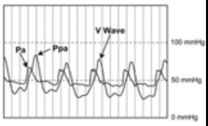
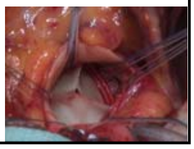


Instabilité hémodynamique

André Denault FRCPC, CSPQ, ABIM-CCM
Professeur agrégé de clinique
Département d'anesthésiologie
Institut de Cardiologie de Montréal
Service des soins intensifs
Centre Hospitalier Universitaire de Montréal

Cours de science de base
2007

Université de Montréal



Support and disclosure

- **Fondation de la Recherche en Santé du Québec**
- **CAS/Abbott Laboratories Ltd Career in Anesthesia**
- **Montreal Heart Institute Foundation**
- **Consultant for Actelion**

Instituts de recherche en santé du Canada / Canadian Institutes of Health Research

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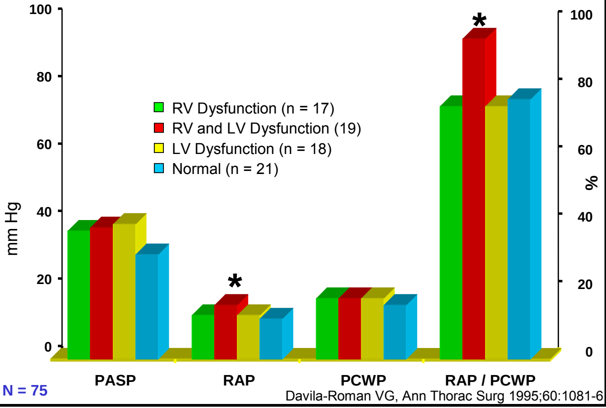
Diagnosis

Étiology of hemodynamic instability in cardiac surgery

Right Ventricular Dysfunction in Low Output Syndrome After Cardiac Operations: Assessment by TEE



N = 75

Davila-Roman VG, Ann Thorac Surg 1995;60:1081-6

The hemodynamically unstable patient in the intensive care unit: Hemodynamic vs. transesophageal echocardiographic monitoring

Tudor Costachescu, MD, FRCPC; André Denault, MD, FRCPC; Jean-Gilles Guimond, MD, FRCPC; Pierre Couture, MD, FRCPC; Stéphane Carignan, MD, FRCPC; Peter Sheridan, MD, FRCPC; Gisèle Hellou, MD, FRCPC; Louis Blair, MD, FRCPC; Louis Normandin, MD, FRCPC; Denis Babin, MSc; Martin Allard; François Harel, MSc; Jean Buithieu, MD, FRCPC

Society of Critical Care Medicine

Critical Care Medicine 2002

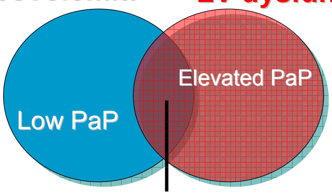
The hemodynamically unstable patient in the intensive care unit: Hemodynamic vs TEE monitoring

Admission	SICU 2hr	SICU 4hr
0.33	0.47	0.28
Kappa	Kappa	Kappa

Diagnostic concordance

Limitations of the Swan-Ganz catheter

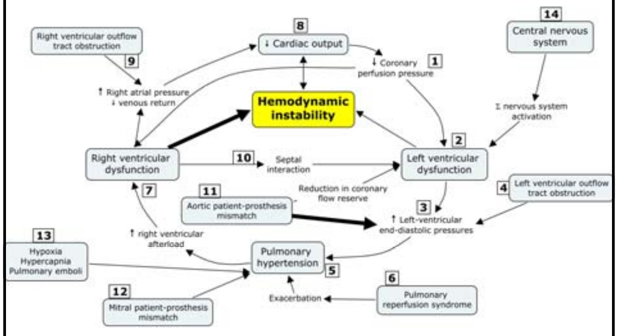
Hypovolemia **LV dysfunction**

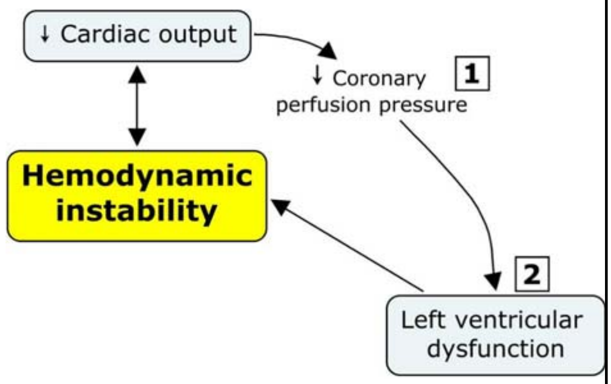


Echographic diagnosis

48 evaluations had
2 causes of hemodynamic instability or more (82%)
72% diastolic dysfunction
45% RV systolic dysfunction
38% LV systolic dysfunction
29% hypovolemia

Our hypothesis





ASE COMMITTEE RECOMMENDATIONS

Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology

Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, Michelle Bierig, MPH, RDCS, FASE, Richard B. Devereux, MD, Frank A. Flachskampf, MD, Elyse Foster, MD, Patricia A. Pellikka, MD, Michael H. Picard, MD, Mary J. Roman, MD, James Seward, MD, Jack S. Shanewise, MD, FASE, Scott D. Solomon, MD, Kirk T. Spencer, MD, FASE, Martin St John Sutton, MD, FASE, and William J. Stewart, MD

Journal of the American Society of Echocardiography

2005

LV hypertrophy: wall thickness

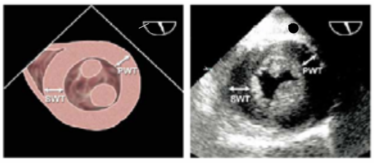
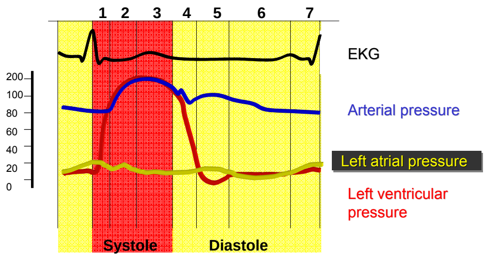


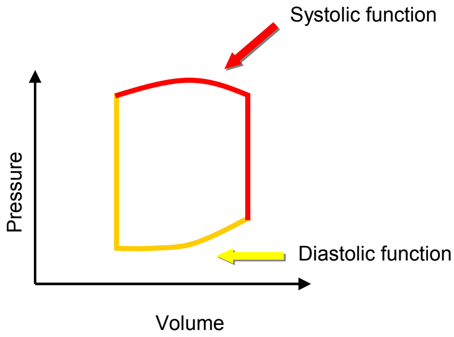
Figure 4 Transesophageal echocardiographic measurements of wall thickness of left ventricular (LV) septal wall (*SWT*) and posterior wall (*PWT*) from transgastric short-axis view of LV, at papillary muscle level, usually best imaged at angle of approximately 0 to 30 degrees.

Table 4 Reference limits and partition values of left ventricular mass and geometry

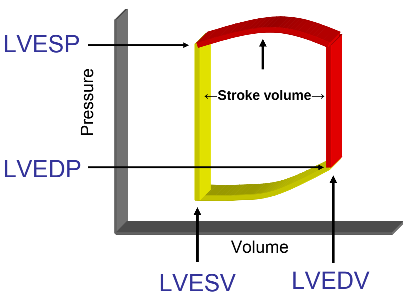
	Women				Men			
	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal
Septal thickness, cm	*0.6–0.9*	*1.0–1.2*	*1.3–1.5*	≥*1.6*	*0.6–1.0*	*1.1–1.3*	*1.4–1.6*	≥*1.7*
Posterior wall thickness, cm	*0.6–0.9*	*1.0–1.2*	*1.3–1.5*	≥*1.6*	*0.6–1.0*	*1.1–1.3*	*1.4–1.6*	≥*1.7*

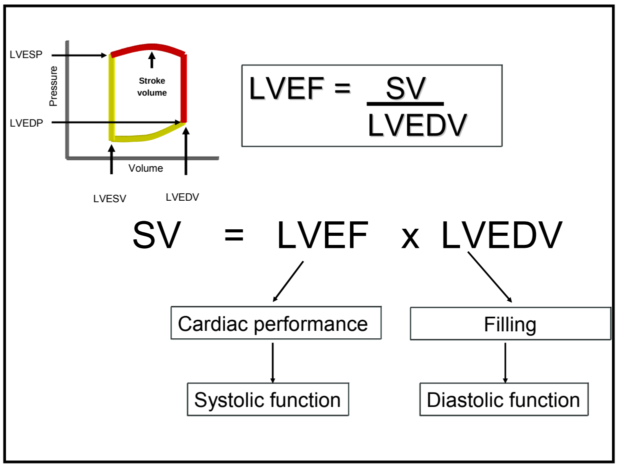


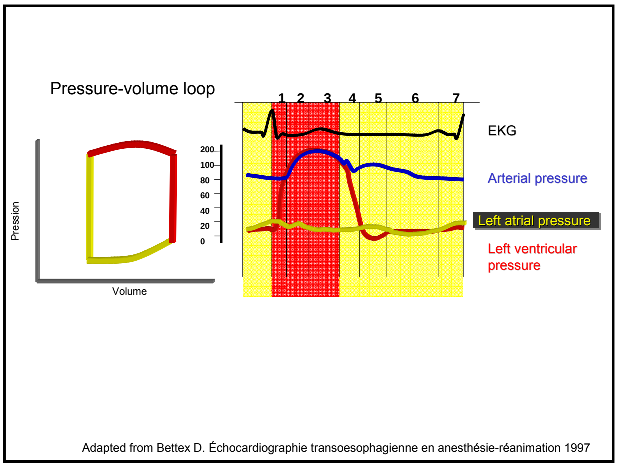
Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997

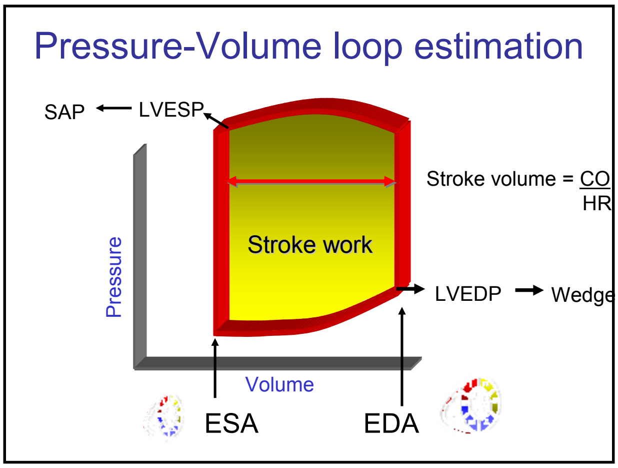


Pressure-Volume loop




LVESP
Pressure
Stroke volume
LVEDP
Volume
LVESV
LVEDV
LVEF = SV / LVEDV
SV = LVEF x LVEDV
Cardiac performance
Filling
Systolic function
Diastolic function

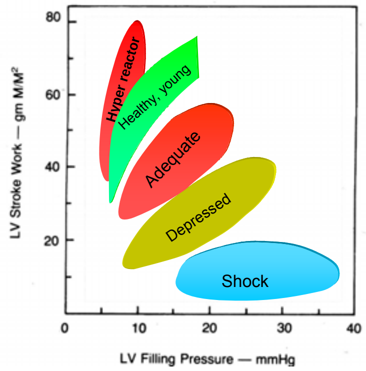

Pressure-volume loop
Pression
Volume
200
100
80
60
40
20
0
1 2 3 4 5 6 7
EKG
Arterial pressure
Left atrial pressure
Left ventricular pressure
Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997


Pressure-Volume loop estimation
SAP
LVESP
Stroke volume = CO / HR
Stroke work
Pressure
LVEDP
Wedge
Volume
ESA
EDA

LV performance

- Load dependant
  - ✓ Cardiac output
  - ✓ LVEF and FAC
  - ✓ LV stroke work
  - ✓ dP/dT
  - ✓ Myocardial Performance Index
- Load independent
  - ✓ Elastance

LV stroke work



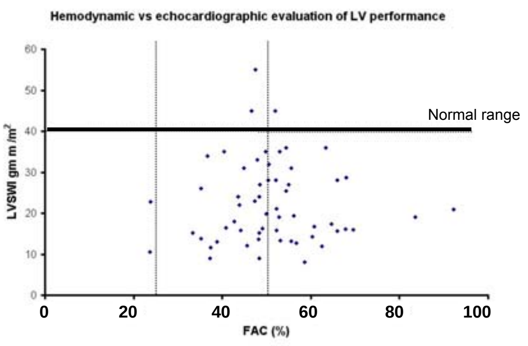
Adapted from Shoemaker Textbook of critical care Saunders 1989

Poor correlation between hemodynamic and echocardiographic indexes of left ventricular performance in the operating room and intensive care unit

Marie-Josée Bouchard, MD; André Denault, MD; Pierre Couture, MD; Marie-Claude Guertin, PhD; Denis Babin, MSc; Paul Ouellet, RRT, FCCM; Michel Carrier, MD; Jean-Claude Tardif, MD

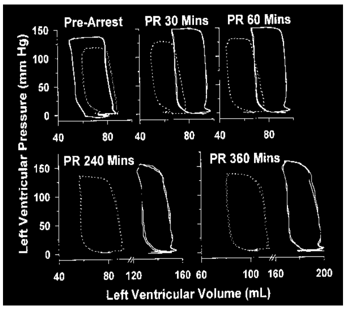
Society of Critical Care Medicine

Critical Care Medicine 2004



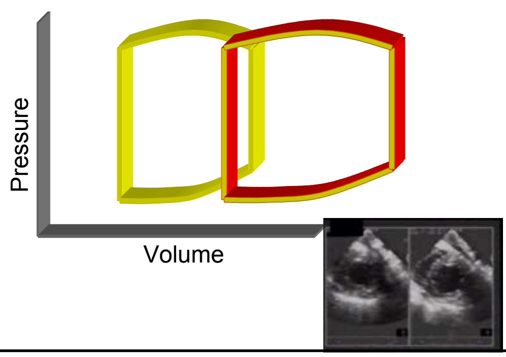
Bouchard et al CCM 2004

Myocardial dysfonction after sucessful resuscitation from cardiac arrest



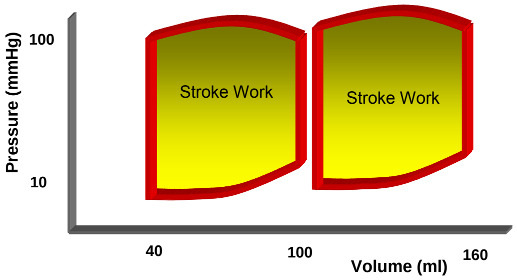
Gazmuri RJ et al. CCM 1996

Left ventricular dysfunction



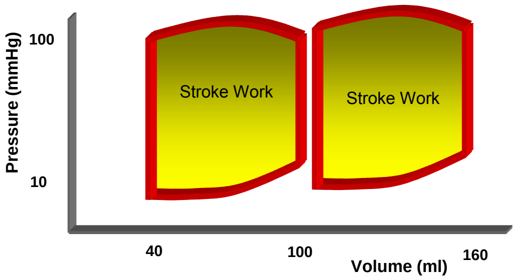
Limitation of LVSW measurement

Stroke volume	60 ml	60 ml
LVSW (X 0.0136)	60 X (100-10)	60 X (100-10)

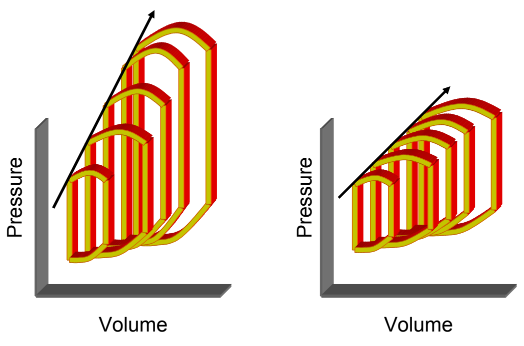


Limitation of LVSW measurement

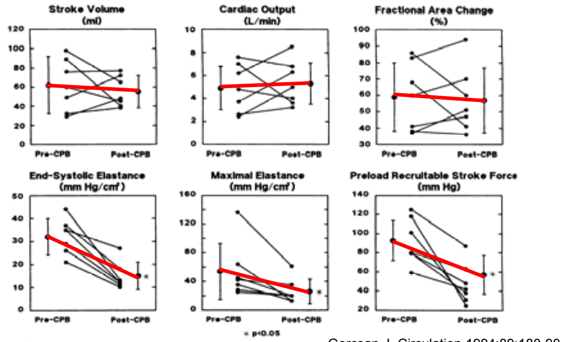
LVEF	60 ml/100ml = 60%	60 ml/160ml = 40%



Contractility

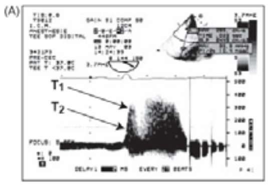


Assessment of the immediate effects of cardiopulmonary bypass on left ventricular performance by on-line pressure-area relations

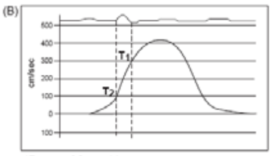


Gorcsan J. Circulation 1994;89:180-90

dP/dT



$(T_1 - T_2) = 0.023$ sec



$\frac{dP}{dt} = \frac{32 \text{ mmHg}}{(T_1 - T_2) \text{ sec}}$

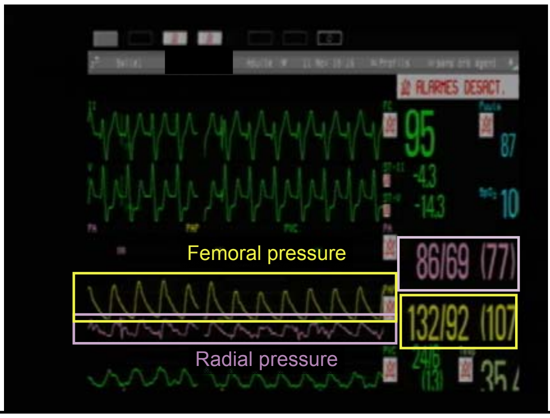
(normal > 1200 mmHg/sec)

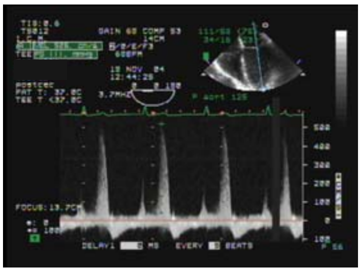
T_1 : time at 300 cm/sec on the CW velocity profile which correspond to 36 mmHg pressure gradient

T_2 : time at 100 cm/sec on the CW velocity profile which correspond to 4 mmHg pressure gradient

1-Estimation of LV function in mitral regurgitation
2-Estimation of left atrial systolic pressure
3-Estimation of systolic arterial pressure: is your radial arterial pressure reliable?

69 yo woman after MVR and AVR





Radial pressure
= 111 mmHg

Aortic pressure
measured by surgeon
= 125 mmHg

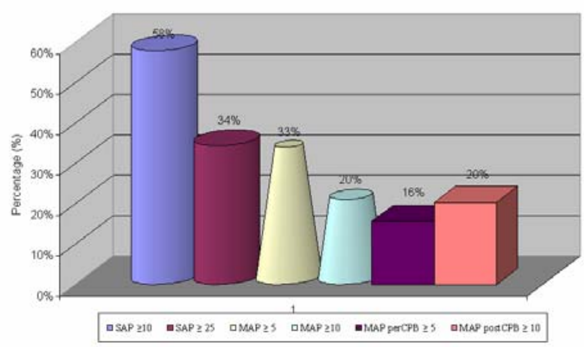
Presssure gradient = 111 mmHg
= LVESP - LAP

LV systolic pressure = PG + LAP ≈ Aortic pressure
= 111 mmHg + pulmonary artery wedge pressure (v wave)
= 111 mmHg + 18 mmHg
Aortic pressure = 129 mmHg

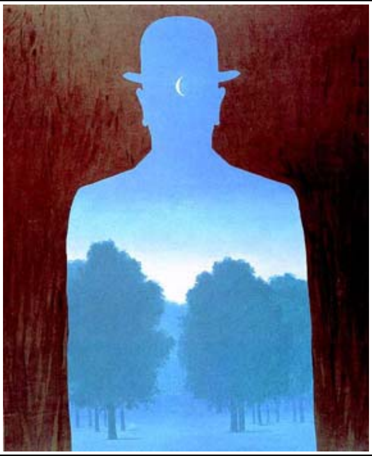
Prevalence of a central to radial pressure gradient in high-risk surgery

Dr Antonio Su

Percentage of central-to-radial gradients in complex surgeries



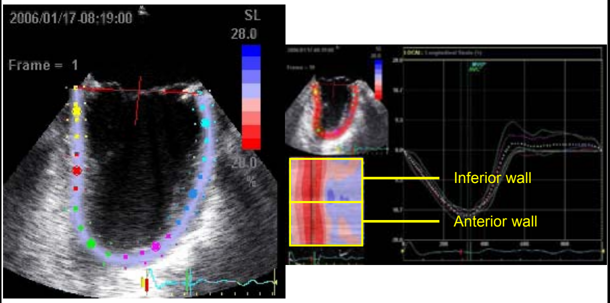
N = 60

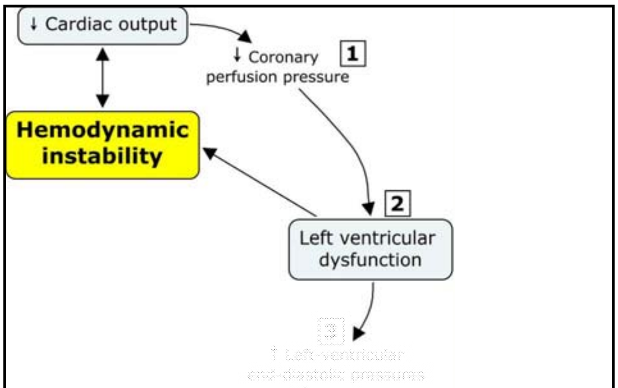


René Magritte

Why is this patient hemodynamically unstable?

2D Longitudinal strain rate

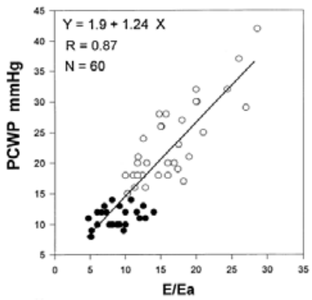




Doppler Tissue Imaging: A Noninvasive Technique for Evaluation of Left Ventricular Relaxation and Estimation of Filling Pressures

SHERIF F. NAGUEH, MD, KATHERINE J. MIDDLETON, RCT, HELEN A. KOPELEN, RDMS, WILLIAM A. ZOGHBI, MD, FACC, MIGUEL A. QUIÑONES, MD, FACC

Houston, Texas



JACC 1997

Left ventricular end-diastolic pressure is a predictor of mortality in cardiac surgery independently of left ventricular ejection fraction

R. Salem[1], A. Y. Denault[1]*, P. Couture[1], S. Bélisle[1], A. Fortier[2], M.-C. Guertin[2], M. Carrier[3] and R. Martineau[1]

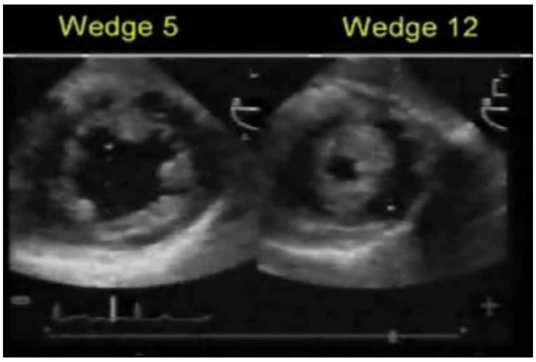
[1]Department of Anesthesiology, [2]Department of Biostatistics and [3]Department of Surgery, Montreal Heart Institute, Montreal, Quebec, H1T 1C8, Canada

Table 2 Multivariate analysis: mortality. CI, confidence interval; LVEDP, left ventricular end-diastolic pressure; LVEF, left ventricular ejection fraction; CPB, cardiopulmonary bypass

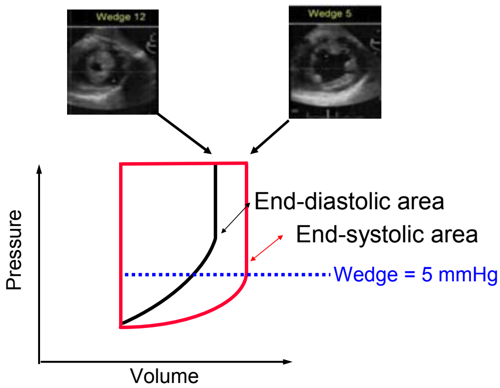
Predictors	*P*-value	Units	Odds ratio	95% CI
Age	<0.0001	20	4.255	2.461–7.355
Weight (kg)	0.0403	–10	1.190	1.008–1.404
LVEDP	0.0062	5	1.195	1.052–1.357
LVEF	0.0002	–10	1.326	1.145–1.535
CPB duration (min)	<0.0001	30	1.813	1.608–2.044
Re-operation	<0.0001	–	2.669	1.636–4.354
Hypertension	0.0211	–	1.687	1.082–2.632
Treated diabetes	0.0277	–	1.759	1.064–2.906

N = 3024

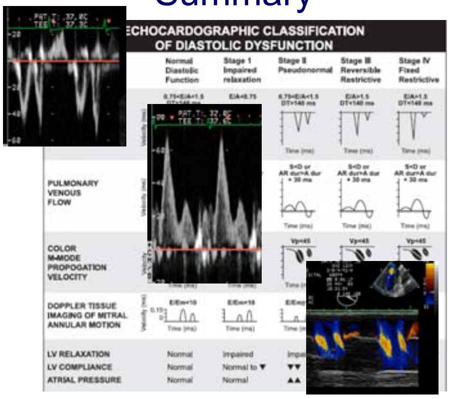
British Journal Anesthesia 2006



Diastolic dysfunction



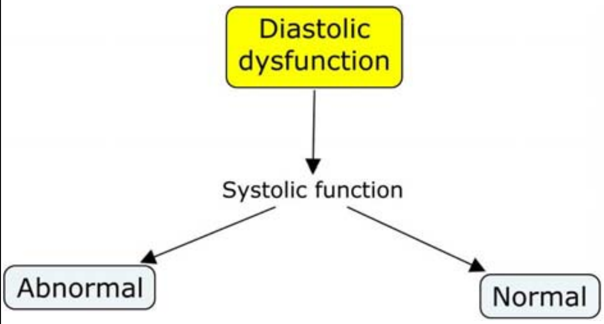
Summary

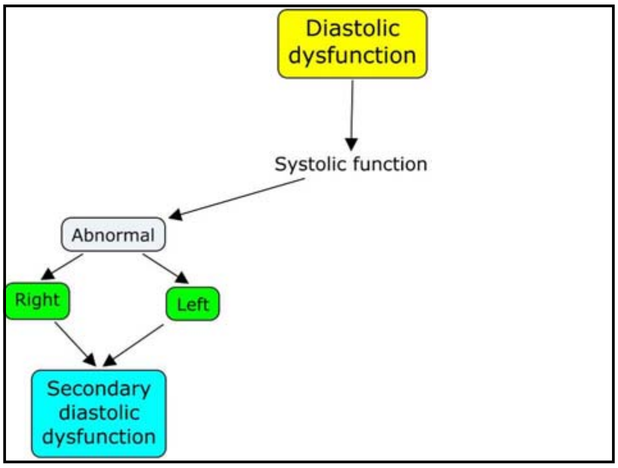


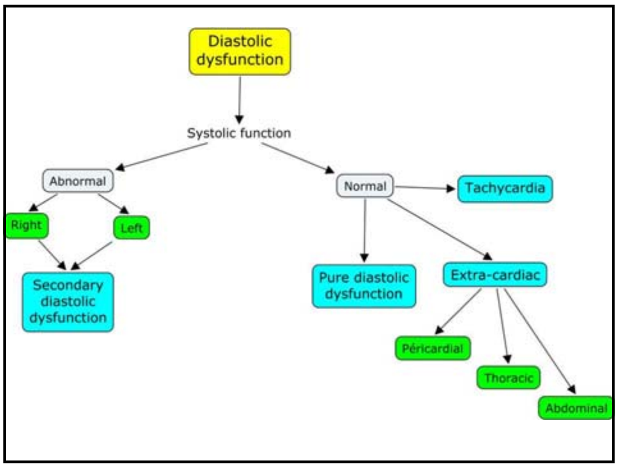
Adapté de Khoury et al JASE 2004

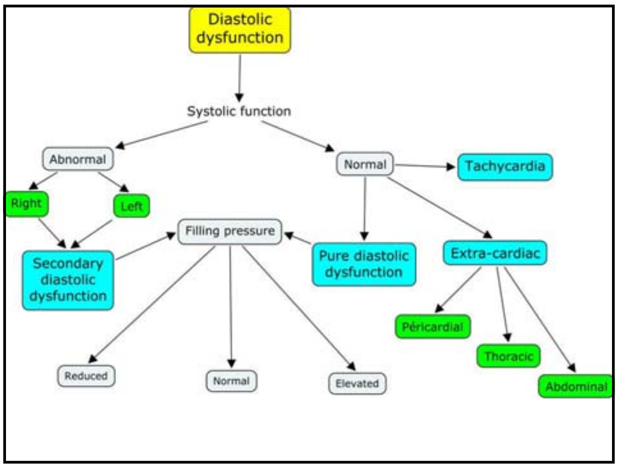
Evaluation of diastolic filling of left ventricle in health and disease: Doppler echocardiography is the clinician's Rosetta Stone

Nishimura RA JACC 1997




Diastolic dysfunction
Systolic function
Abnormal
Right
Left
Secondary diastolic dysfunction


Diastolic dysfunction
Systolic function
Abnormal
Normal
Tachycardia
Right
Left
Secondary diastolic dysfunction
Pure diastolic dysfunction
Extra-cardiac
Péricardial
Thoracic
Abdominal


Diastolic dysfunction
Systolic function
Abnormal
Normal
Tachycardia
Right
Left
Filling pressure
Secondary diastolic dysfunction
Pure diastolic dysfunction
Extra-cardiac
Péricardial
Thoracic
Abdominal
Reduced
Normal
Elevated

CARDIOVASCULAR ANESTHESIA
SECTION EDITOR
KENNETH J. TUMAN

SOCIETY OF CARDIOVASCULAR ANESTHESIOLOGISTS

Diastolic Dysfunction is Predictive of Difficult Weaning from Cardiopulmonary Bypass

Francis Bernard, MD*, André Denault, MD, FRCPC†, Denis Babin, MSc†, Caroline Goyer, MD†, Pierre Couture, MD, FRCPC†, André Couturier, MSc†, and Jean Buithieu, MD, FRCPC*‡

Departments of *Medicine and ‡Cardiology, CHUM, Notre-Dame Hospital; and †Department of Anesthesia, Montreal Heart Institute Montreal, Quebec, Canada

Anesth Analgesia 2001;92:291-8

Cardiothoracic Anesthesia, Respiration and Airway

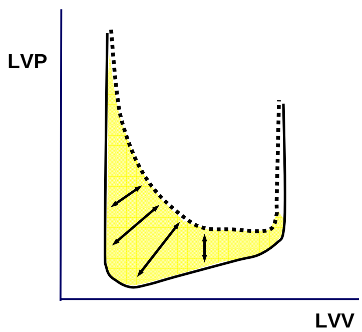
Left and right ventricular diastolic dysfunction as predictors of difficult separation from cardiopulmonary bypass

[La dysfonction ventriculaire diastolique gauche et droite comme prédicteur des difficultés de sevrage de la circulation extracorporelle]

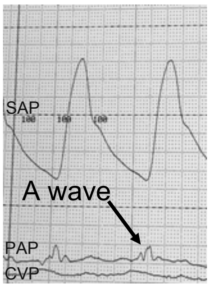
André Y. Denault MD FRCPC,* Pierre Couture MD FRCPC,* Jean Buithieu MD FRCPC,¶ Francois Haddad MD FRCPC,* Michel Carrier MD FRCPC,‡ Denis Babin MSc,* Sylvie Levesque MSc,§ Jean-Claude Tardif MD FRCPC†

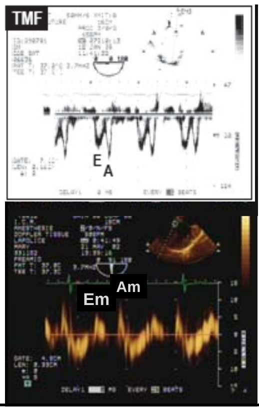
Canadian J Anesthesia 2006

Grade I: relaxation abnormality

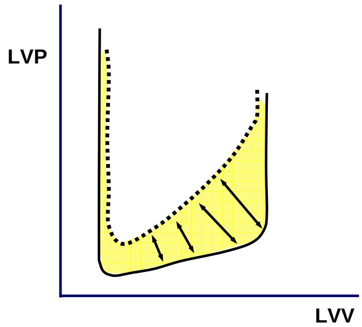


76 yo woman with aortic stenosis





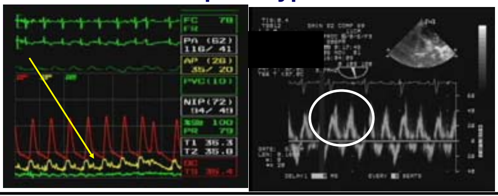
Grade III: Increased Chamber Stifness



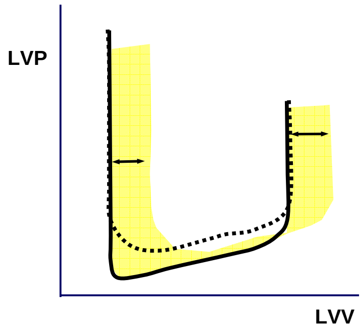
62 yo patient unstable after AVR

Beginnning post-bypass

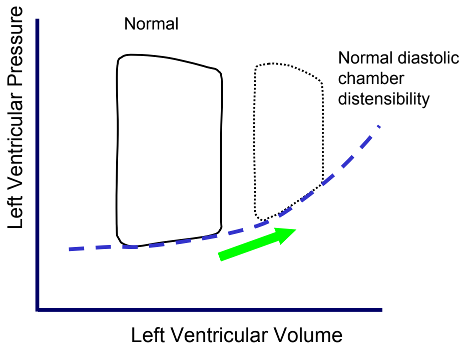
End post-bypass



Chamber Dilatation



Systolic Failure



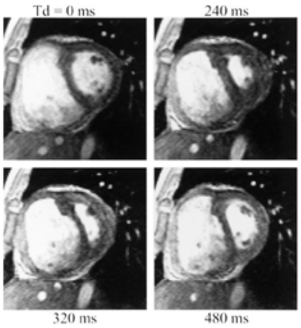
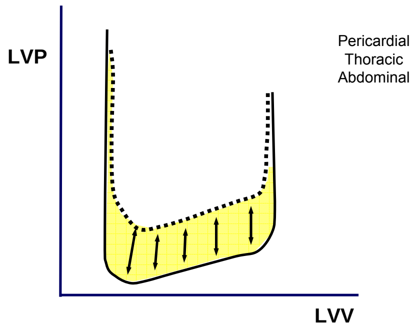


FIGURE 1. Short-axis cine frames at different trigger delays (Td) during the cardiac cycle in a patient with PPH. In early diastole (Td = 320), the ventricular septum bows to the left.

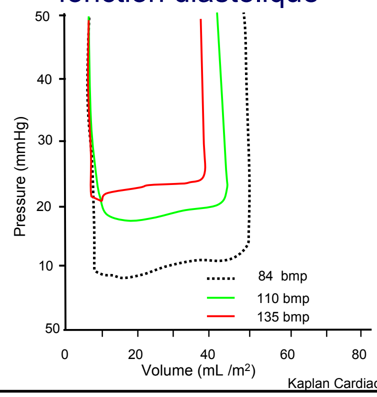
Impaired Left Ventricular Filling Due to Right Ventricular Pressure Overload in Primary Pulmonary Hypertension* Noninvasive Monitoring Using MRI

Marcus JT Chest 2001;119:1761-5

Pericardial Restraint



Effet de la fréquence cardiaque sur la fonction diastolique



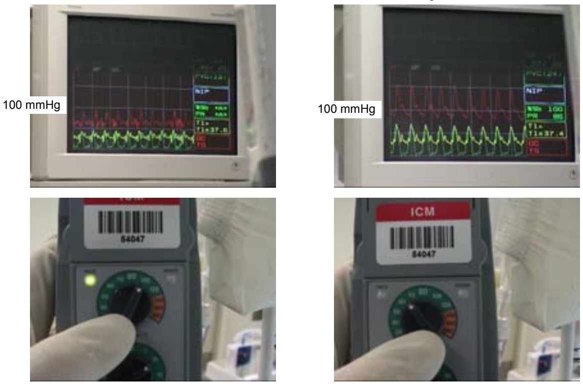
Kaplan Cardiac anesthesia 1998

Hemodynamically unstable after cardiac surgery: paced

Slow down the pacemaker

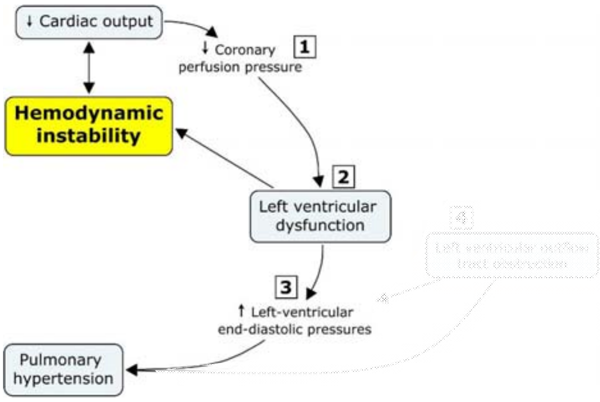
Hemodynamically unstable after cardiac surgery

Homme de 70 ans instable après RVA

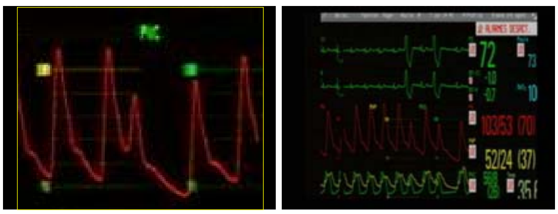


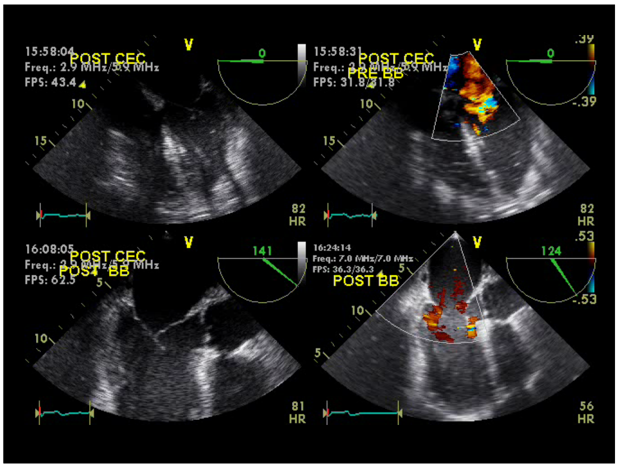
Noradrenaline 4ug/min

Noradrenaline 0.5 ug/min

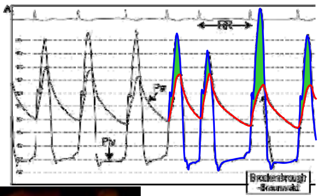


Unexpected hemodynamic instability. What happened?



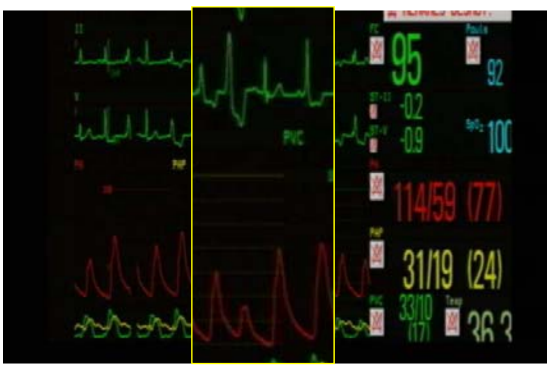


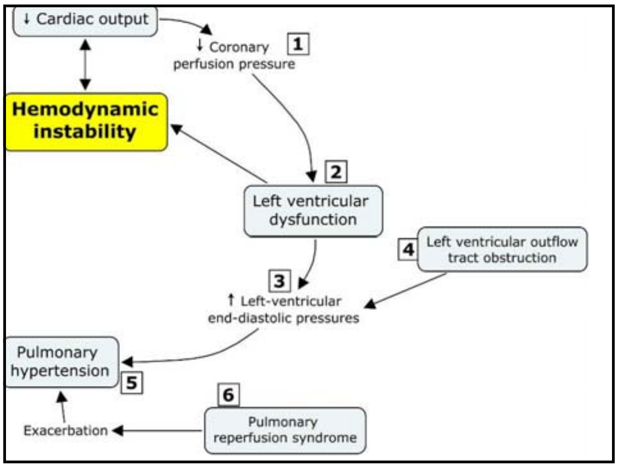
LVOT obstruction



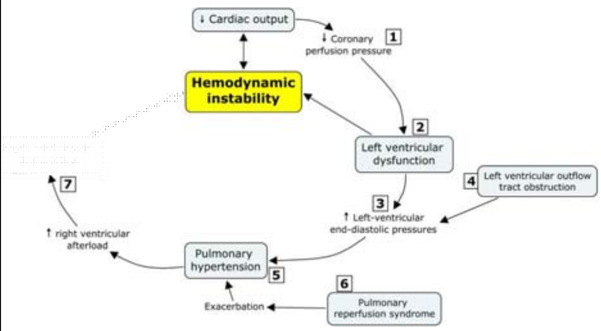
Courtesy of Gaudiani

Normally





Fearful consequence



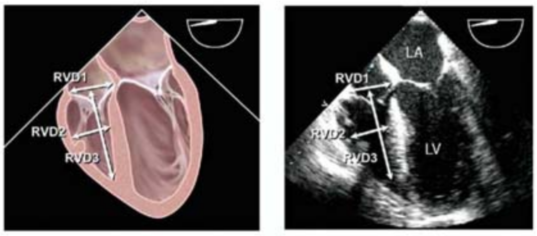


Table 7 Reference limits and partition values of right ventricular and pulmonary artery size

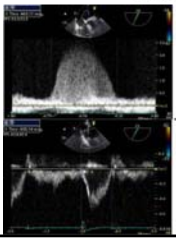
	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal
RV dimensions (Figure 12)				
Basal RV diameter (RVD 1), cm	2.0–2.8	2.9–3.3	3.4–3.8	≥3.9
Mid-RV diameter (RVD 2), cm	2.7–3.3	3.4–3.7	3.8–4.1	≥4.2
Base-to-apex length (RVD 3), cm	7.1–7.9	8.0–8.5	8.6–9.1	≥9.2
RVOT diameters (Figure 13, 14)				
Above aortic valve (RVOT 1), cm	2.5–2.9	3.0–3.2	3.3–3.5	≥3.6
Above pulmonic valve (RVOT 2), cm	1.7–2.3	2.4–2.7	2.8–3.1	≥3.2
PA diameter				
Below pulmonic valve (PA 1), cm	1.5–2.1	2.2–2.5	2.6–2.9	≥3.0

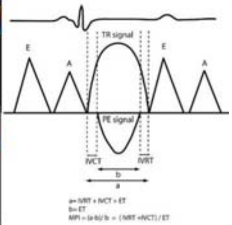
RV, Right ventricular; *RVOT*, right ventricular outflow tract; *PA*, pulmonary artery.
Data from Foale et al.[78]

With permission from Lang et al JASE 2005;18:1440-1463

Right Ventricular Myocardial Performance Index Predicts Perioperative Mortality or Circulatory Failure in High-Risk Valvular Surgery

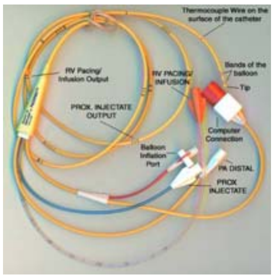
François Haddad, MD, André Y. Denault, MD, Pierre Couture, MD, Raymond Cartier, MD, Michel Pellerin, MD, Sylvie Levesque, MSc, Jean Lambert, PhD, and Jean-Claude Tardif, MD, *Montreal, Quebec, Canada*





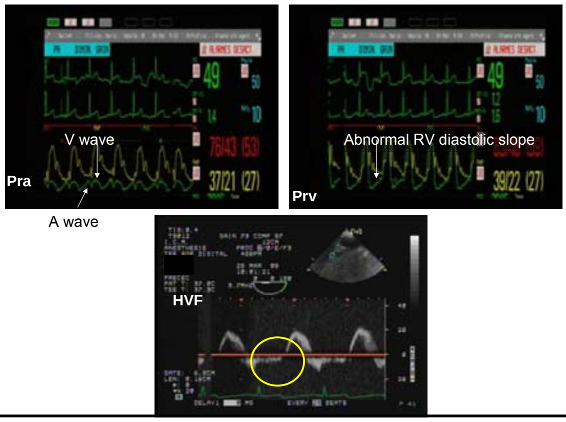
JASE 2007 (In press)

Right ventricular pressure monitoring

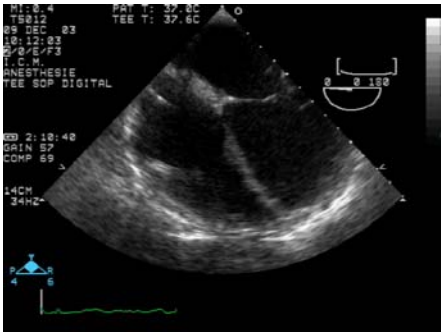


ME: Normal RV waveform

RA and RV pressure waveform correlation



56 yo woman: CABG, MVR and LV remodeling

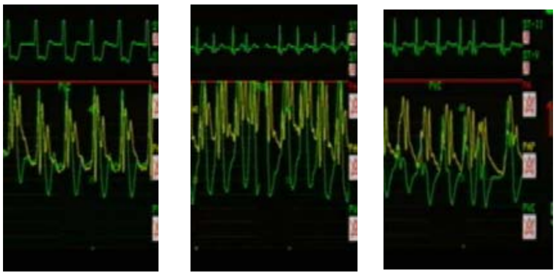


Effect of adrenalin and thoracic closure

End of CPB

Adrenalin

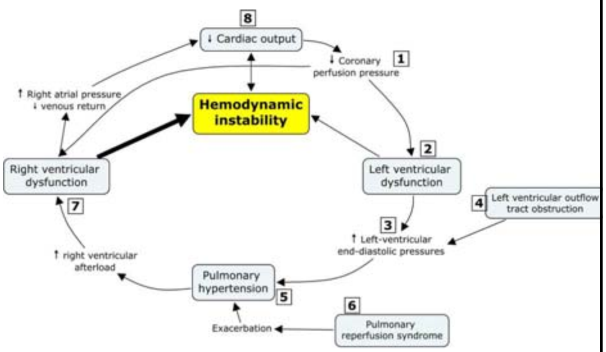
Thoracic closure



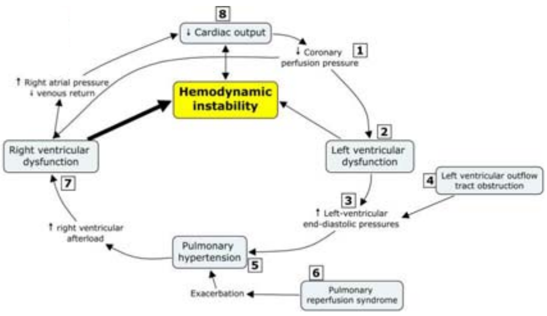
Évolution ScO2

Effect of adrenalin upon weaning from CPB

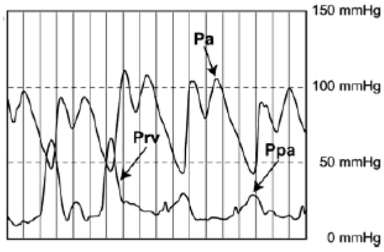
RV dysfunction impact



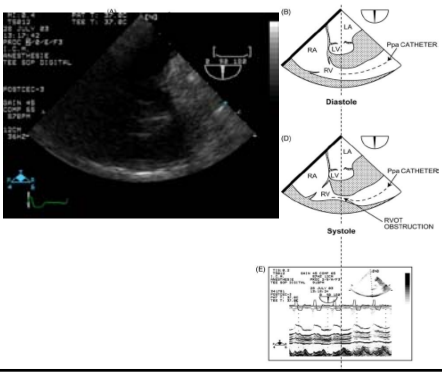
Another confounding factor


8
↓ Cardiac output
↓ Coronary perfusion pressure
1
↑ Right atrial pressure
↓ venous return
Hemodynamic instability
2
Right ventricular dysfunction
Left ventricular dysfunction
4
Left ventricular outflow tract obstruction
7
3
↑ Left-ventricular end-diastolic pressures
↑ right ventricular afterload
Pulmonary hypertension
5
6
Exacerbation
Pulmonary reperfusion syndrome

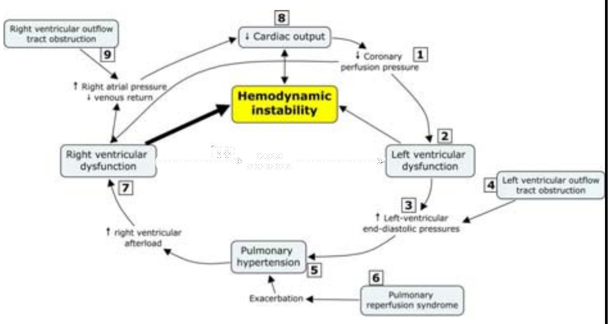
Right ventricular outflow tract obstruction



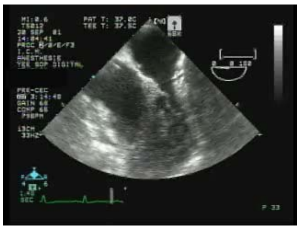
Right ventricular outflow tract obstruction

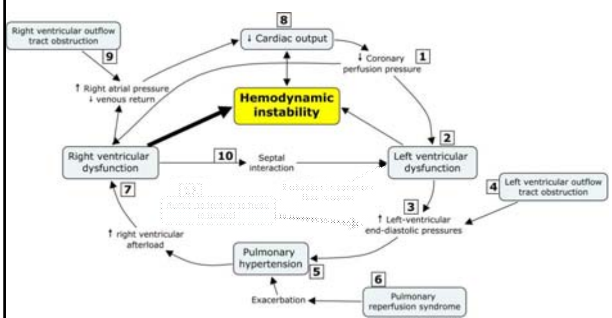


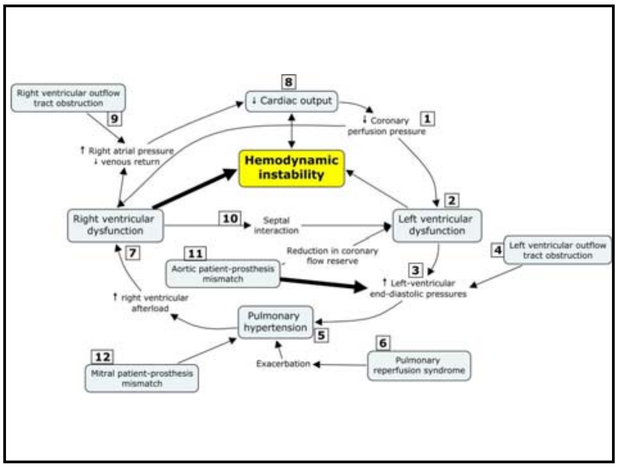
Right ventricular outflow tract obstruction



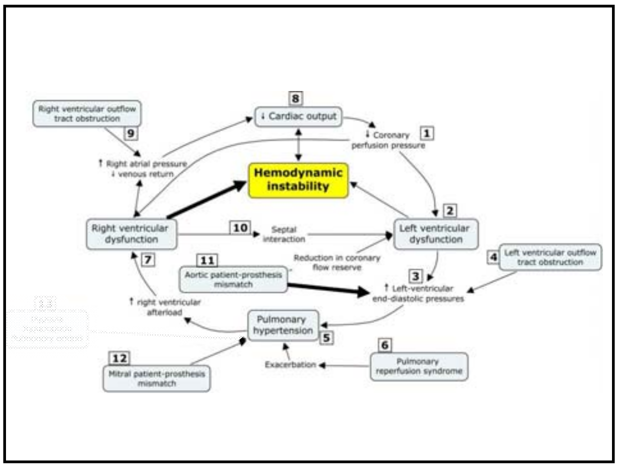
Septal interaction







Right ventricular outflow tract obstruction
9
8
↓ Cardiac output
↓ Coronary perfusion pressure
1
↑ Right atrial pressure ↓ venous return
Hemodynamic instability
2
Right ventricular dysfunction
10
Septal interaction
Left ventricular dysfunction
7
11
Reduction in coronary flow reserve
4
Left ventricular outflow tract obstruction
Aortic patient-prosthesis mismatch
3
↑ Left-ventricular end-diastolic pressures
↑ right ventricular afterload
Pulmonary hypertension
5
6
12
Exacerbation
Pulmonary reperfusion syndrome
Mitral patient-prosthesis mismatch



Right ventricular outflow tract obstruction
9
8
↓ Cardiac output
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1
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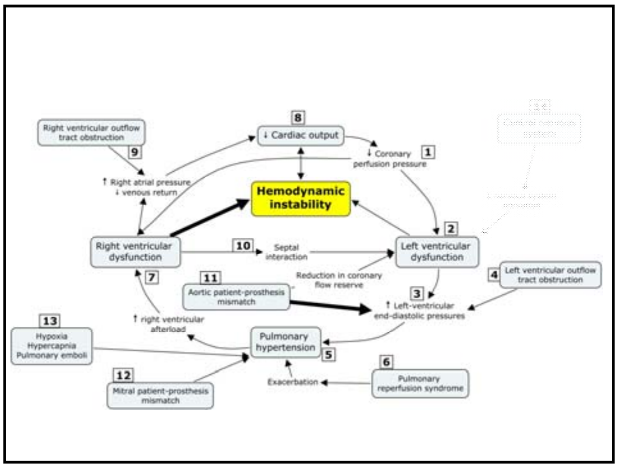
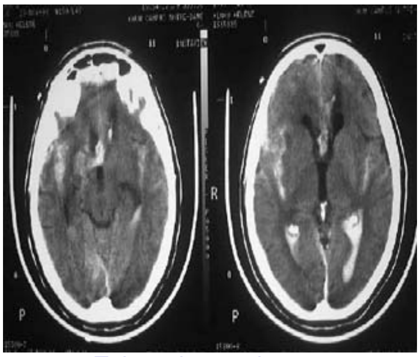


Right ventricular outflow tract obstruction
9
8
↓ Cardiac output
↓ Coronary perfusion pressure
1
↑ Right atrial pressure ↓ venous return
Hemodynamic instability
2
Right ventricular dysfunction
10
Septal interaction
Left ventricular dysfunction
7
11
Reduction in coronary flow reserve
4
Left ventricular outflow tract obstruction
Aortic patient-prosthesis mismatch
3
↑ Left-ventricular end-diastolic pressures
13
Hypoxia
Hypercapnia
Pulmonary emboli
↑ right ventricular afterload
Pulmonary hypertension
5
6
12
Exacerbation
Pulmonary reperfusion syndrome
Mitral patient-prosthesis mismatch

38 yo woman with grade IV SHA



Takotsubo syndrome

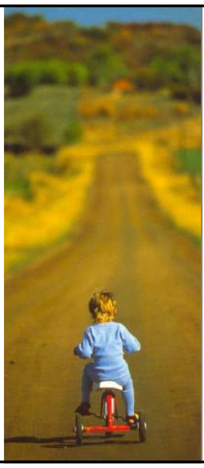
Diagnosis

Hemodynamic clues

ECG clues

In summary

- ✓ Hemodynamic instability often result from several mechanisms
- ✓ The concept of the pressure-volume allow the understanding of these various causes
- ✓ Every diagnosis can be diagnosed with TEE and has associated hemodynamic and ECG clues
- ✓ The hemodynamic clues are more often based on the appearance of the waveform rather than absolute pressure values
- ✓ Diastolic dysfunction or filling abnormalities is invariably present with or without systolic dysfunction
- ✓ The treatment of hemodynamic instability should be based on the underlying mechanism



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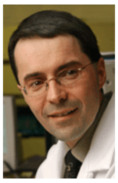

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