

## Courbe pression-volume

André Denault MD PhD

Université   
de Montréal

Montréal, le 9 octobre 2013



## Chapter 3 Mechanisms of difficult separation from cardiopulmonary bypass

Intraoperative hemodynamic instability during and after separation from cardiopulmonary bypass: importance, mechanism and prevention

par  
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Faculté de médecine

Thèse présentée à la Faculté des études supérieures  
en vue de l'obtention du grade de PhD  
en Sciences Biomédicales (6484-1-0)

Septembre 2009

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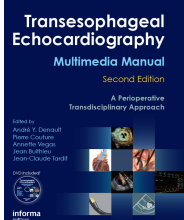
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### Global Ventricular Function and Hemodynamics

André Y. Denault and Pierre Couture  
*Université de Montréal, Montréal, Québec, Canada*

Jean Buthieu  
*McGill University, Montréal, Québec, Canada*

Annette Vegas  
*University of Toronto, Toronto, Ontario, Canada*



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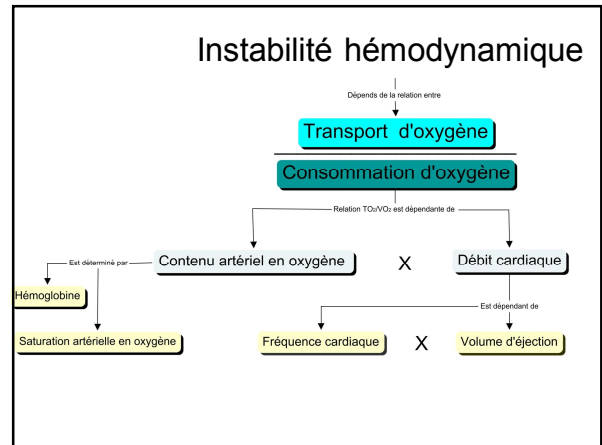
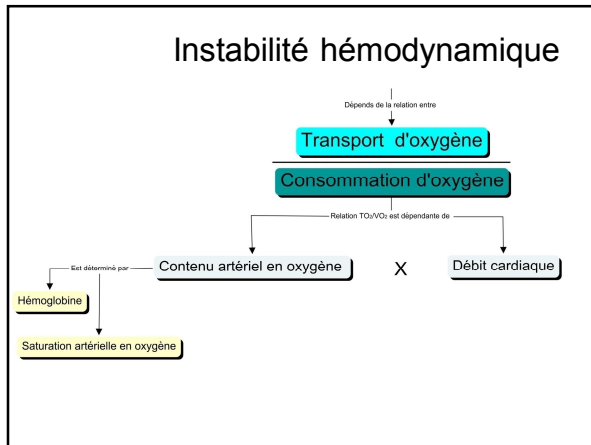
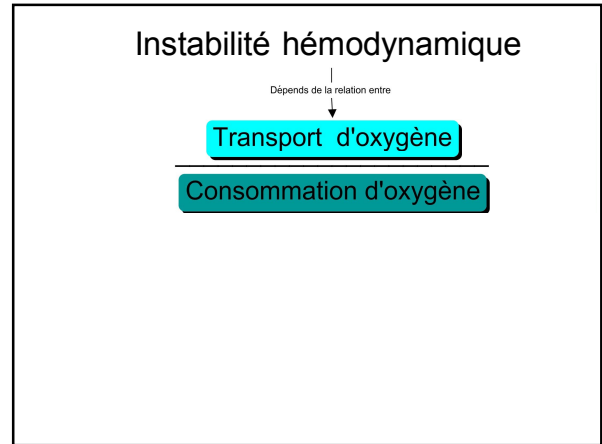
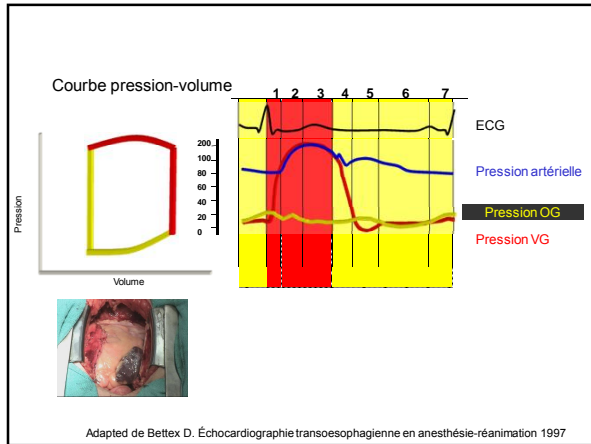
## Objectifs

- 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



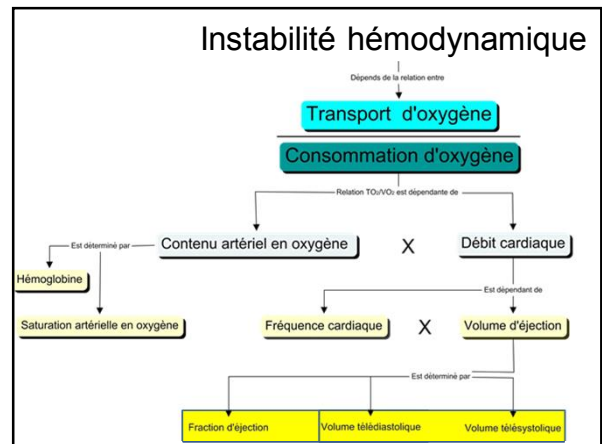


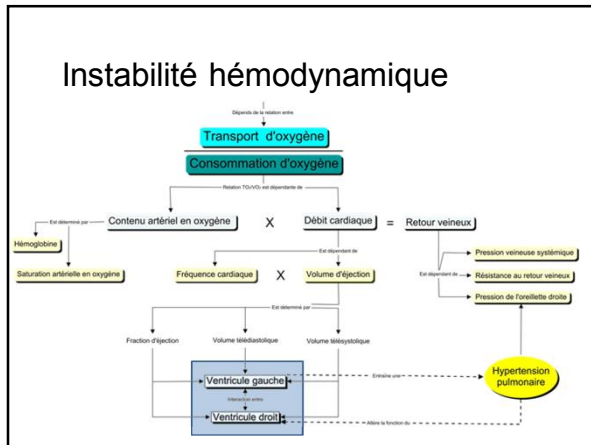
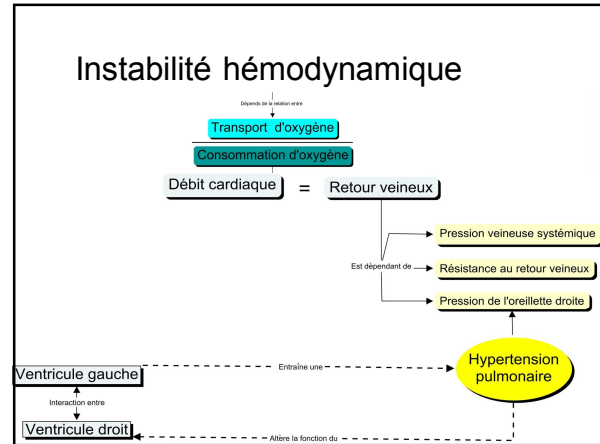
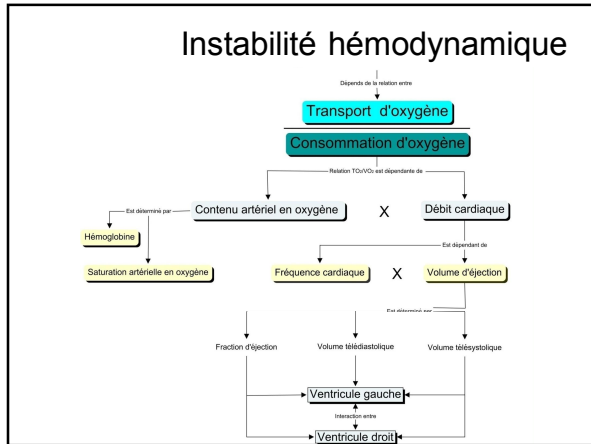
$$FEVG = \frac{VE}{VTDVG}$$

$$VE = FEVG \times VTDVG$$

Performance cardiaque → **Fonction systolique**

Remplissage → **Fonction diastolique**





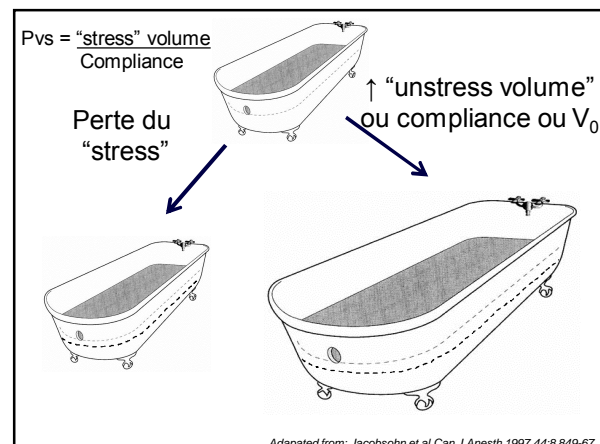
### Déterminants du retour veineux

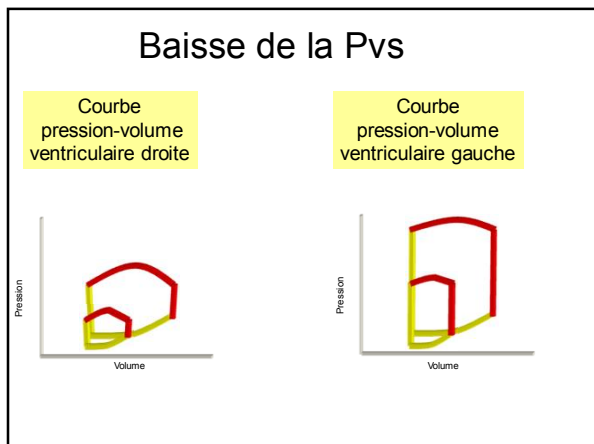
$$RV = \frac{\text{Gradient de pression}}{\text{Résistance au RV}} = \frac{P_{vs} - P_{od}}{R_{rv}}$$

- 1-↓ Pms: hypovolemia, vasodilatation
- 2-↑ Pra: Left and right systolic dysfunction  
Left and right diastolic dysfunction  
Left and right outflow tract obstruction  
Pulmonary emboli  
Hypoxia and hypercapnia
- 3-↑ Rrv: intrinsic obstruction and compartment syndrome (pericardial, mediastinal, thoracic, abdominal)

### Most common condition associated with hemodynamic instability

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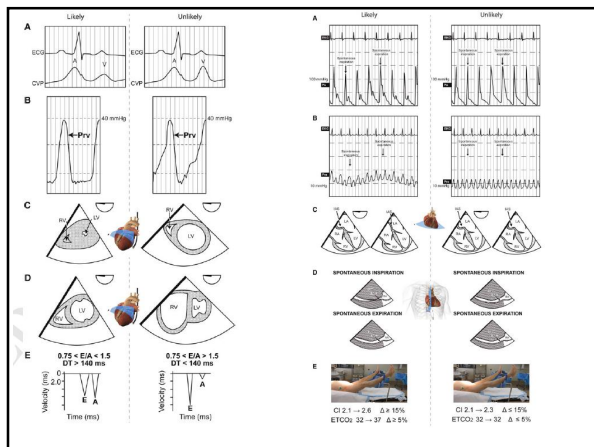


Can J Anesth/ Can Anesth  
DOI 10.1007/s12630-013-0036-2

PERIOPERATIVE CARDIOVASCULAR ROUNDS

### Hemodynamic instability and fluid responsiveness

Francis Toupin, MD · André Denault, MD PhD ·  
Yoan Lamarche, MD · Alain Deschamps, MD PhD



### Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge\*

David Osman, MD; Christophe Ridel, MD; Patrick Ray, MD; Xavier Monnet, MD, PhD; Nadia Anguel, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

150 fluid challenges were performed in 96 septic patients (73 men, 23 women; mean age, 62.14 yrs).  
65/150 (43%) = positive response to fluid

Crit Care Med 2007

### Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge\*

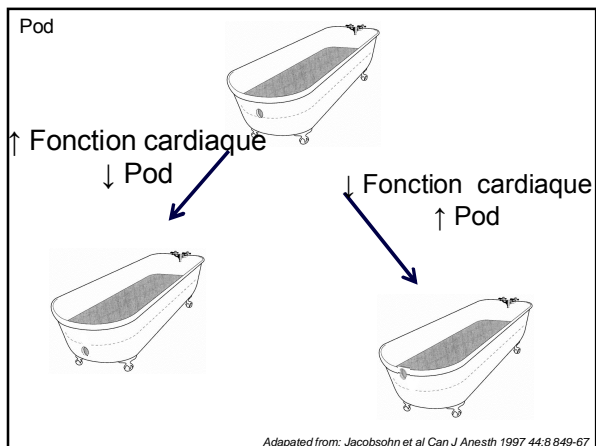
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CCM 2007

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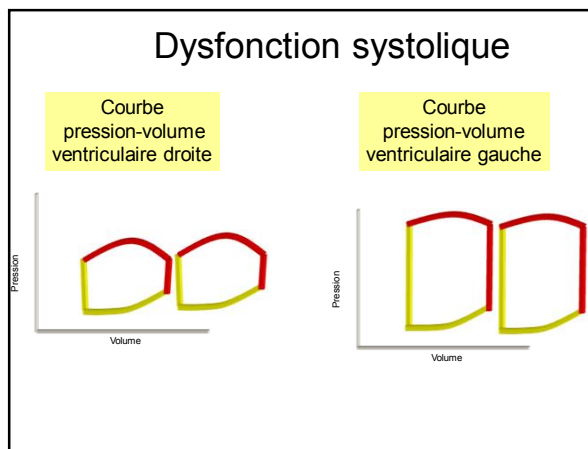
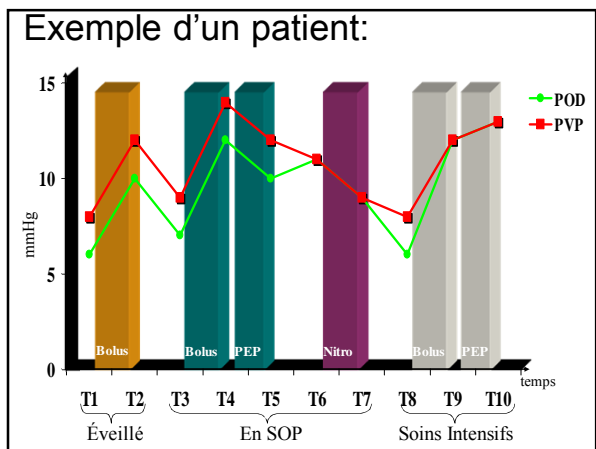
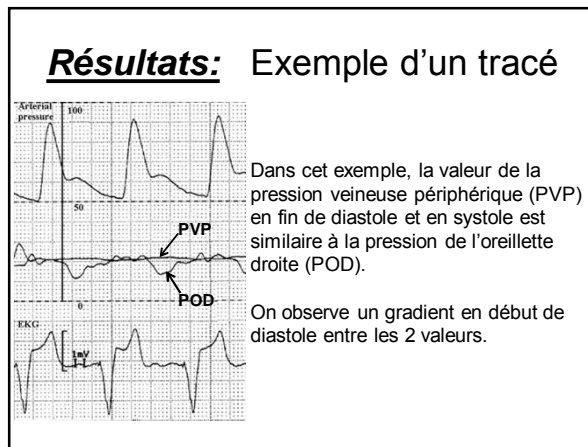
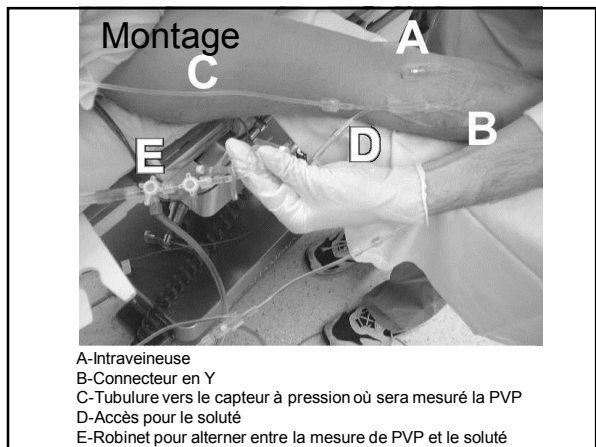


Intensive Care Med (2004) 30:627-632  
DOI 10.1007/s00134-003-2052-0

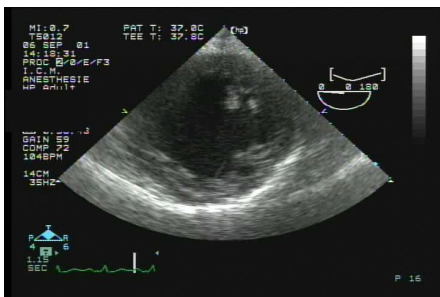
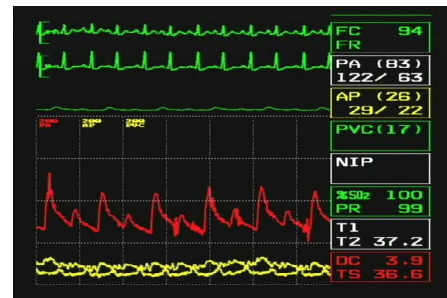
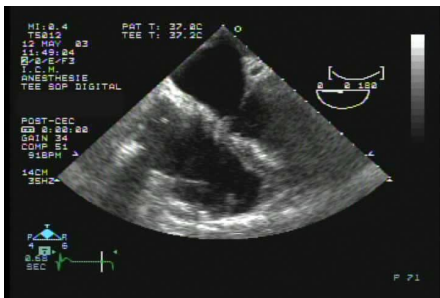
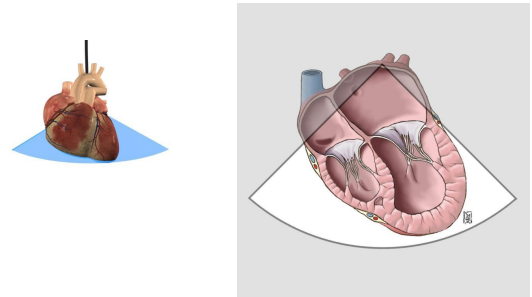
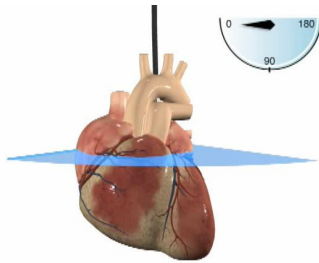
**ORIGINAL**

Roger Desjardins  
André Y. Denault  
Sylvain Béliste  
Michel Carrier  
Denis Babin  
Sylvie Lévesque  
Raymond Martineau

**Can peripheral venous pressure be interchangeable with central venous pressure in patients undergoing cardiac surgery?**

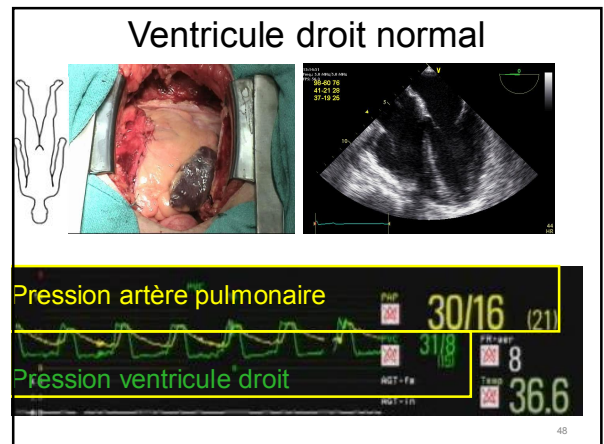
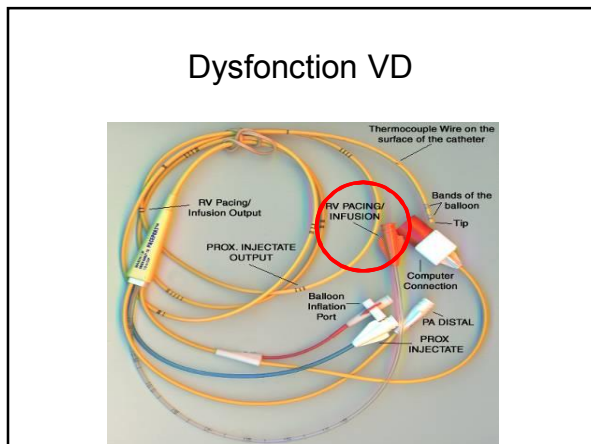
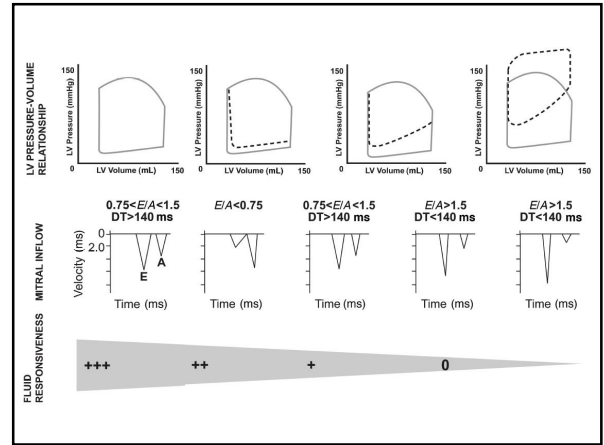
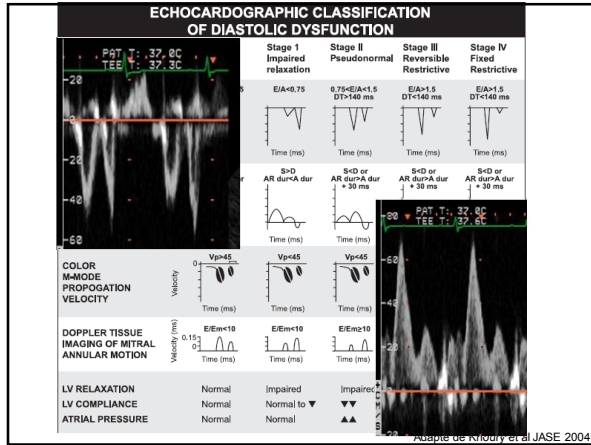
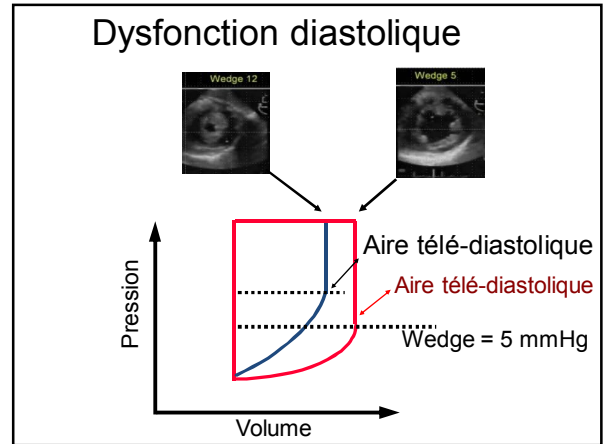
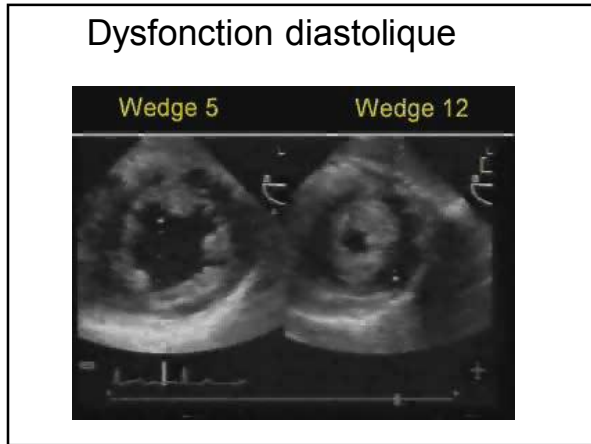


Mid-esophageal four-chamber view

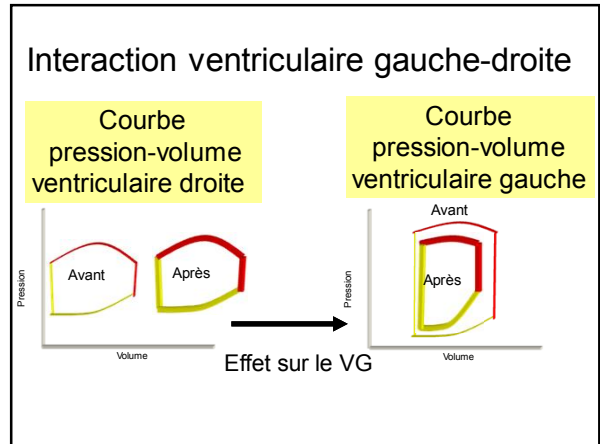
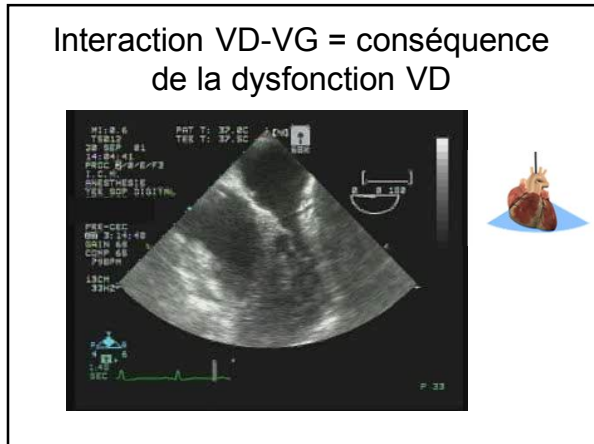
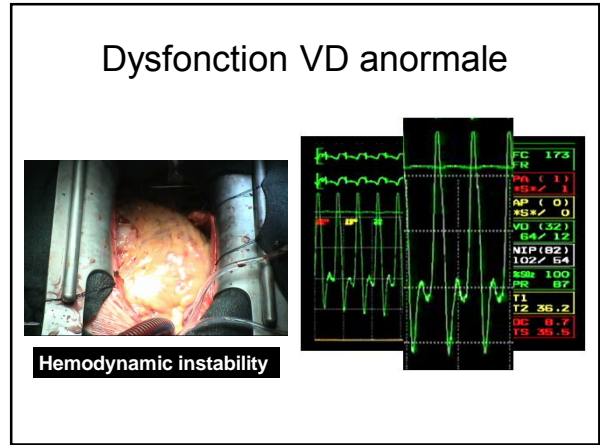
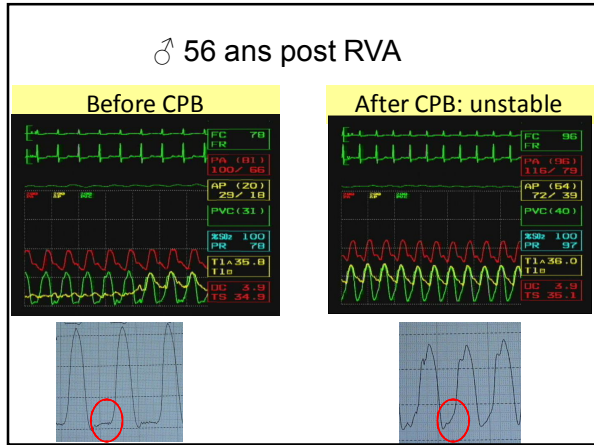
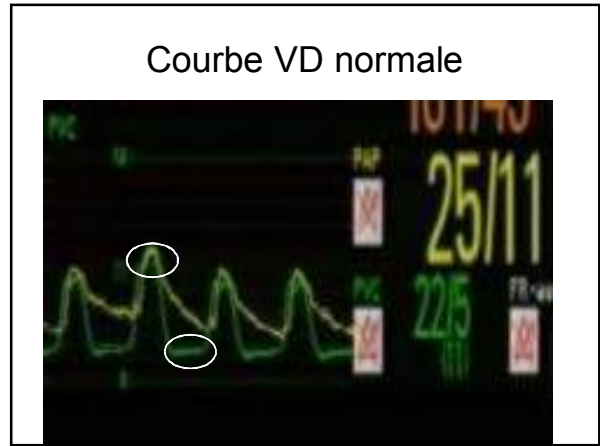
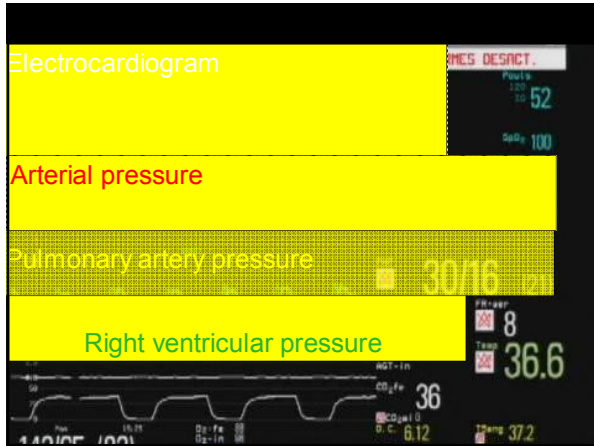


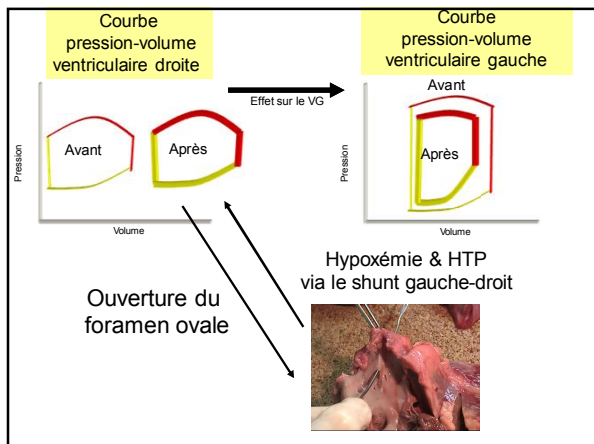
Most common condition associated with hemodynamic instability

- 1-↓ Pms: hypovolemia, vasodilatation
- 2-↑ Pra: Left and right systolic dysfunction
  - Left and right diastolic dysfunction**
  - Left and right outflow tract obstruction
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**Always consider left ventricular outflow tract obstruction in hemodynamically unstable patients**

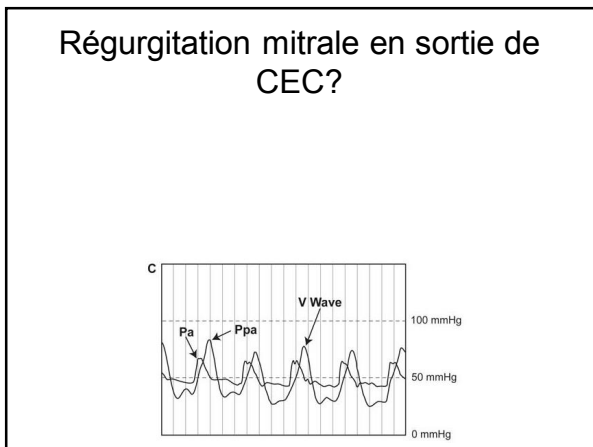
Antoine G. Rochon, MD · Philippe L. L'Allier, MD · André Y. Denault, MD

- 1 PML = 14 mm
- 2 AML = 27 mm
- 3 LVOT = 19 ± 2 mm
- 4 SLCL
- 5 Coarctation point
- 6 Mitral annulus
- 7 Mitro-aortic angle

**Risk of SAM/SPASM**

- SLCL < 25 mm
- PML length > 19 mm
- AML / PML < 1.3
- Spoutum = 13 mm
- Mitro-aortic angle < 130°

Can J Anesth/J Can Anesth (2009) 56:962-968



**Régurgitation mitrale en sortie de CEC?**

LA Ao LV SAM

Pa Ppa V Wave

100 mmHg

50 mmHg

0 mmHg

A B C D E F

LA Ao LV SAM

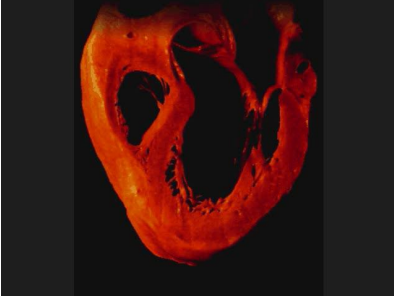
Pa Ppa V Wave

100 mmHg

50 mmHg

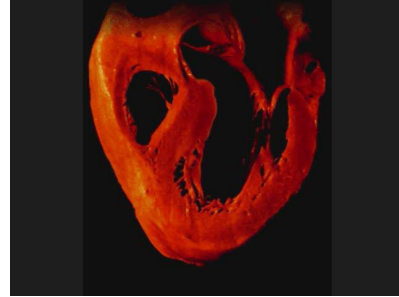
0 mmHg

Obstruction de la chambre de chasse du ventricule gauche



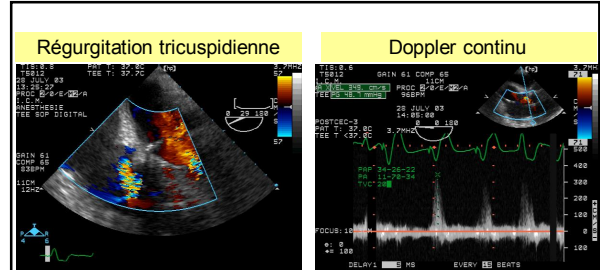
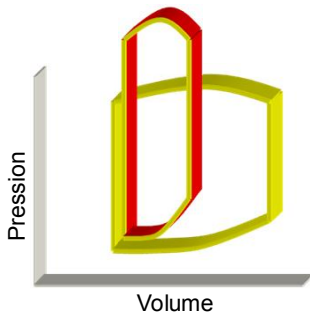
Courtoisie de Gaudiani

Obstruction de la chambre de chasse du ventricule gauche



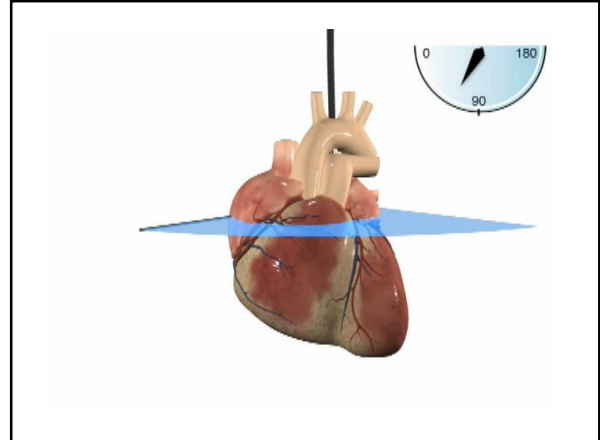
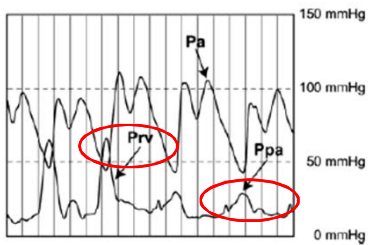
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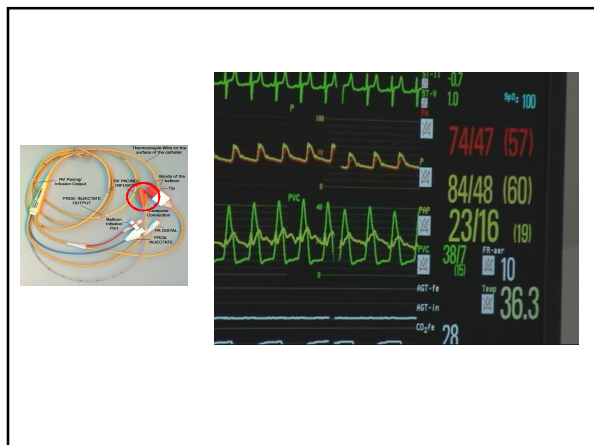
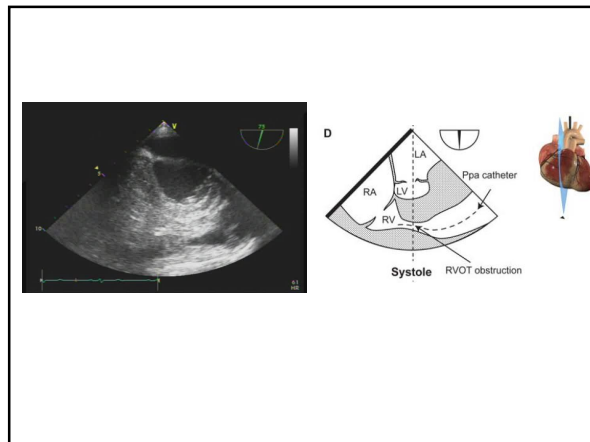
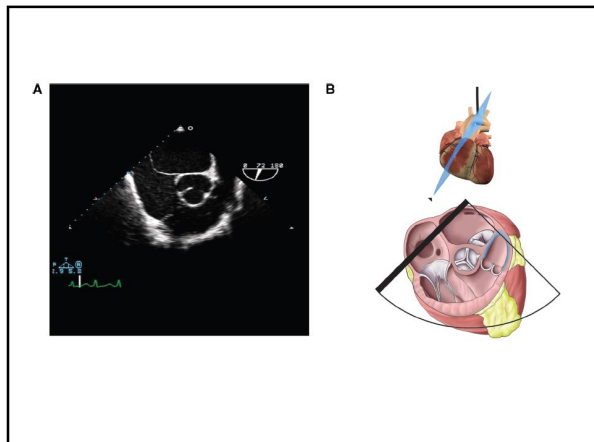
Obstruction de la chambre de chasse du ventricule gauche



Gradient de 48 mmg avec une Pod de 20 mmHg  
 PAP systolique de 68 mmHg  
 PAP systolique mesurée de 34 mmHg ???

Obstruction de la chambre de chasse du ventricule gauche





### Dynamic right ventricular outflow tract obstruction in cardiac surgery

André Y. Denault, MD, FRCPC,<sup>a</sup> Miguel Chaput, MD,<sup>b</sup> Pierre Couture, MD, FRCPC,<sup>a</sup> Yves Hébert, MD, FRCSC,<sup>b</sup> François Haddad, MD, FRCPC,<sup>c</sup> Jean-Claude Tardif, MD, FRCPC<sup>c</sup>

- Systolic RV to Pap > 6 mmHg (18%)
- Systolic RV to Pap > 25 mmHg (4%)
  - N = 11 patients
  - 50% with AVR
  - 73% on milrinone
  - 91% with hemodynamic instability

(n = 800)

JTCVS 2006

### Most common condition associated with hemodynamic instability

- 1-↓ Pms: hypovolemia, vasodilatation
  - 2-↑ Pra: Left and right systolic dysfunction  
Left and right diastolic dysfunction  
Left and right outflow tract obstruction
- #### Pulmonary emboli
- Hypoxia and hypercapnia
- 3-↑ Rrv: intrinsic obstruction and compartment syndrome (pericardial, mediastinal, thoracic, abdominal)

### 68 yo ♀ hypotensive at the ER 3 weeks after removal of a meningioma



Noradrenalin at 0.15 µg/kg/min  
(40 ml/h de 4mg/250ml)

68 yo ♀ hypotensive at the ER  
3 weeks after removal of a meningioma

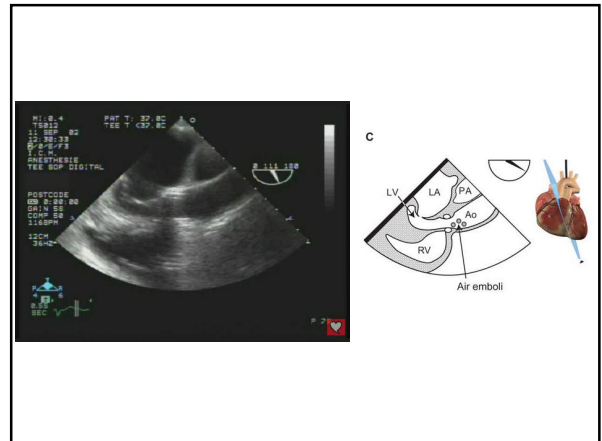
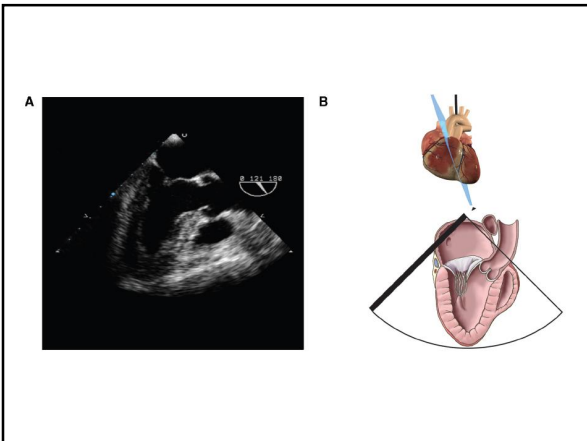
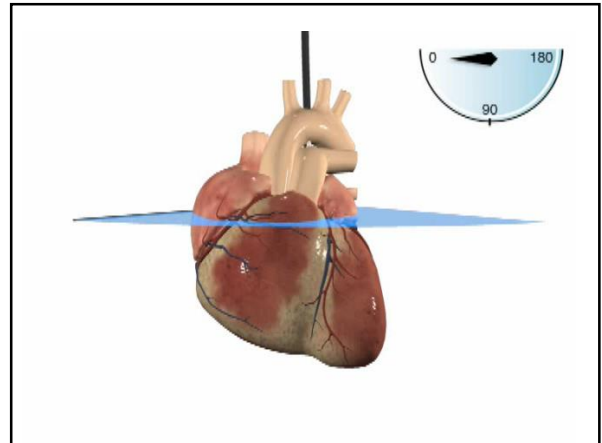
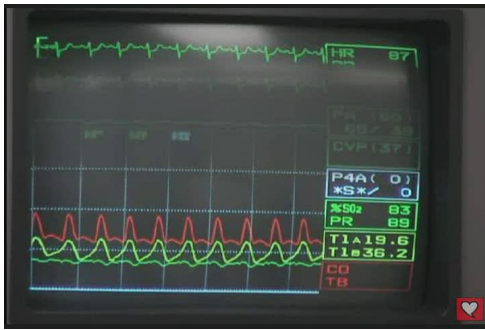


Noradrenalin at 0.15 µg/kg/min  
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68 yo ♀ hypotensive at the ER  
3 weeks after removal of a meningioma



Patient instable après remplacement  
valve aortique



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### Hypoxia and hypercapnia

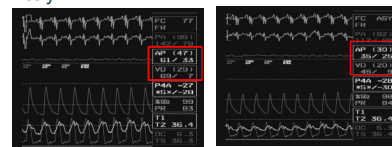
- 3-↑ Rrv: intrinsic obstruction and compartment syndrome (pericardial, mediastinal, thoracic, abdominal)

### Hemodynamic effect of hypoxia



- 48 yo ♂ with ischemic cardiomyopathy
- Systemic désaturation post-CPB with pulmonary hypertension
- Rx: PEEP and nitroglycerine

NIRS brain oximetry

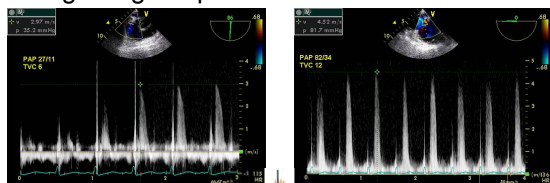


During hypoxia

After hypoxia

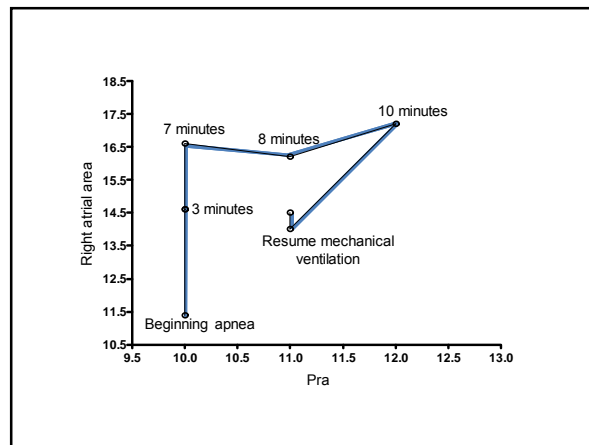
Beginning of apnea

10 minutes after

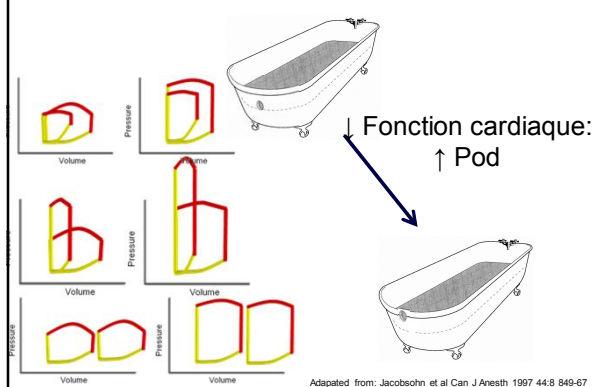


10 minutes after

Ventilation restarted



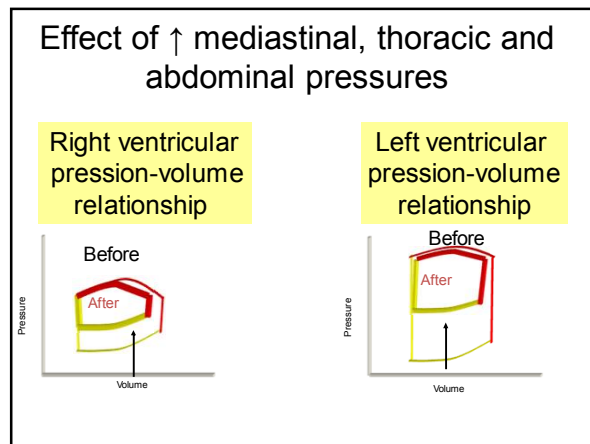
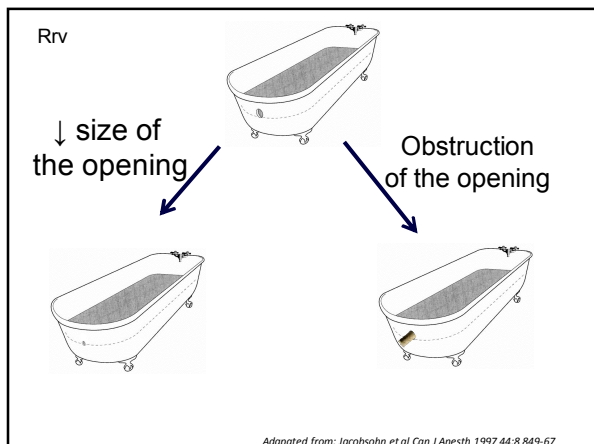
### Pression de l'oreillette droite



### Most common condition associated with hemodynamic instability

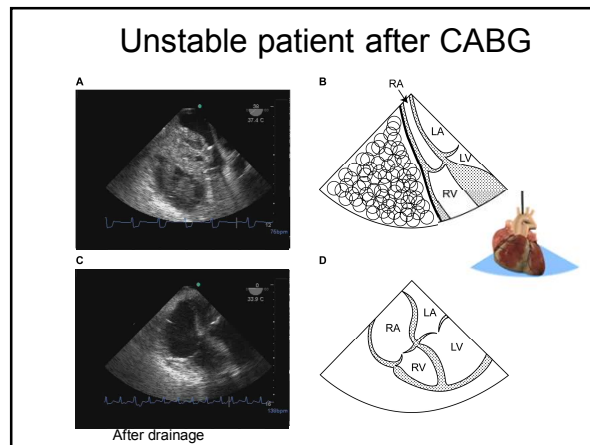
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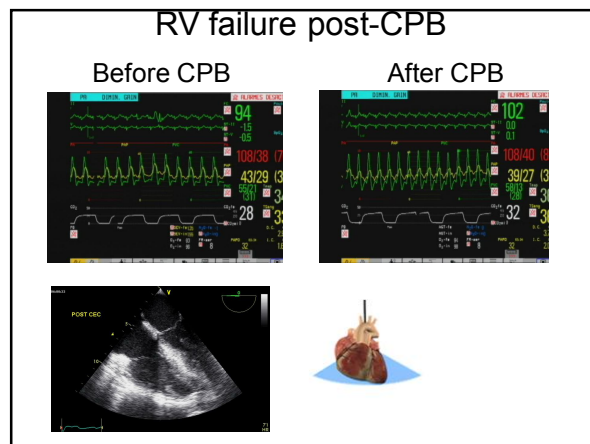
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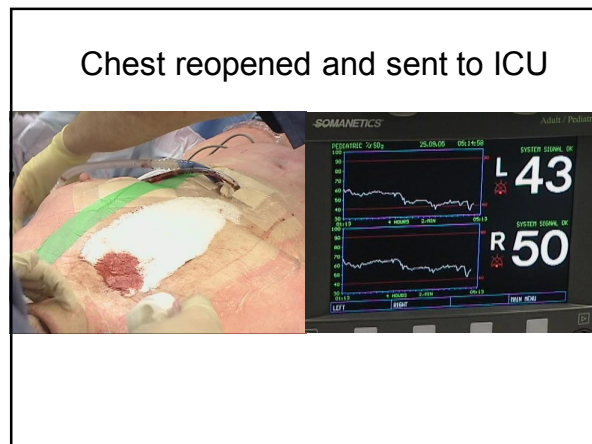
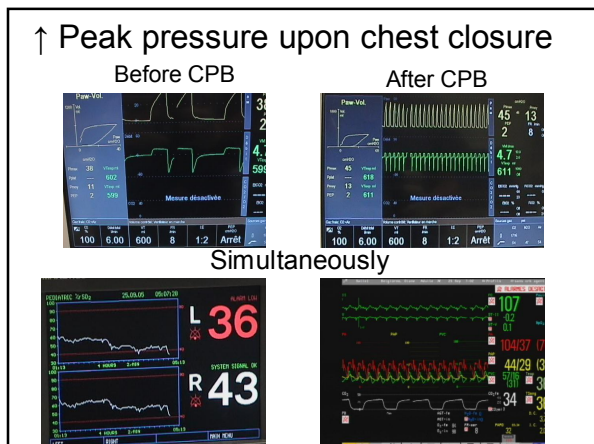
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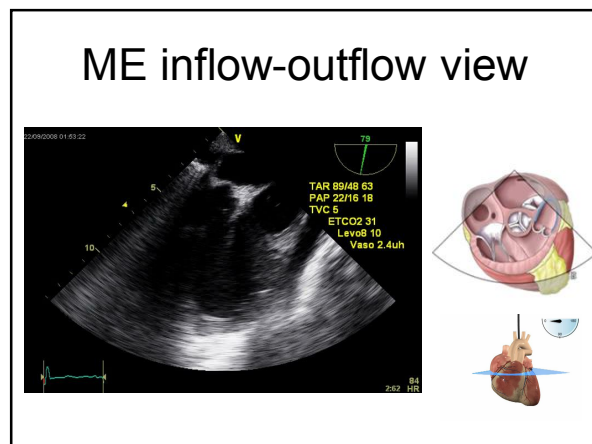
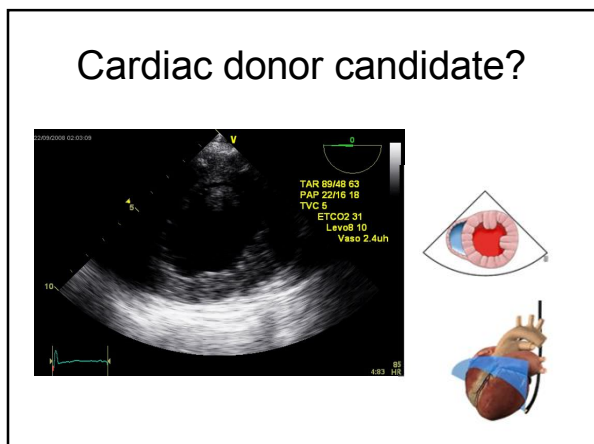


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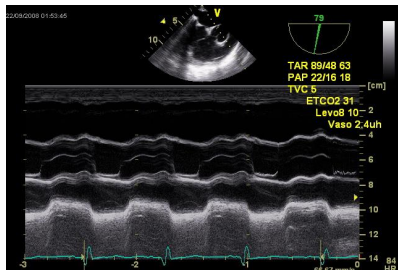
19 yo ♂ polytrauma transferred to our ICU: organ donation

HR	84 beats/min
Pa (radial)	89/48 63 mmHg
PAP	22/16 18 mmHg
Pra	5 mmHg
ETCO <sub>2</sub>	31 mmHg
Noradrenaline	5.3 ug/min + vaso 2.4 units/h
Unchanged since transfer	



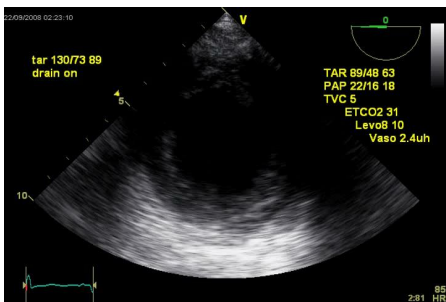
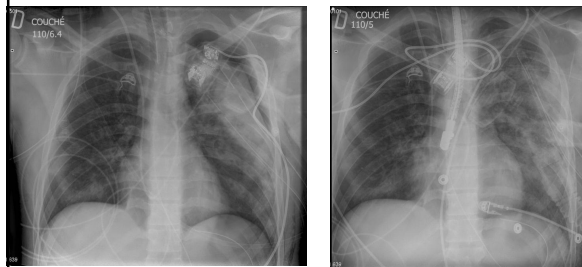


M-Mode: **diastolic** right ventricular outflow tract obstruction

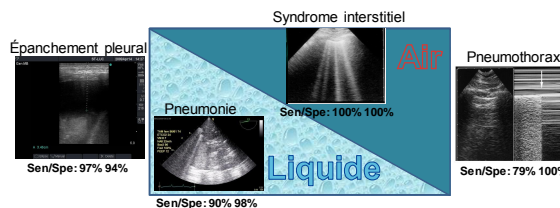


Chest radiograph

Before chest tube      After chest tube on



Contenu pulmonaire



Most common condition associated with hemodynamic instability

- 1-↓ Pms: hypovolemia, vasodilatation
- 2-↑ Pra: Left and right systolic dysfunction  
Left and right diastolic dysfunction  
Left and right outflow tract obstruction  
Pulmonary emboli  
Hypoxia and hypercapnia
- 3-↑ Rrv: intrinsic obstruction and compartment syndrome (pericardial, mediastinal, thoracic, abdominal)

65 yo ♀ unstable after induction: difficult intubation. Treatment?



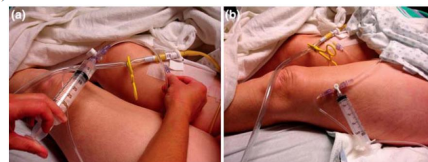


Can J Anesth/J Can Anesth (2009) 56:678-682  
DOI 10.1007/s12630-009-9140-8

PERIOPERATIVE CARDIOVASCULAR ROUNDS

**Acute abdominal compartment syndrome**

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



63 yo ♂ ans with cirrhosis in shock after UGI endoscopy

Noradrenaline (8 mg/250 at 100 ml/h) = 53 µg/min

Noradrenalin (8mg/250 at 10 ml/h) = ↓5.3 µg/min

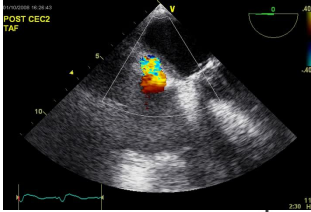


42 yo ♀ HR 155, acidosis, hypoxic and abdominal pressure of 31 mmHg: removal of 2.5 L

**Most common condition associated with hemodynamic instability**

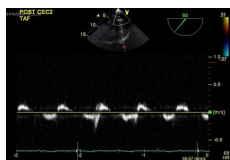
- 1-↓ Pms: hypovolemia, vasodilatation
- 2-↑ Pra: Left and right systolic dysfunction  
Left and right diastolic dysfunction  
Left and right outflow tract obstruction  
Pulmonary emboli  
Hypoxia and hypercapnia
- 3-↑ Rrv: **intrinsic obstruction** and compartment syndrome (pericardial, mediastinal, thoracic, abdominal)

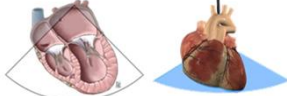
**75 yo ♂ complex re-operation (AVR, MVR): unstable +++++**



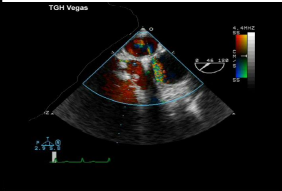
POST CEC2  
TAF

**Hepatic venous flow**

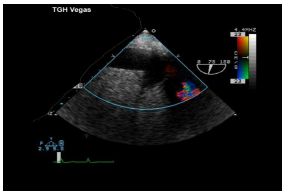





**Similar case in Toronto General Hospital**



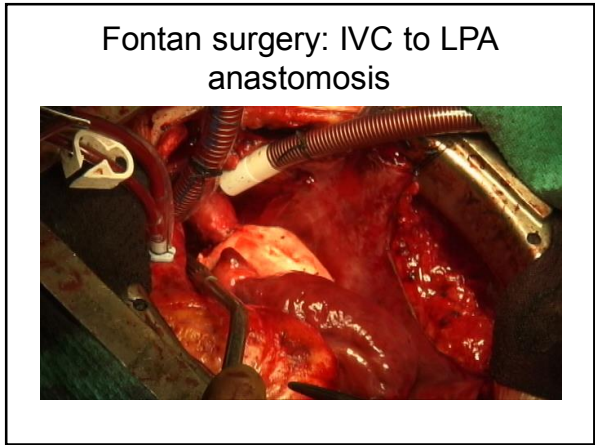
TGH Vegas



TGH Vegas




Courtesy Dr. A. Vegas




**Hemodynamically unstable from iatrogenic IVC stenosis**

**Before**



103 HR  
2:39

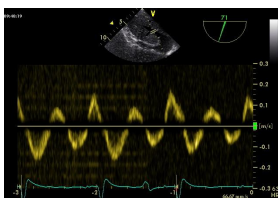
**After correction**



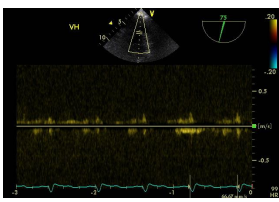
102 HR  
2:48

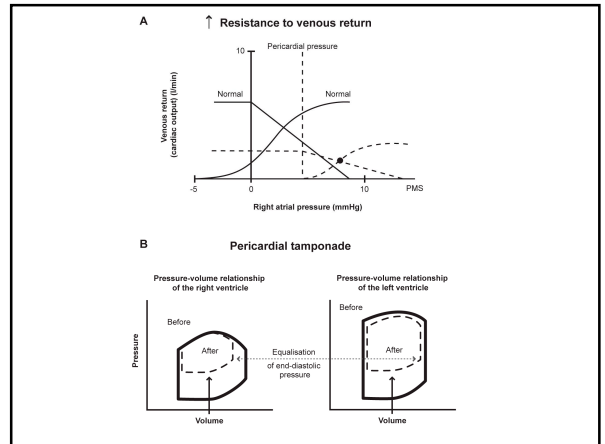
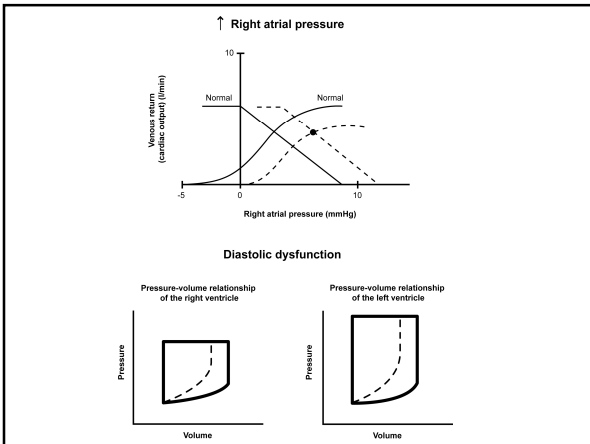
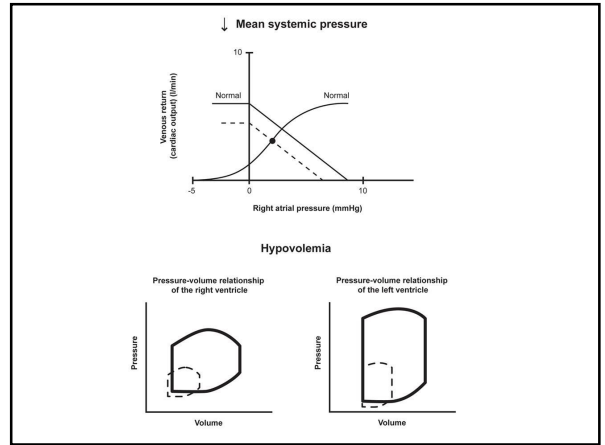
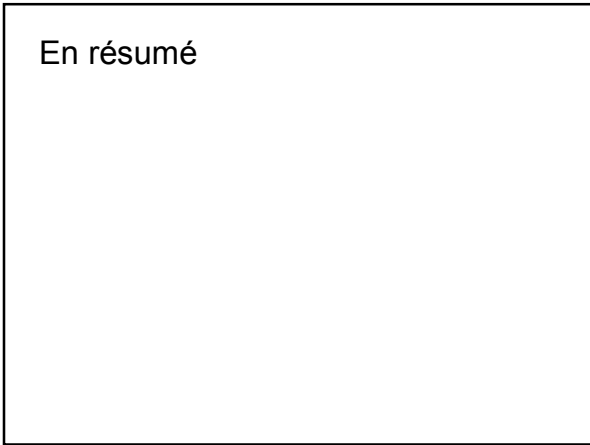
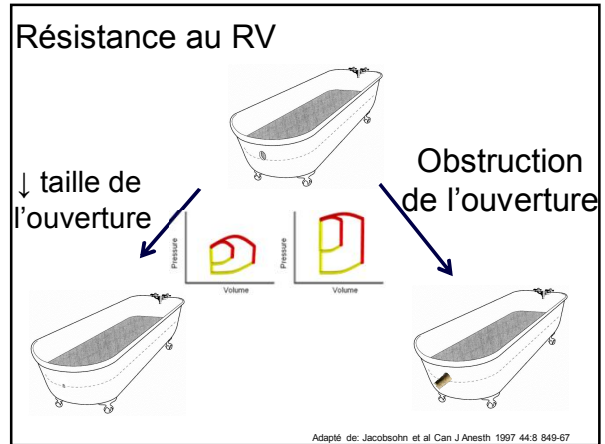
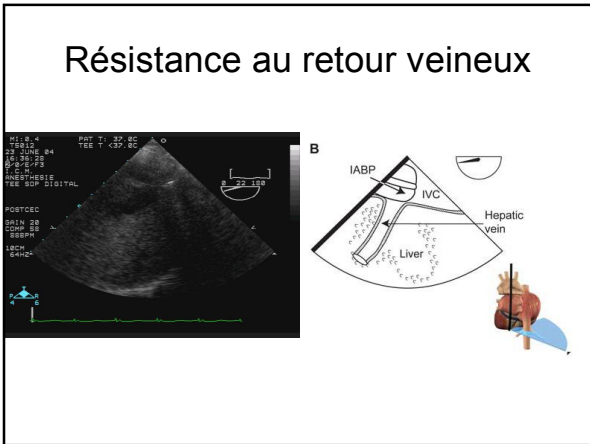
**Hemodynamically unstable from iatrogenic IVC stenosis**

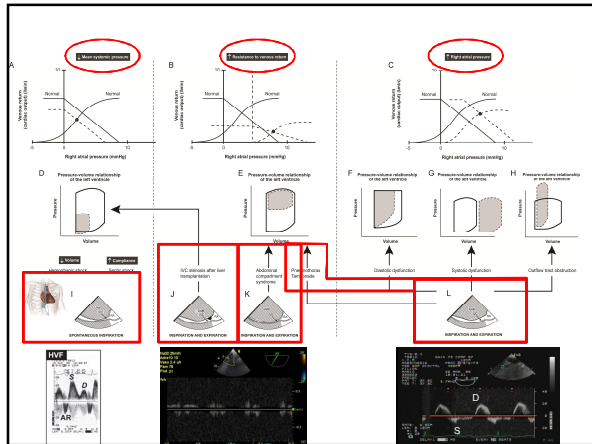
**HVF before CPB**



**HVF after CPB**







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Assistant de recherche

Remerciements