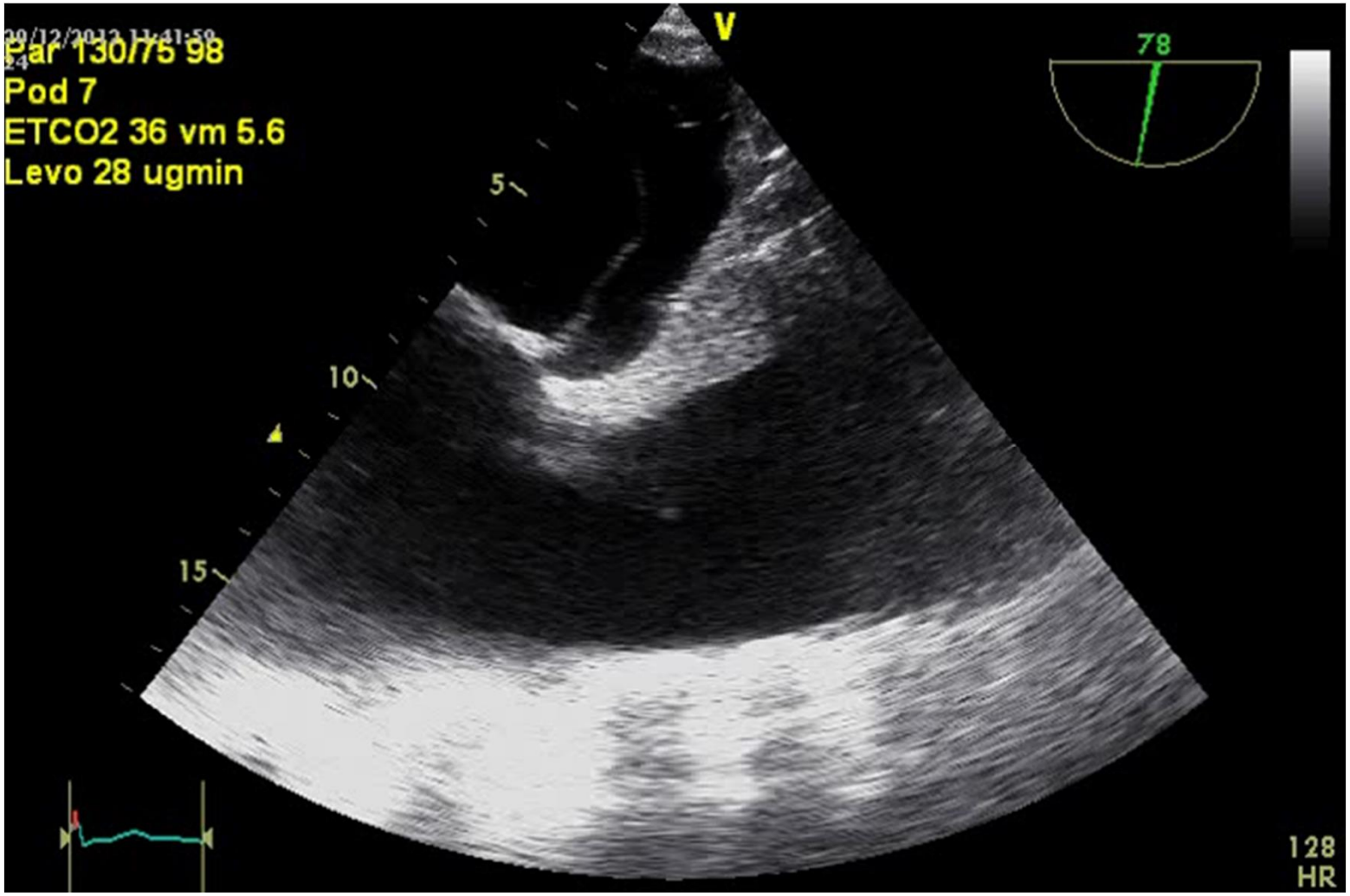
Mid-esophageal four-chamber view



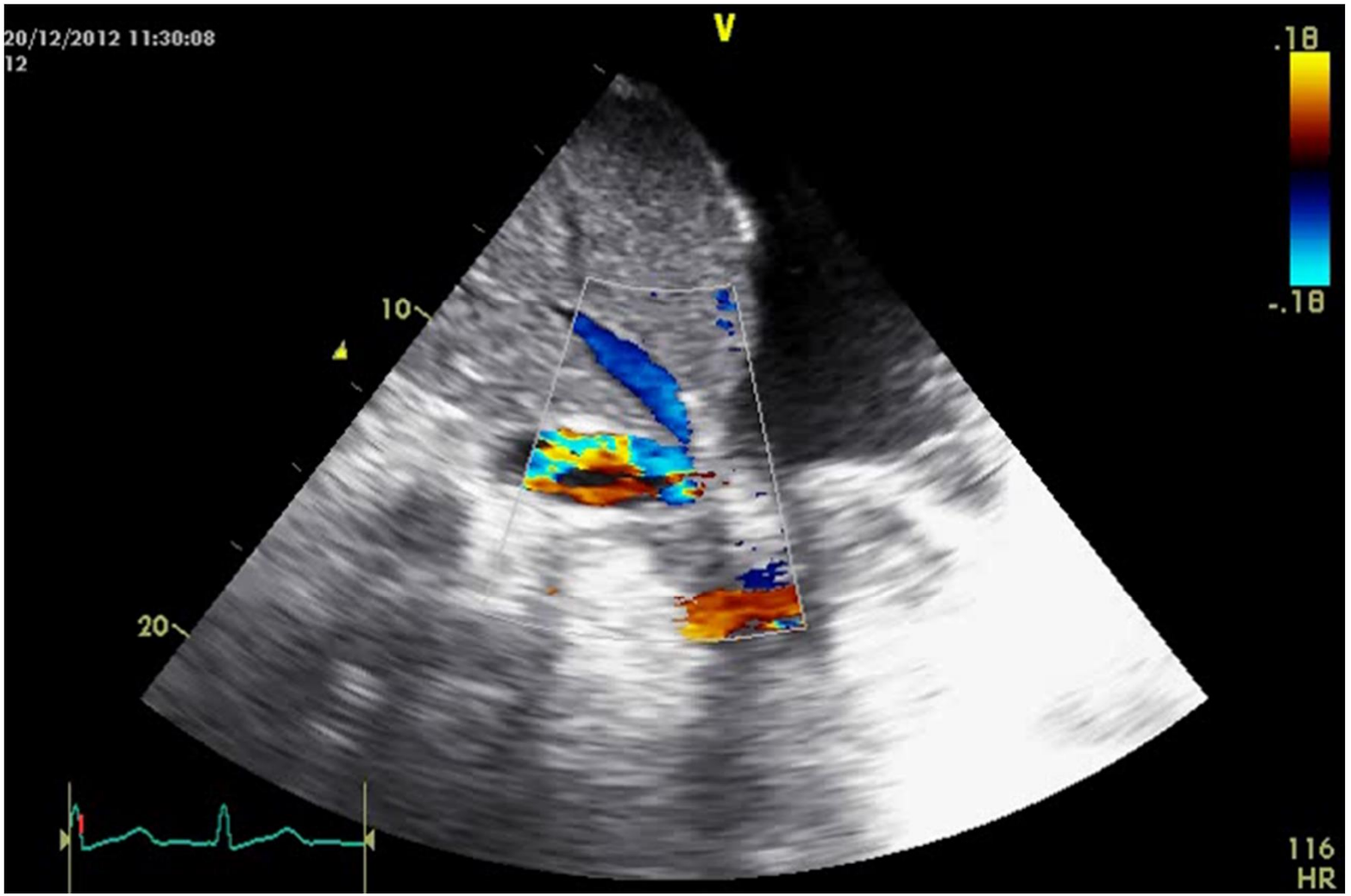
ME four-chamber view



Right thorax mid coronal view

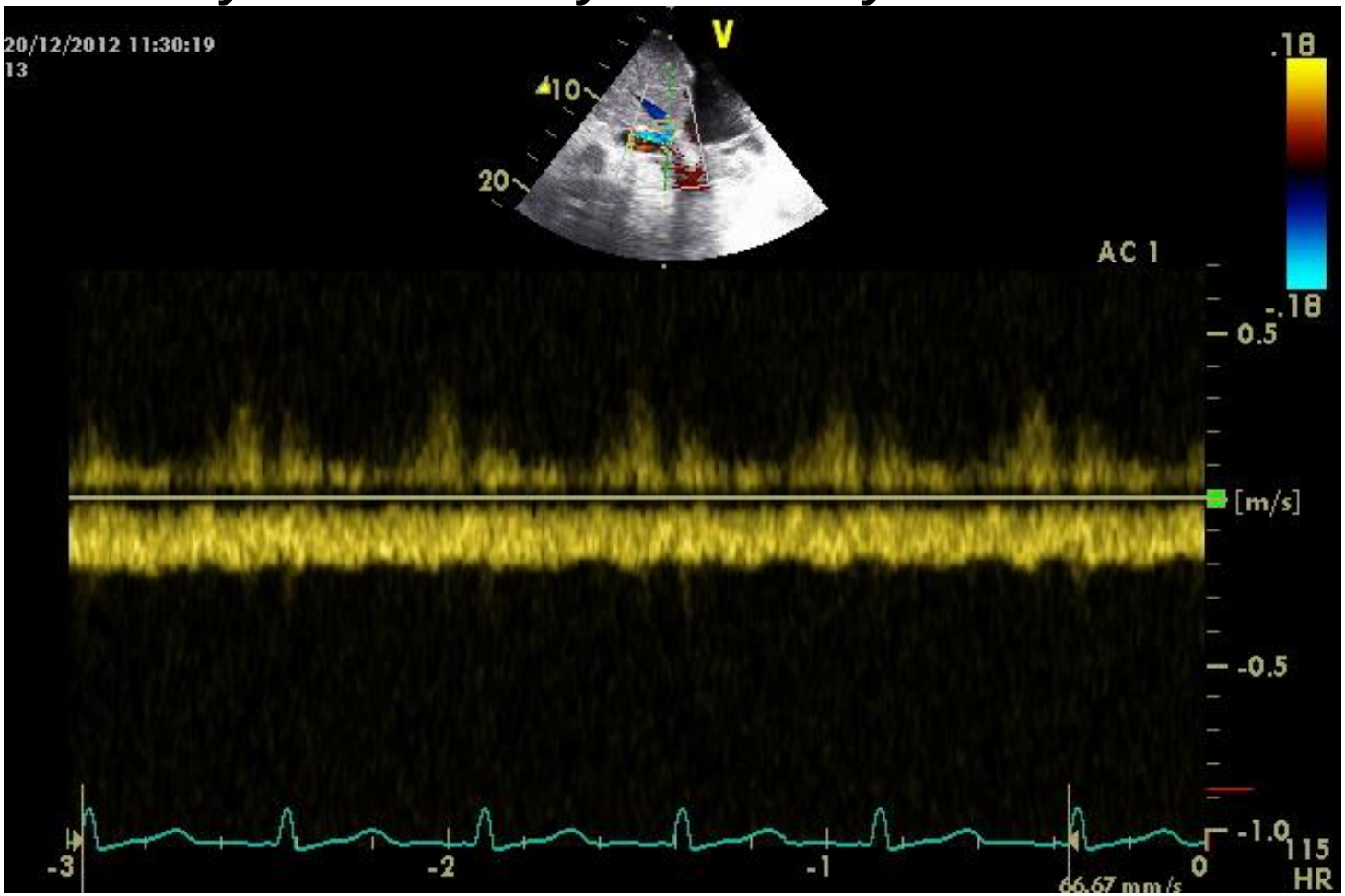


Subcostal view 90^0



Hepatic venous flow

Huge pleural effusion,
but why so hemodynamically unstable?



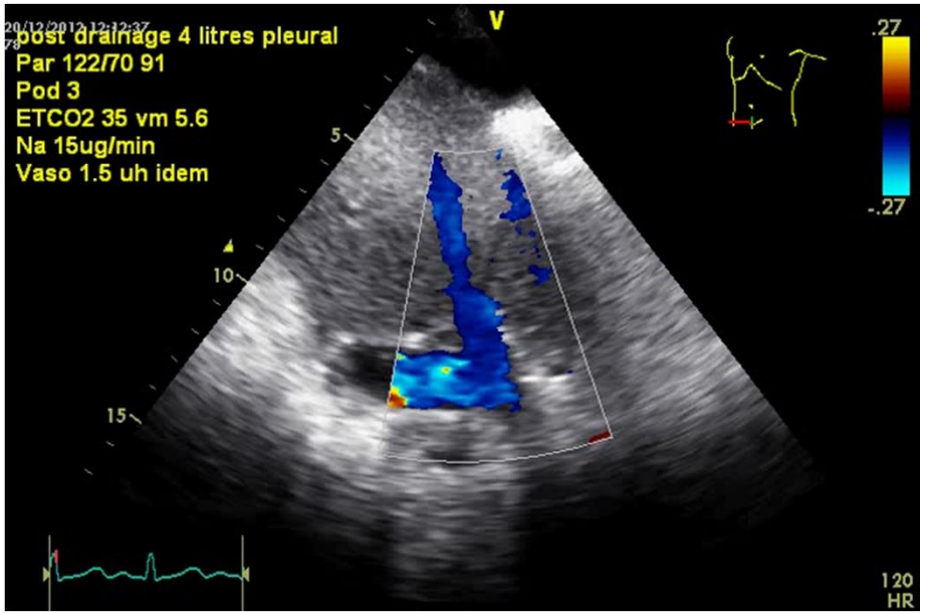
Case #2

- After 4 liters of pleural effusion drainage.
- Rapid stabilisation of hemodynamics and fast wean of vasoconstrictive support.
- HVF goes back to his normal phasic aspect.

Hepatic venous blood flow

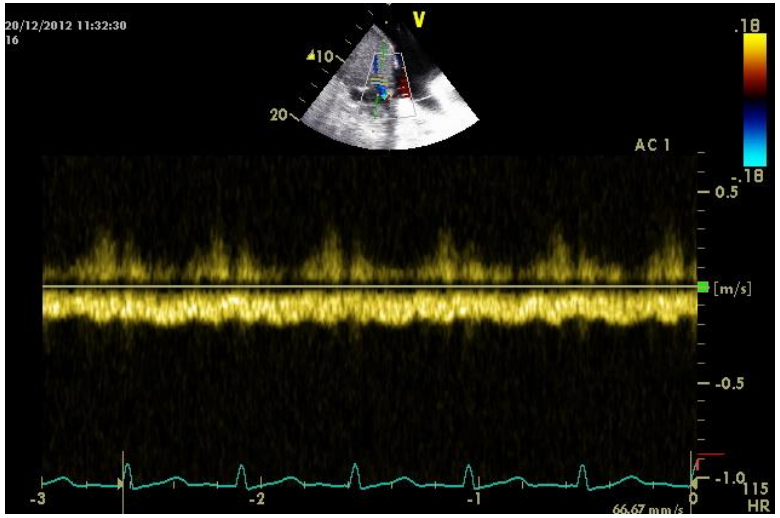
Before

After

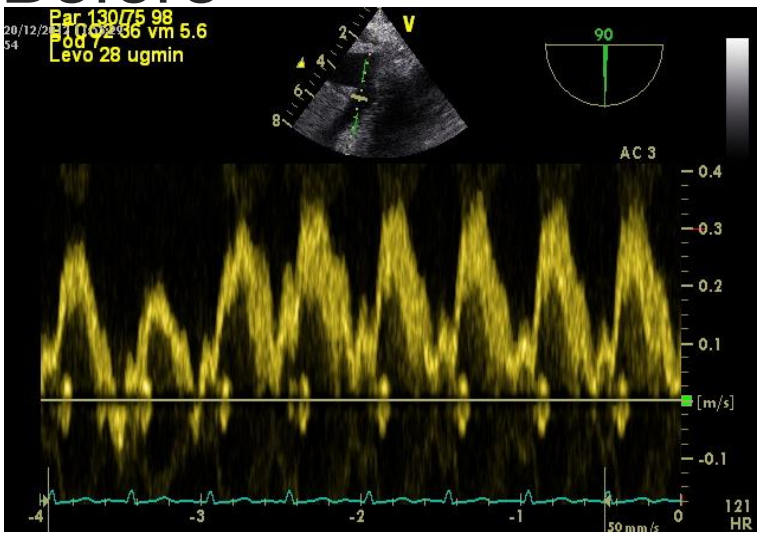


Hepatic venous blood flow

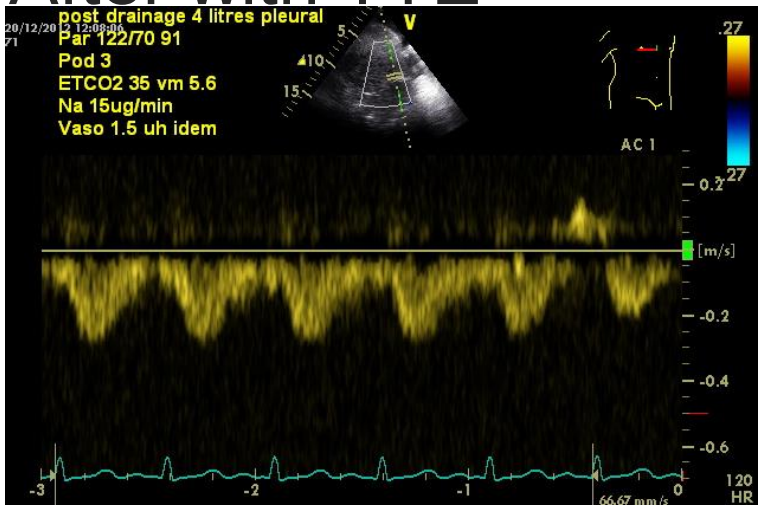
After with TEE



Before



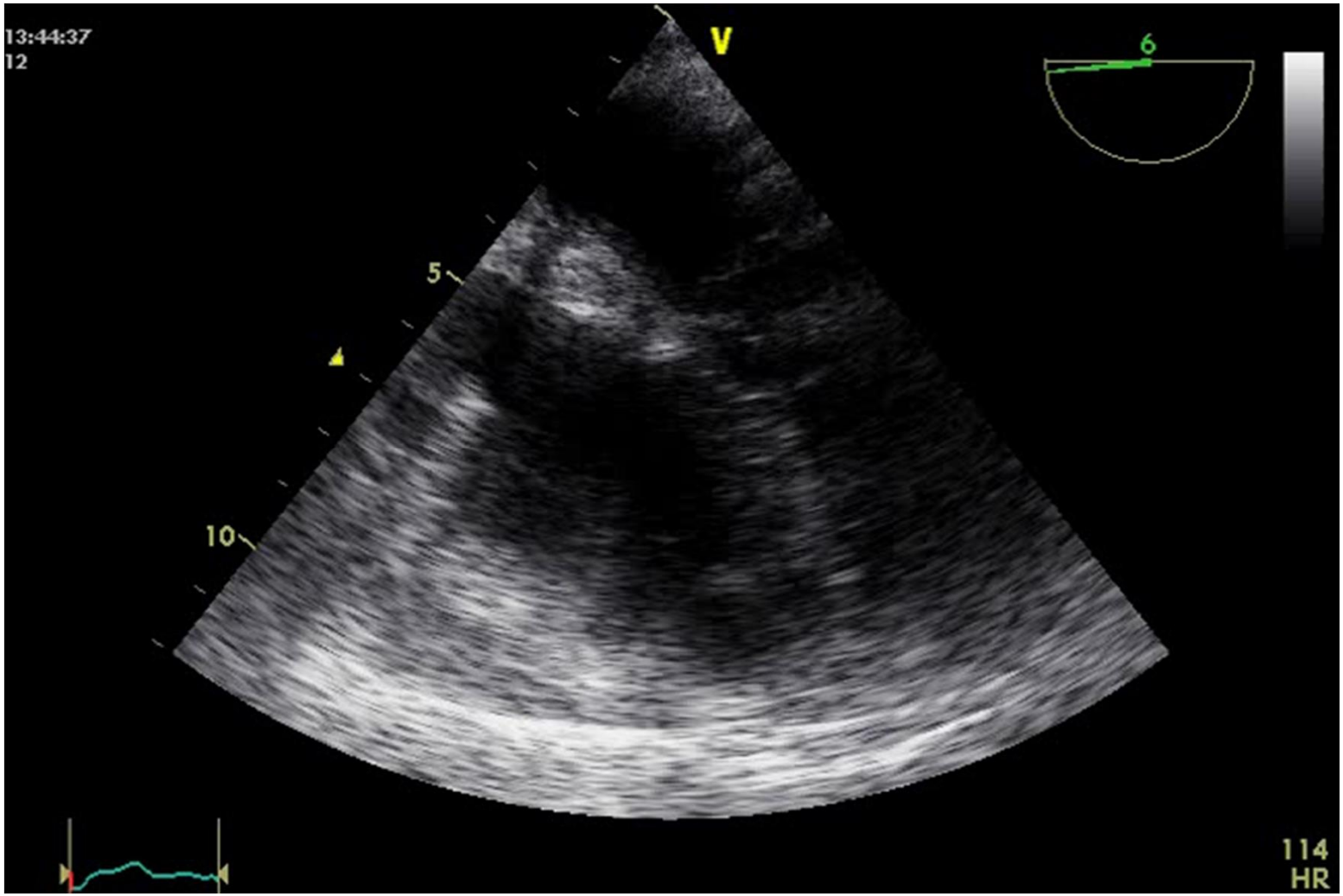
After with TTE



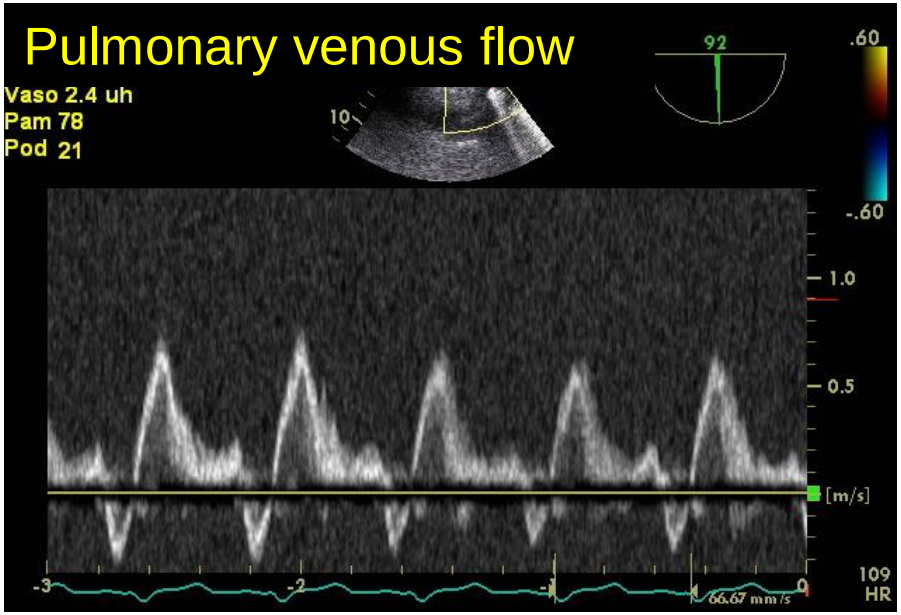
Case #3 Post cardiac arrest

- 67 yo women
- Post-op day #4 of percutaneous aortic valve replacement
- Blue code: asystolic upon arrival
- CPR started
- Pulse back coincident with insertion of a nasogastric tube after intubation
- Transfered back in the ICU with significant vasoactive support

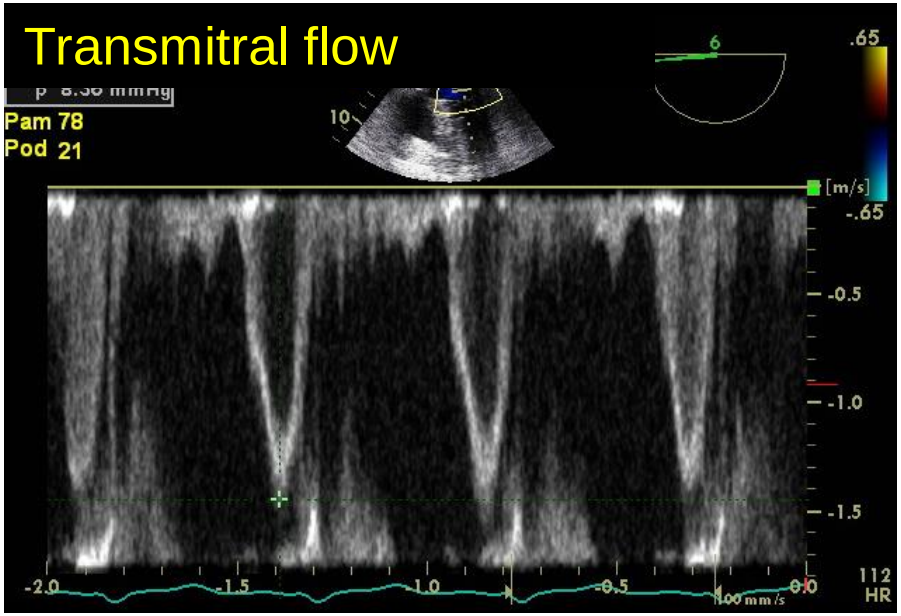
ME four-chamber view



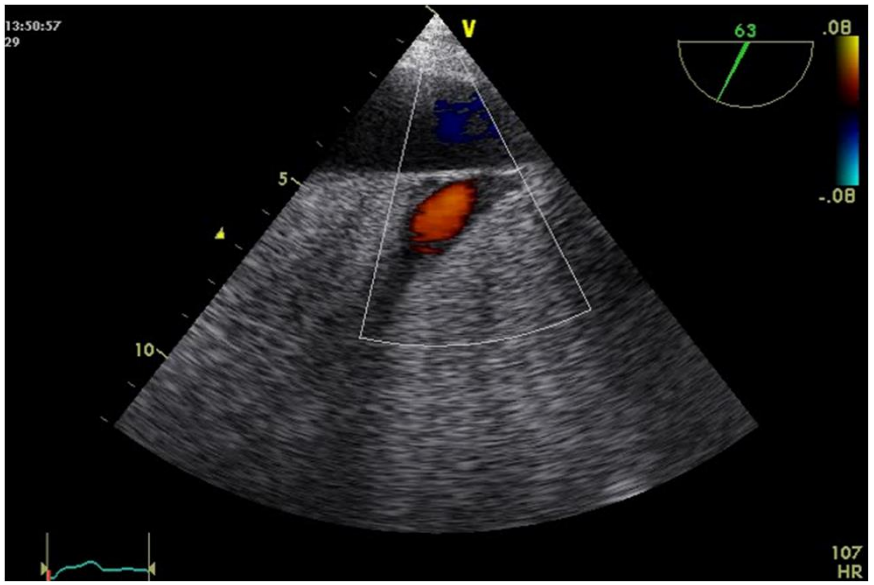
Pulmonary venous flow

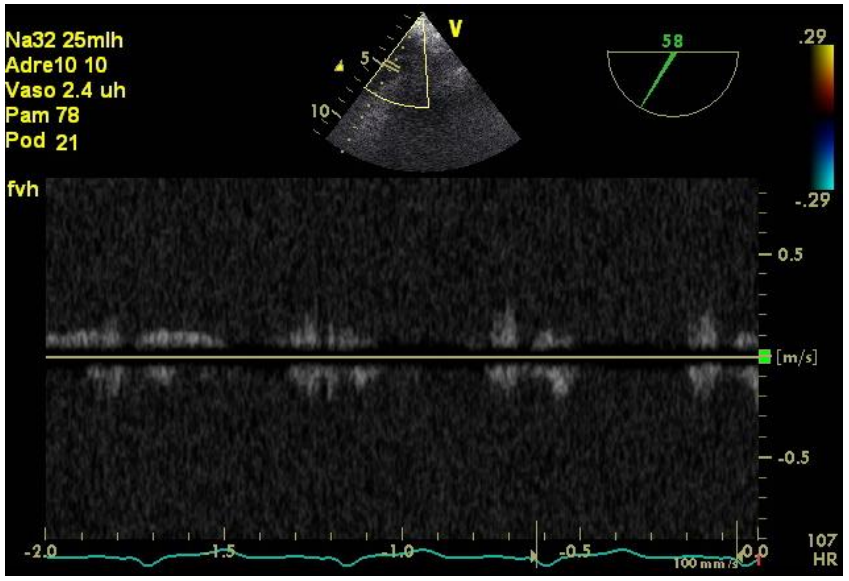


Transmitral flow



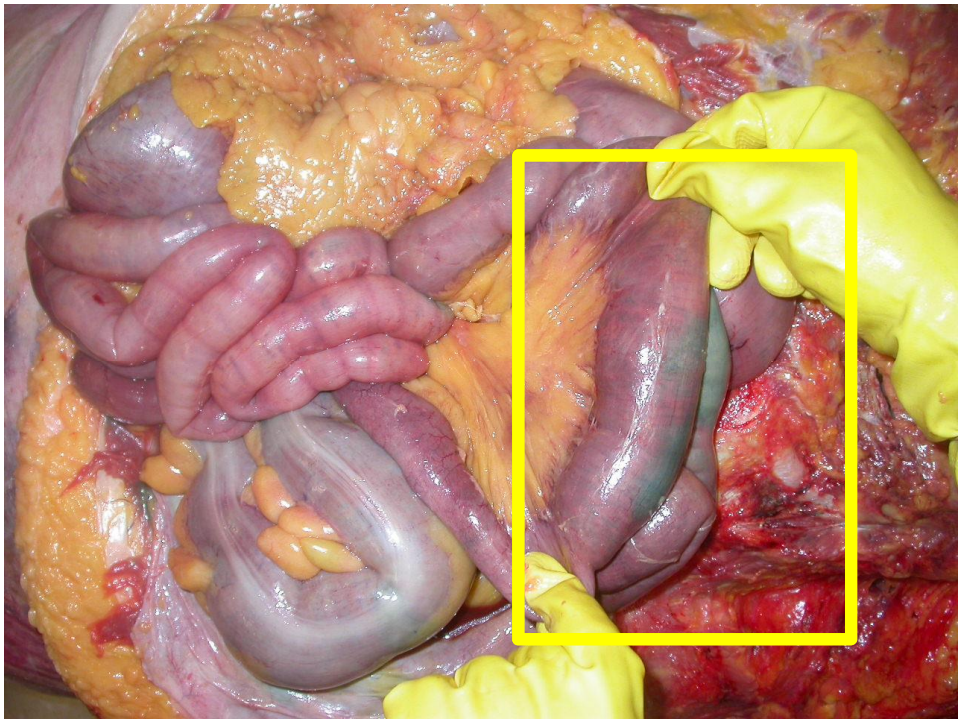
Hepatic venous flow





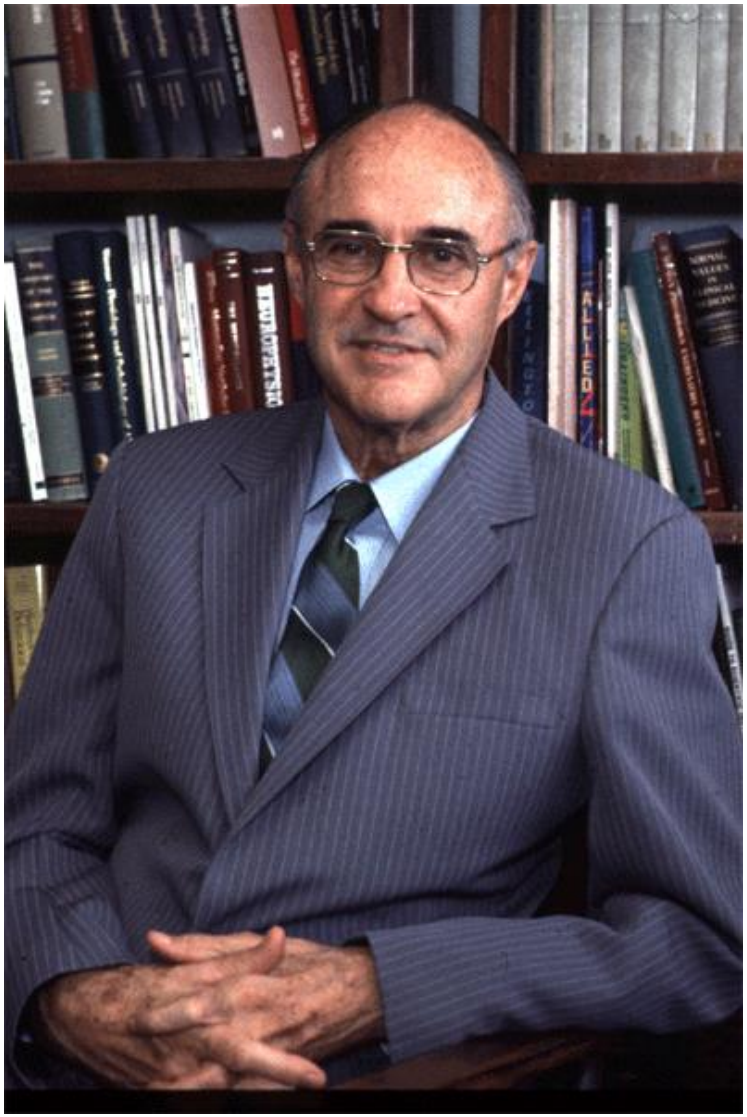
Case #3

- Measurement of IAB pressure = 40 mmHg
- Autopsy finding



Conclusion

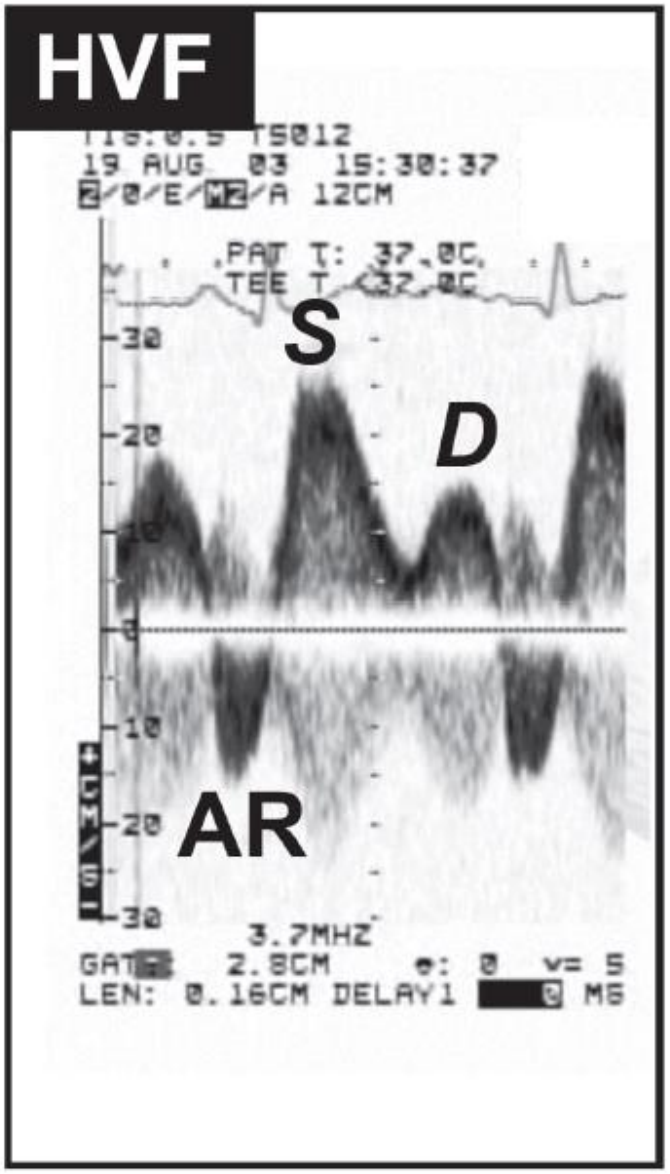
Arthur C. Guyton

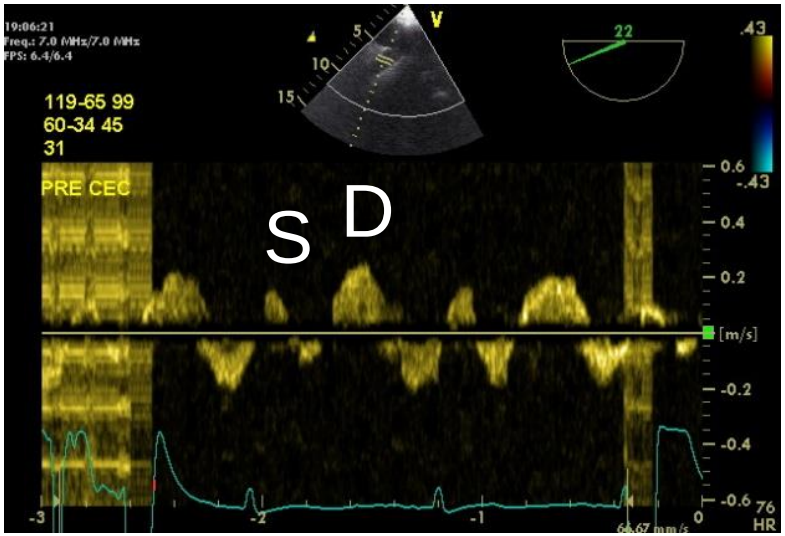


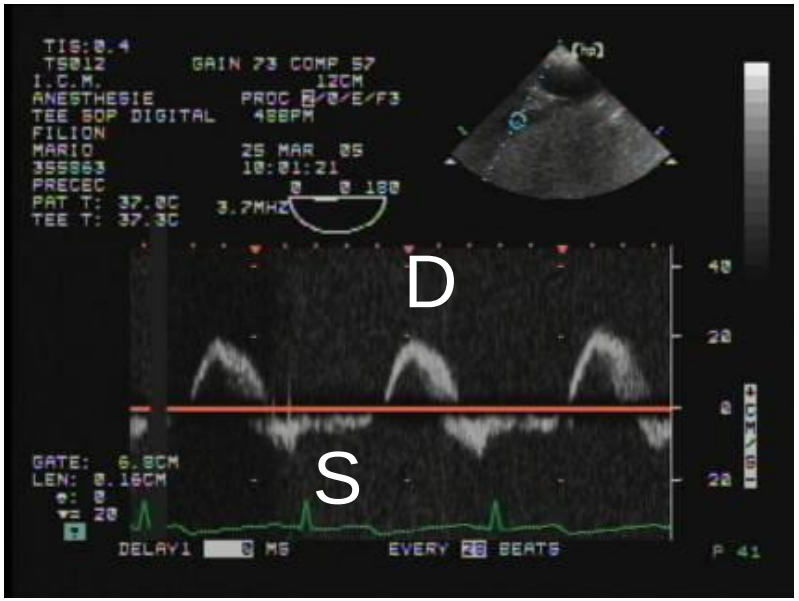
1919 - 2003

Shock state

Hypotension
Oliguria
Cold extremities
Neurological alteration
Acidosis







Shock state

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Shock state

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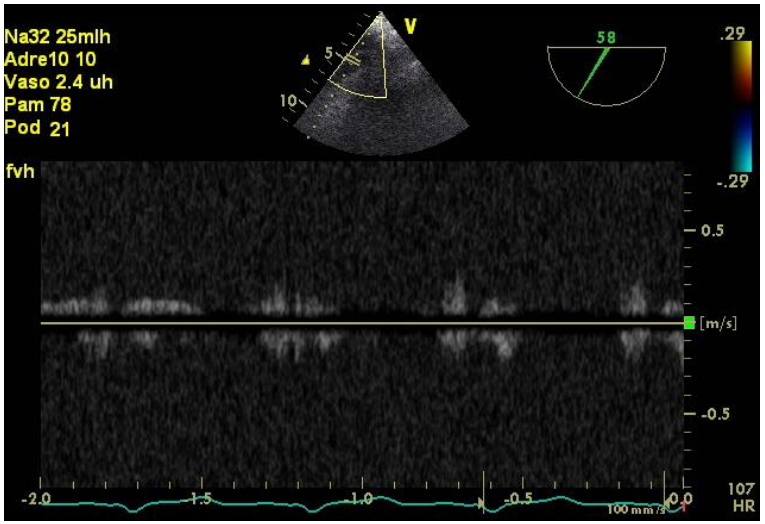
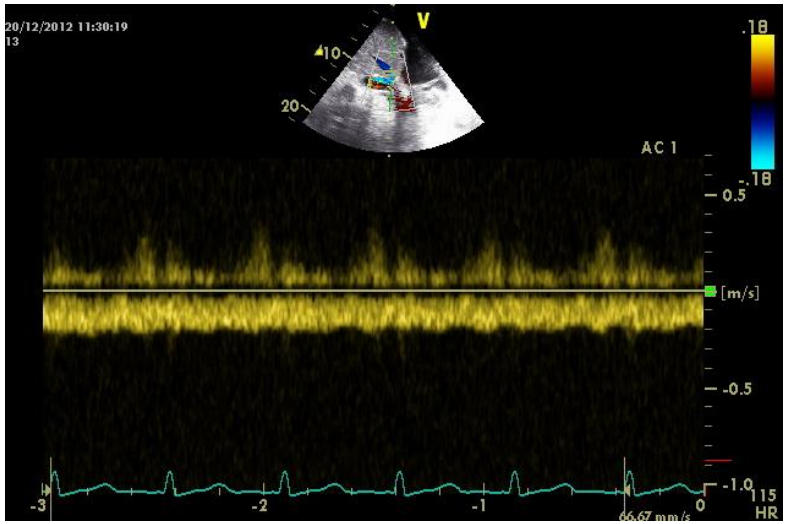
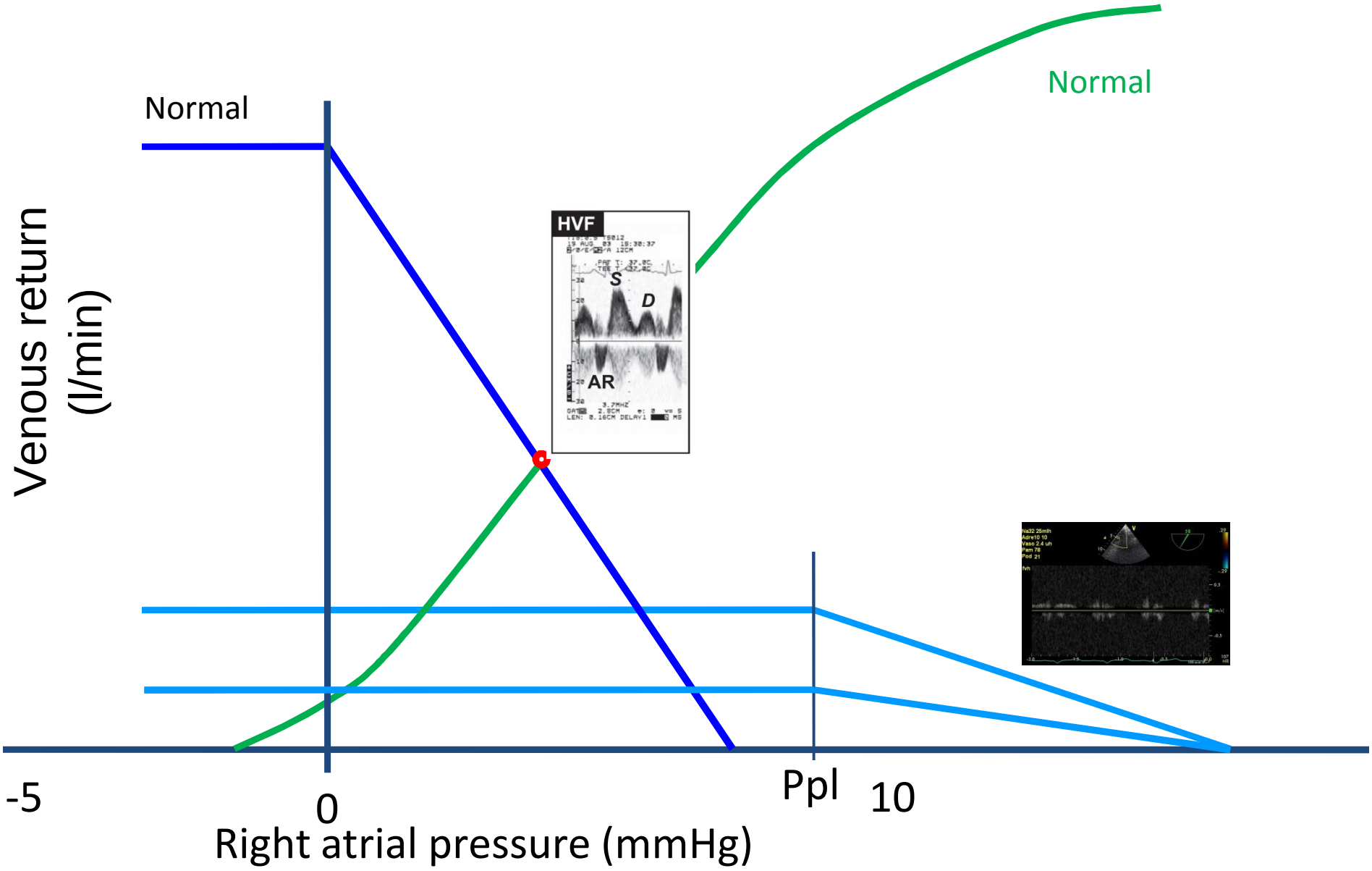




Résistance au retour veineux ↑



Adapated from: Jacobsohn et al Can J Anesth 1997 44:8 849-67

In summary

Hypotension + normal♥
=
extra ♥ TTE or TEE

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Assistant de recherche
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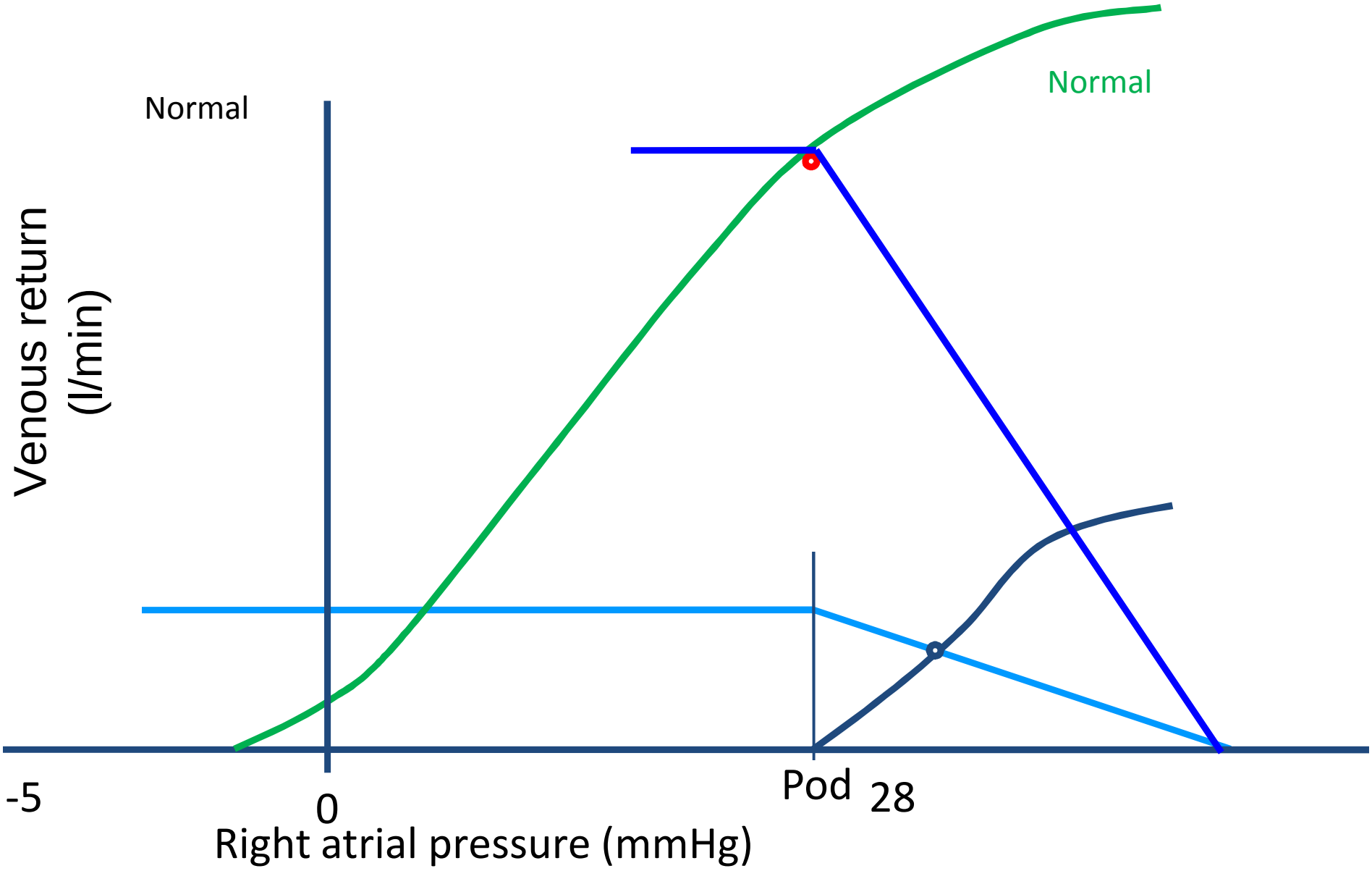
Remerciements

Homme de 24 ans sténose dû une prothèse tricuspidienne

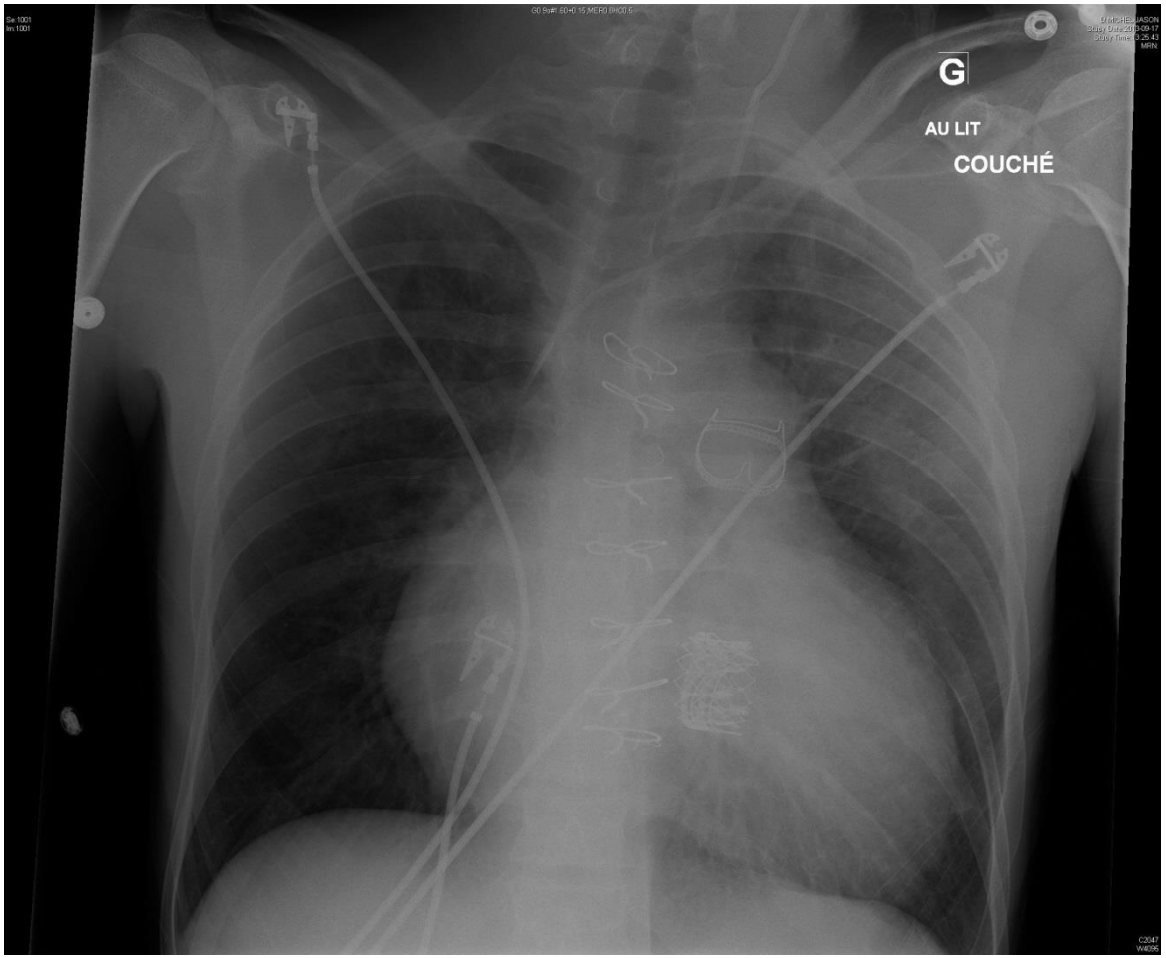
- Pression artérielle = 120/65
- Pod = 28 mmHg
- Que va-t-il se passer après la correction percutanée de la sténose tricuspidienne?

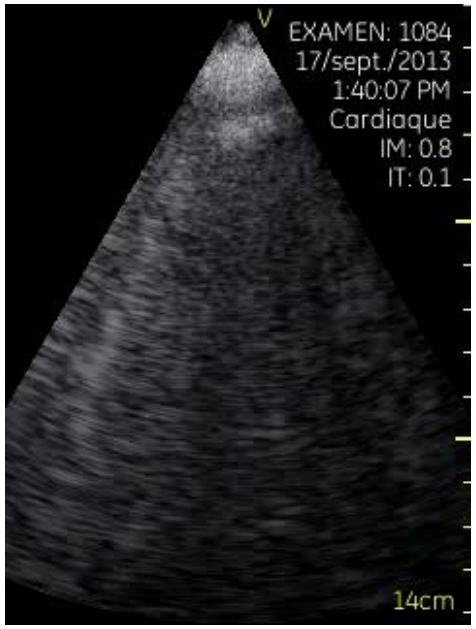
Choc obstructif: pneumothorax

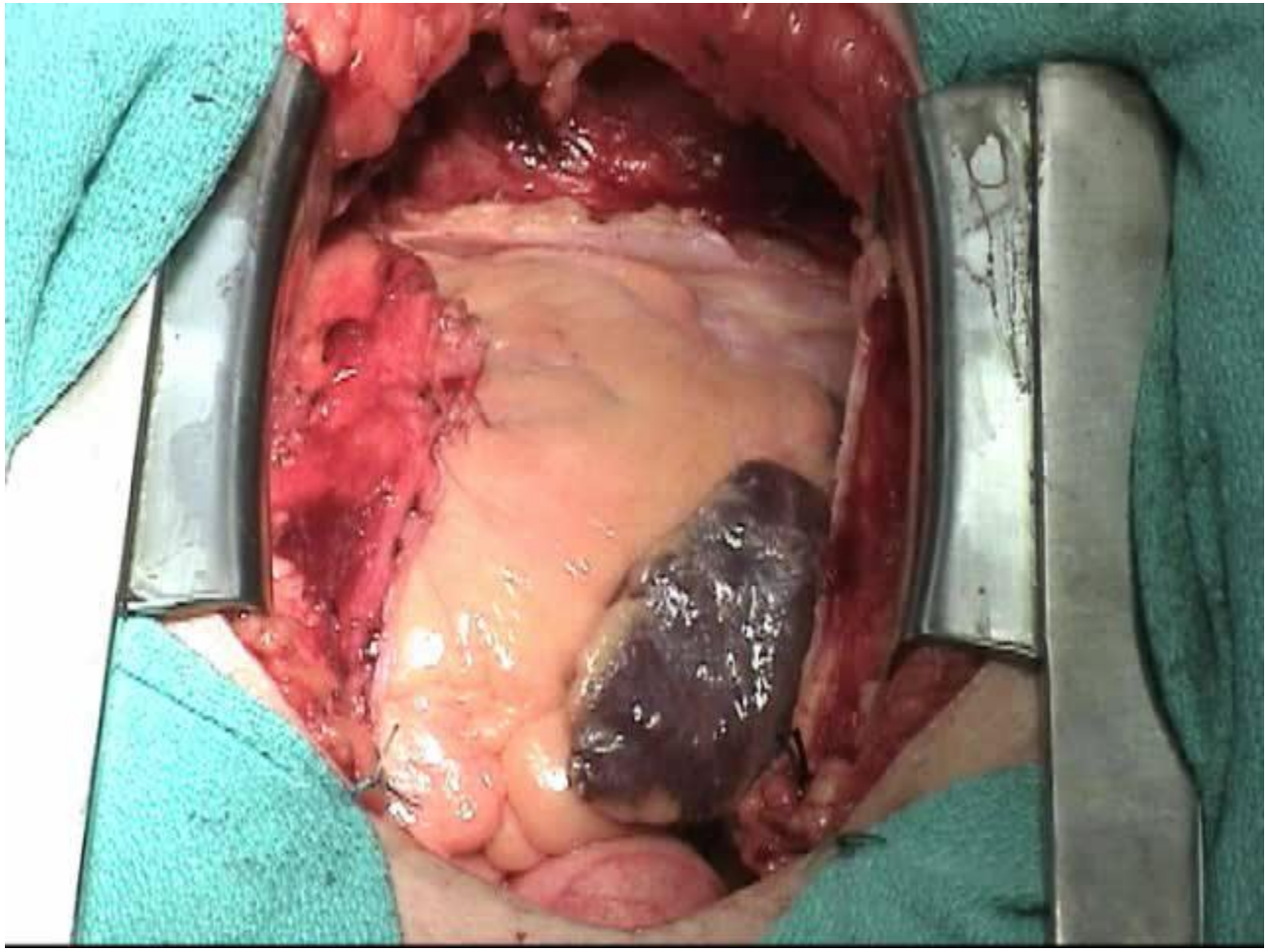


Adapated from: Jacobsohn et al Can J Anesth 1997 44:8 849-67

Désature en salle de réveil







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