

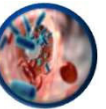
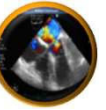
# DIU TUSAR

*Bordeaux – Mardi 16 décembre 2025*

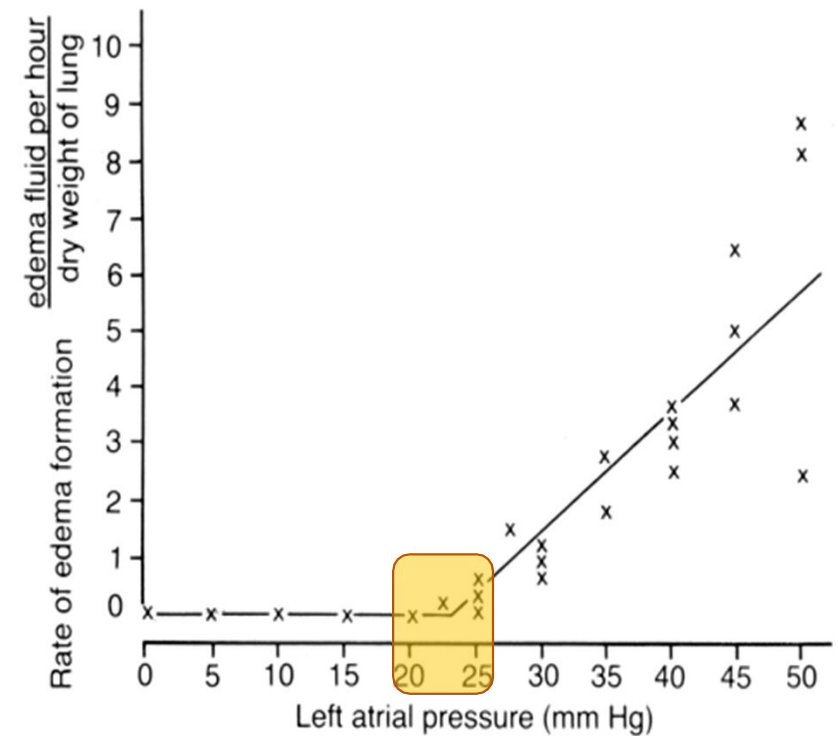
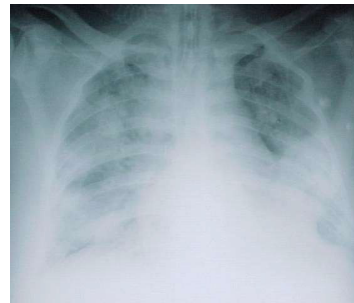
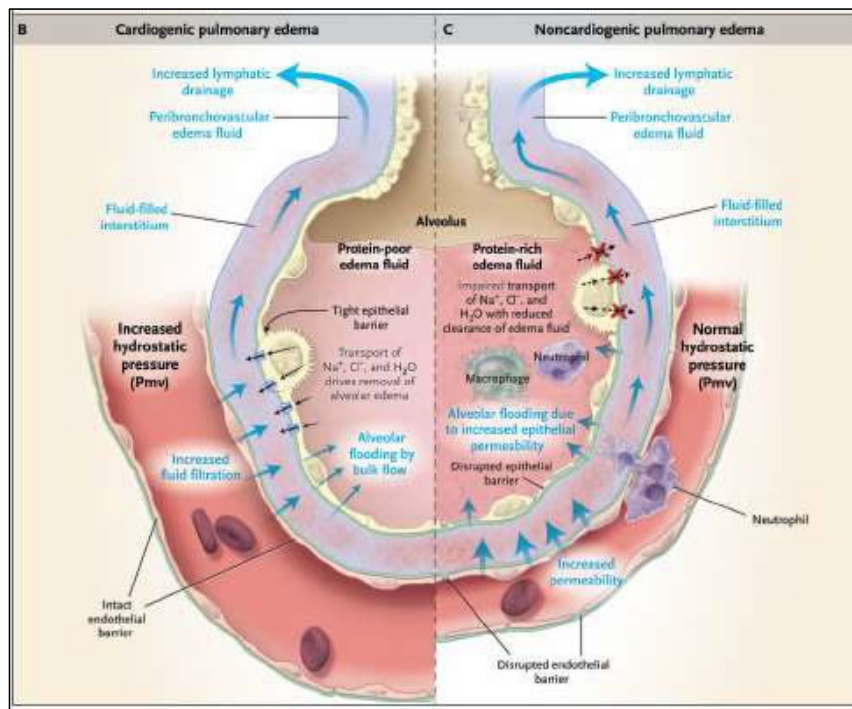
## Fonction diastolique et pressions de remplissage du ventricule gauche

Philippe Vignon

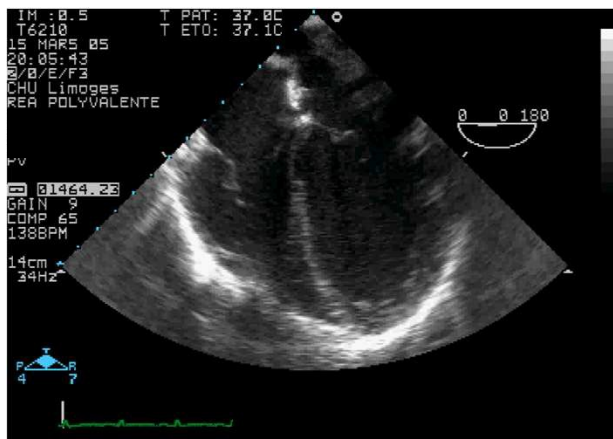
Réanimation Polyvalente  
Inserm CIC 1435  
CHU Limoges



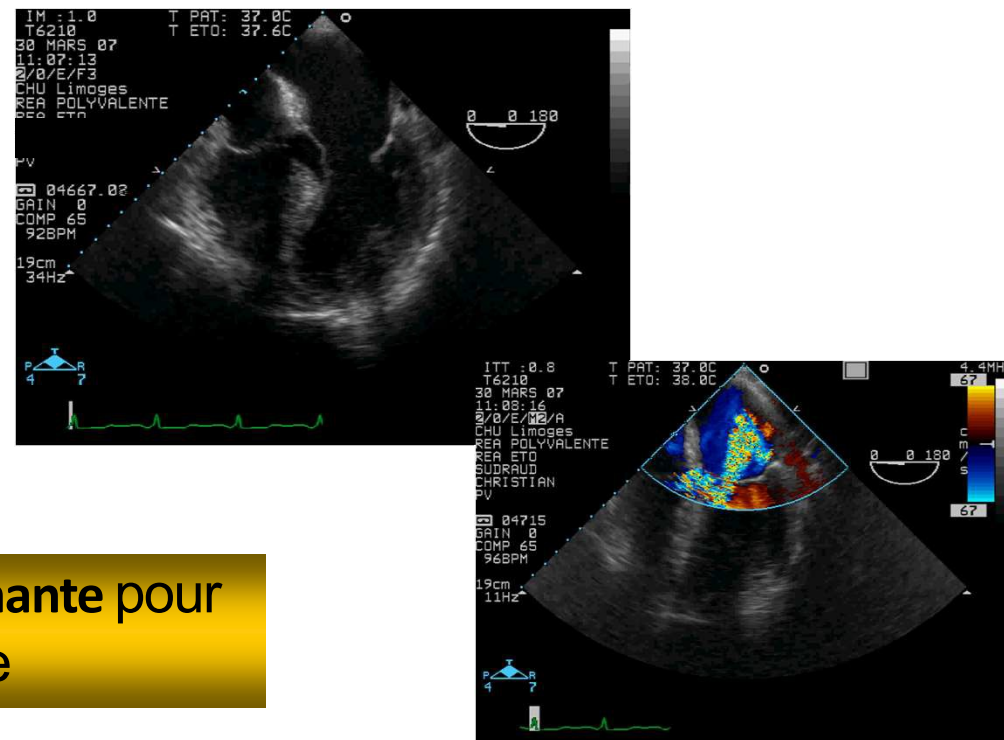
# OAP cardiogénique vs. lésionnel



SDRAet choc septique :  
Dysfonction systolique VG



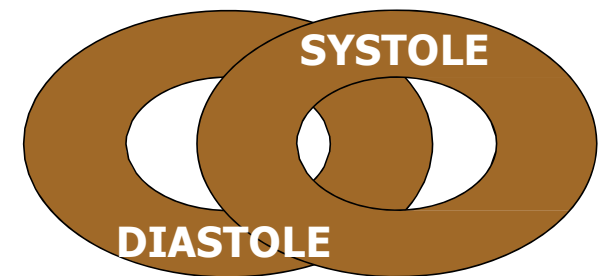
OAPcardiogénique :  
Fonction systolique VG normale



La fonction systolique VG n'est **PAS** discriminante pour  
le diagnostic d'OAP cardiogénique

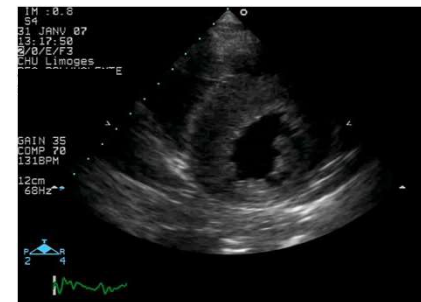
## (Dys)fonction diastolique

- ❖ Fonction diastolique **normale** : capacité du VG à se remplir jusqu'à atteindre un volume télédiastolique normal, au repos et à l'exercice, **sans élévation** de la pression auriculaire gauche (< 12 mmHg)
- ❖ **Dysfonction diastolique** : **allongement** de la **relaxation** (active) du VG souvent associée à une **diminution** de sa **compliance** (passive), notamment en cas de dysfonction systolique sévère.

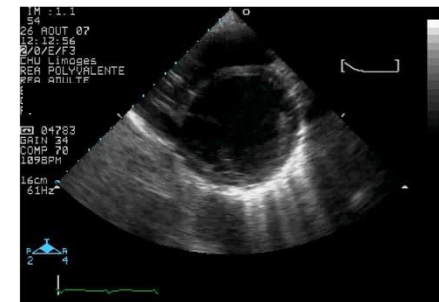


Hypertrophie

Ischémie



FEVG conservée

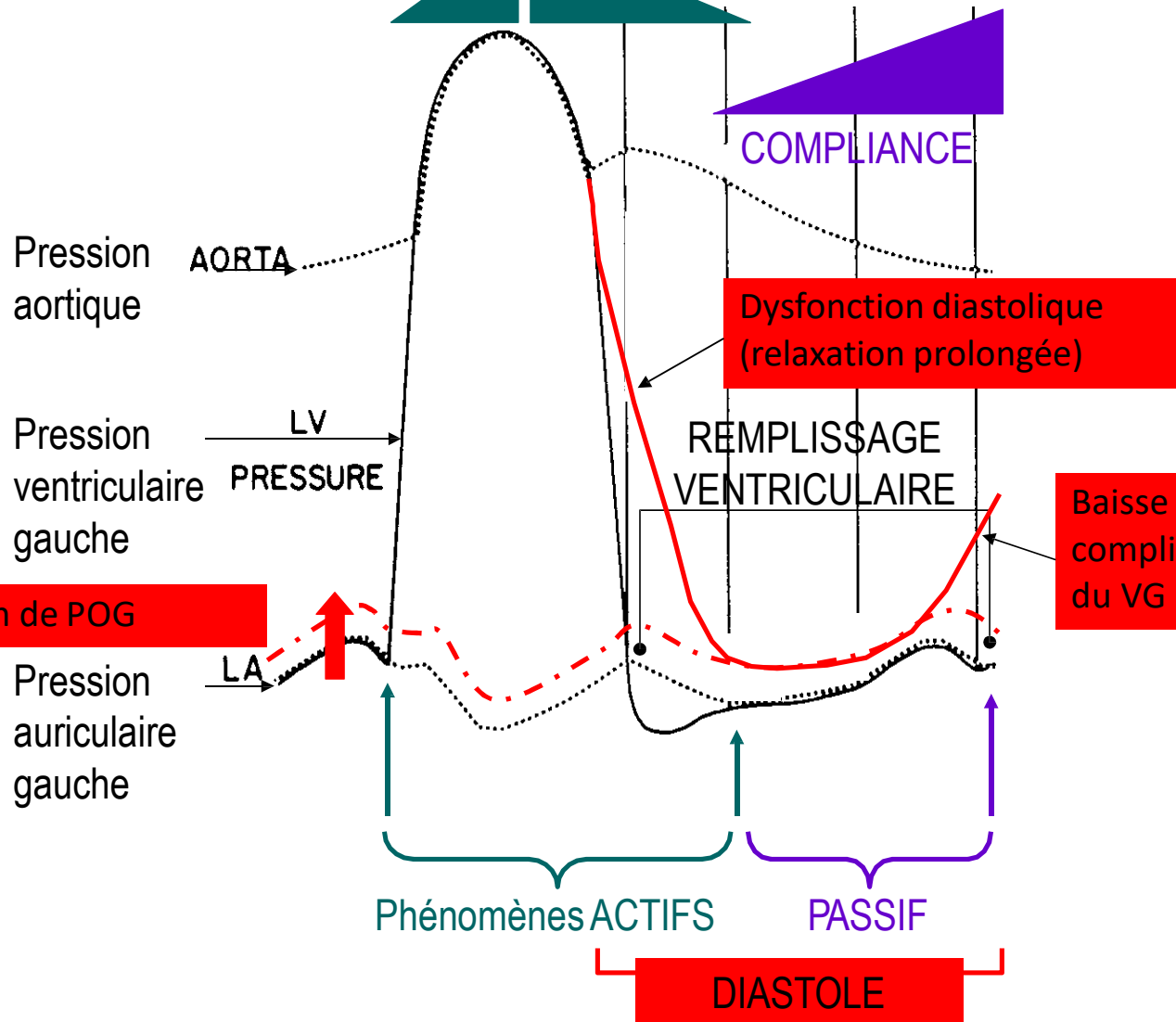
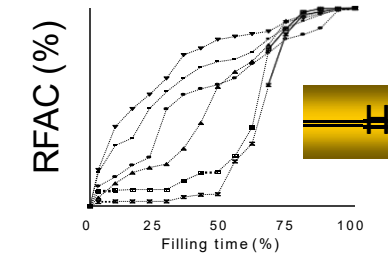
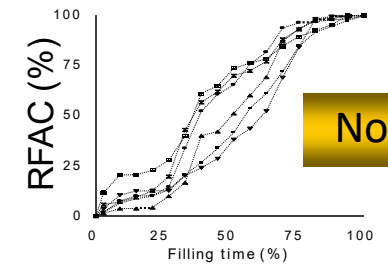
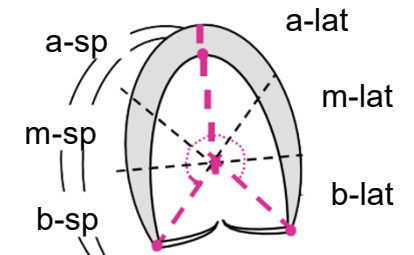


FEVG diminuée



CONTRACTION RELAXATION

Quantitative Evaluation of Global and Regional Left Ventricular Diastolic Function With Color Kinesis  
Philippe Vignon, Victor Mor-Avi, Lynn Weinert, Rick Koch, Kirk T. Spencer and Roberto M. Lang  
*Circulation* 1998;97:1053-1061



Elévation de POG



# Rôle accru de la contribution OG au remplissage VG

Intensive Care Med  
https://doi.org/10.1007/s00134-025-07871-8

## CORRESPONDENCE

Left atrial reservoir strain: an essential tool for evaluating left ventricular diastolic dysfunction in 2025—response. Authors' reply

Philippe Vignon<sup>1,2,3\*</sup>, Julien Vaidie<sup>1,2</sup>, Marine Goudelin<sup>1,2</sup> and Bruno Evrard<sup>1,2</sup>

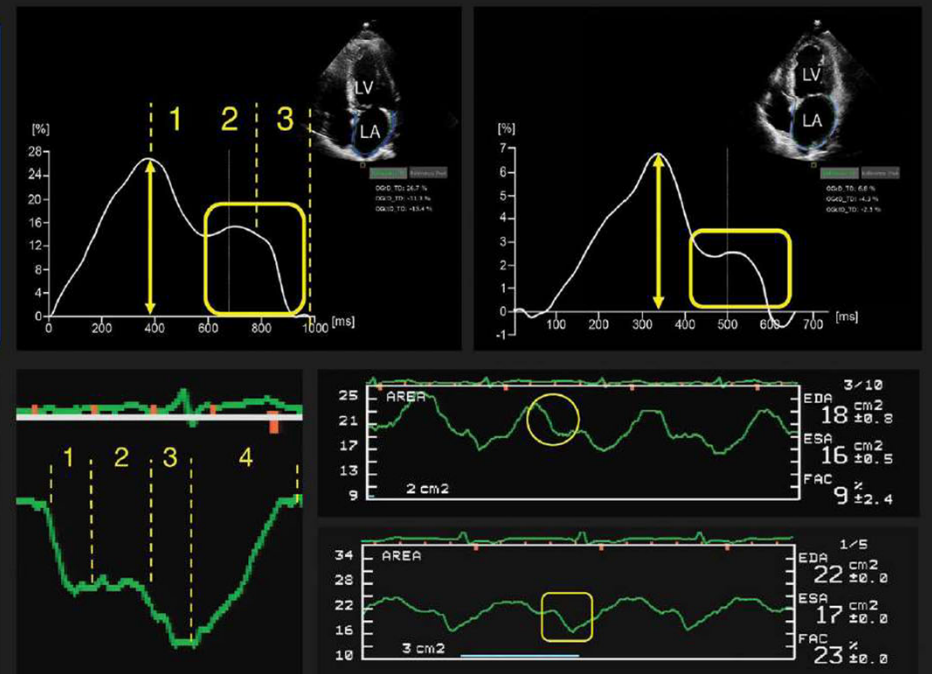


- 1 : Passive emptying (conduit phase)
- 2 : Diastasis
- 3 : Active emptying (booster phase)
- 4 : Atrial filling (left ventricular ejection)

↑ Left atrial reservoir strain (peak velocity)

□ Contribution of left atrial contraction to ventricular filling

○ Contribution of left atrial passive emptying to ventricular filling



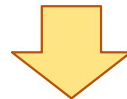


## Dysfonction diastolique du VG

- ❖ Atteinte hétérogène du VG
- ❖ Conséquence 1 : élévation des pressions de remplissage du VG
- ❖ Conséquence 2 : augmentation de la contribution de l'OG au remplissage du VG



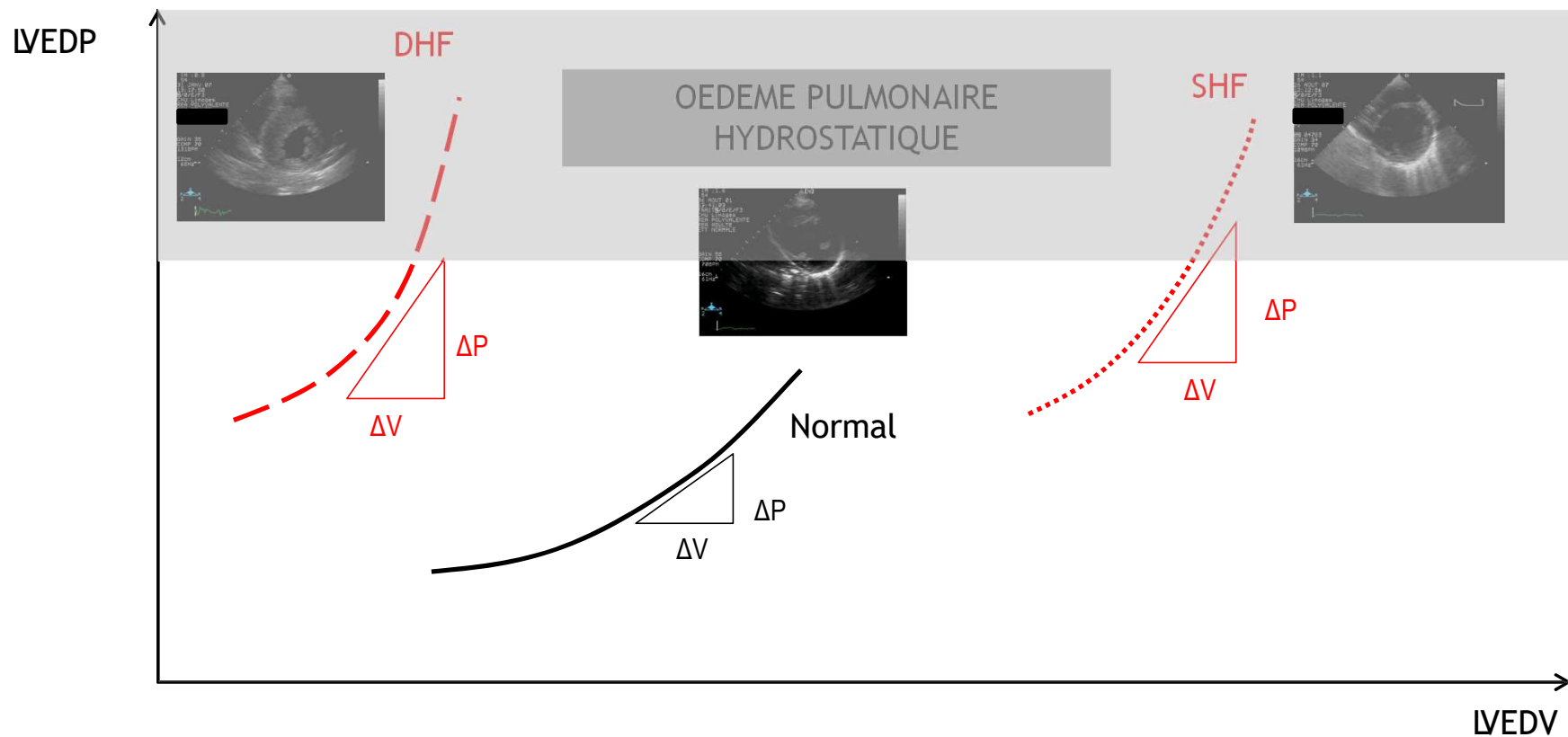
Propriétés diastoliques du VG et pressions de remplissage du VG sont donc intimement intriquées



L'OG augmente sa contraction puis se dilate et défaille

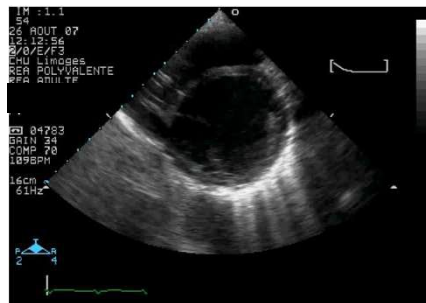
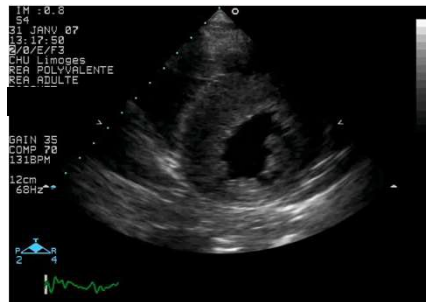


## Risque : OAP hydrostatique / cardiogénique

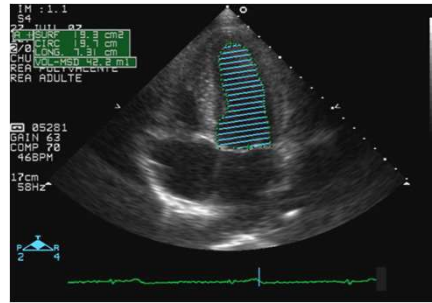
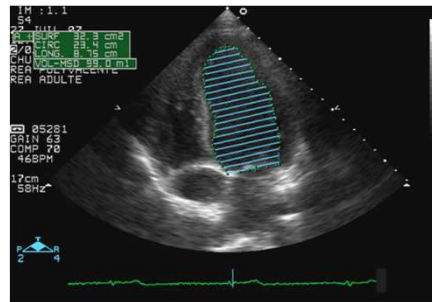


# Echocardiographie bidimensionnelle

Identification de la cardiopathie  
gauche responsable



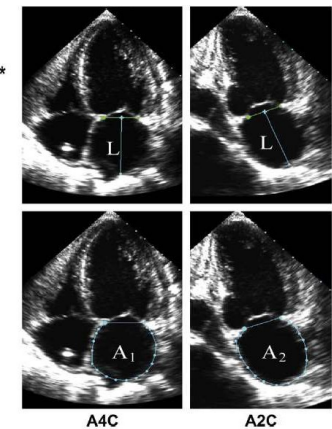
FEVG conservée  
ou diminuée



Dilatation de l'OG

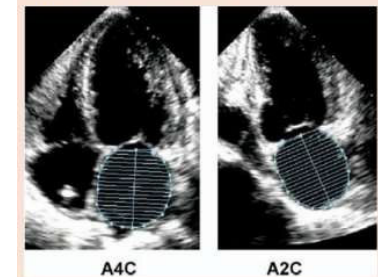
Left Atrial  
Volume =  
 $\frac{8}{3}\pi[(A_1)(A_2)/(L)]^*$

\* (L) is the shortest  
of either the A4C  
or A2C length



Dilatation OG:  
volume  
> 34 mL/m<sup>2</sup>

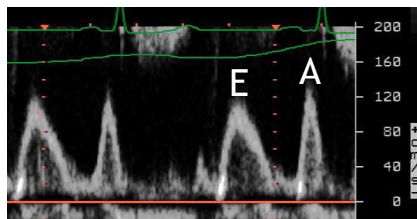
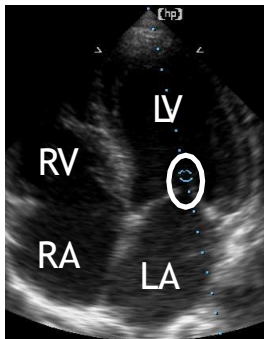
Biplane method of disks



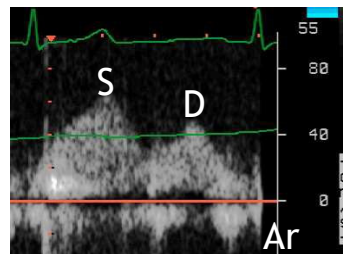
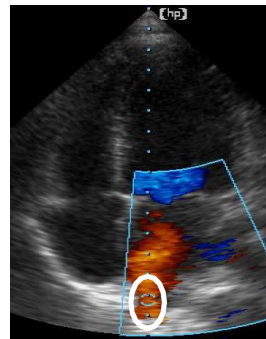
# Doppler pulsé

## Remplissage du cœur gauche

Mitral Doppler

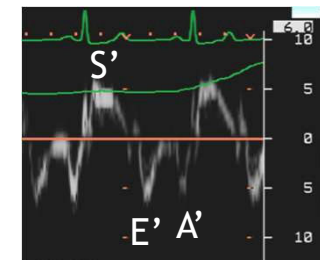
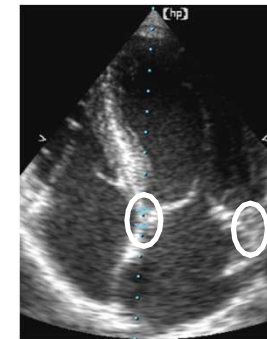


Pulmonary  
vein Doppler

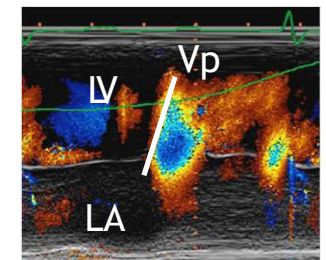
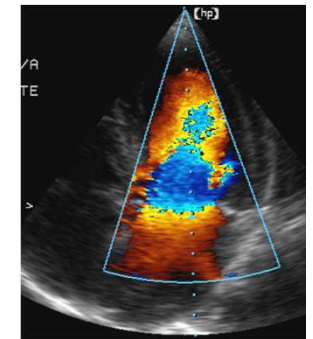


## Relaxation

Tissue Doppler  
imaging (mitral ring)



M-mode color  
Doppler

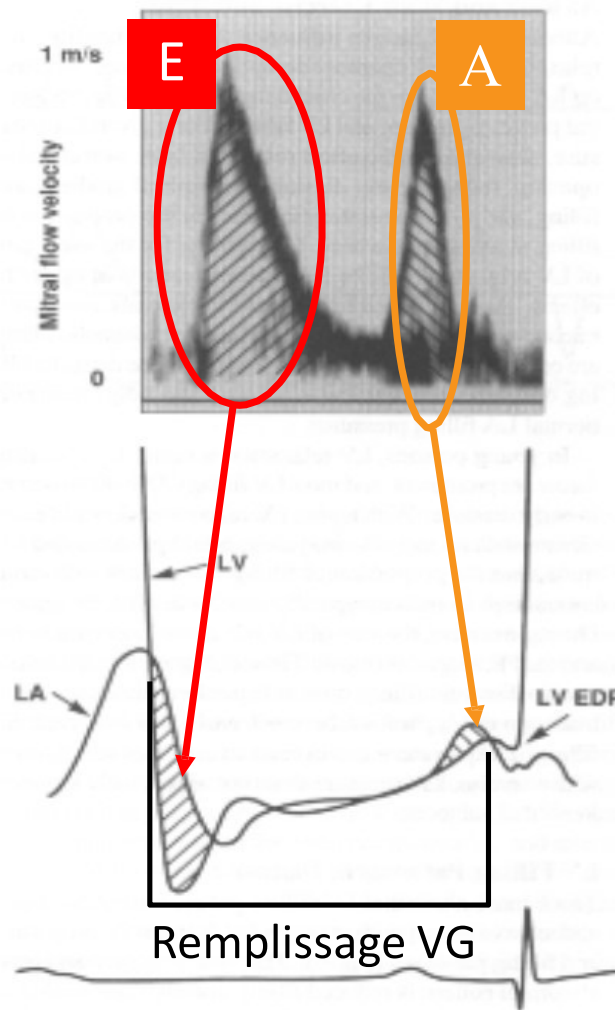
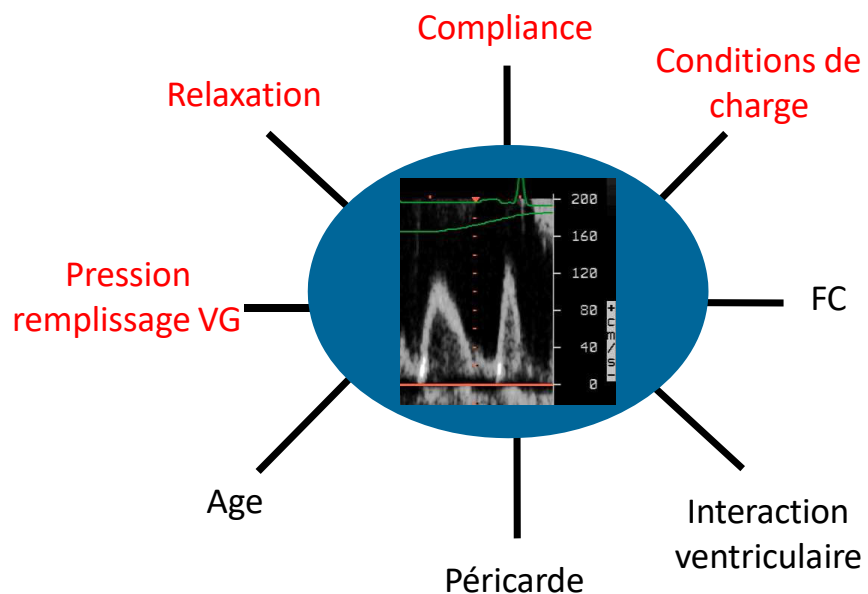




Physio-  
pathologie

Outils  
diagnostique

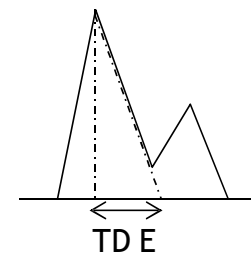
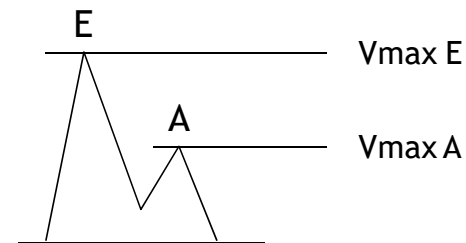
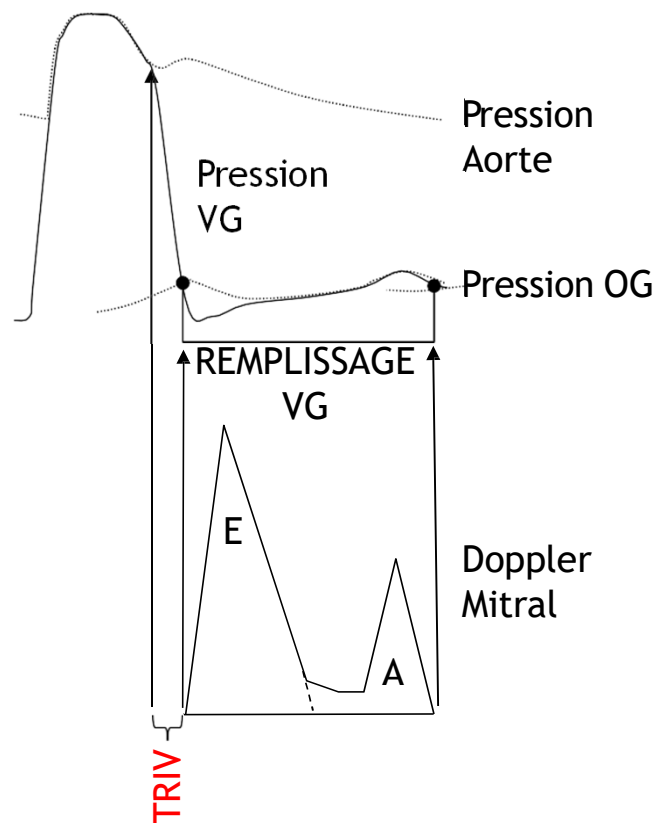
Doppler  
pulsé mitral



ITV E : gradient de pression  
OG-VG pendant le remplissage  
ventriculaire précoce :  
**RELAXATION**

ITV A : gradient de pression  
OG-VG pendant la contraction  
auriculaire : **COMPLIANCE**

E / A : contribution relative  
du remplissage VG précoce  
et par contraction de l'OG  
(en l'absence de  
valvulopathie mitrale)

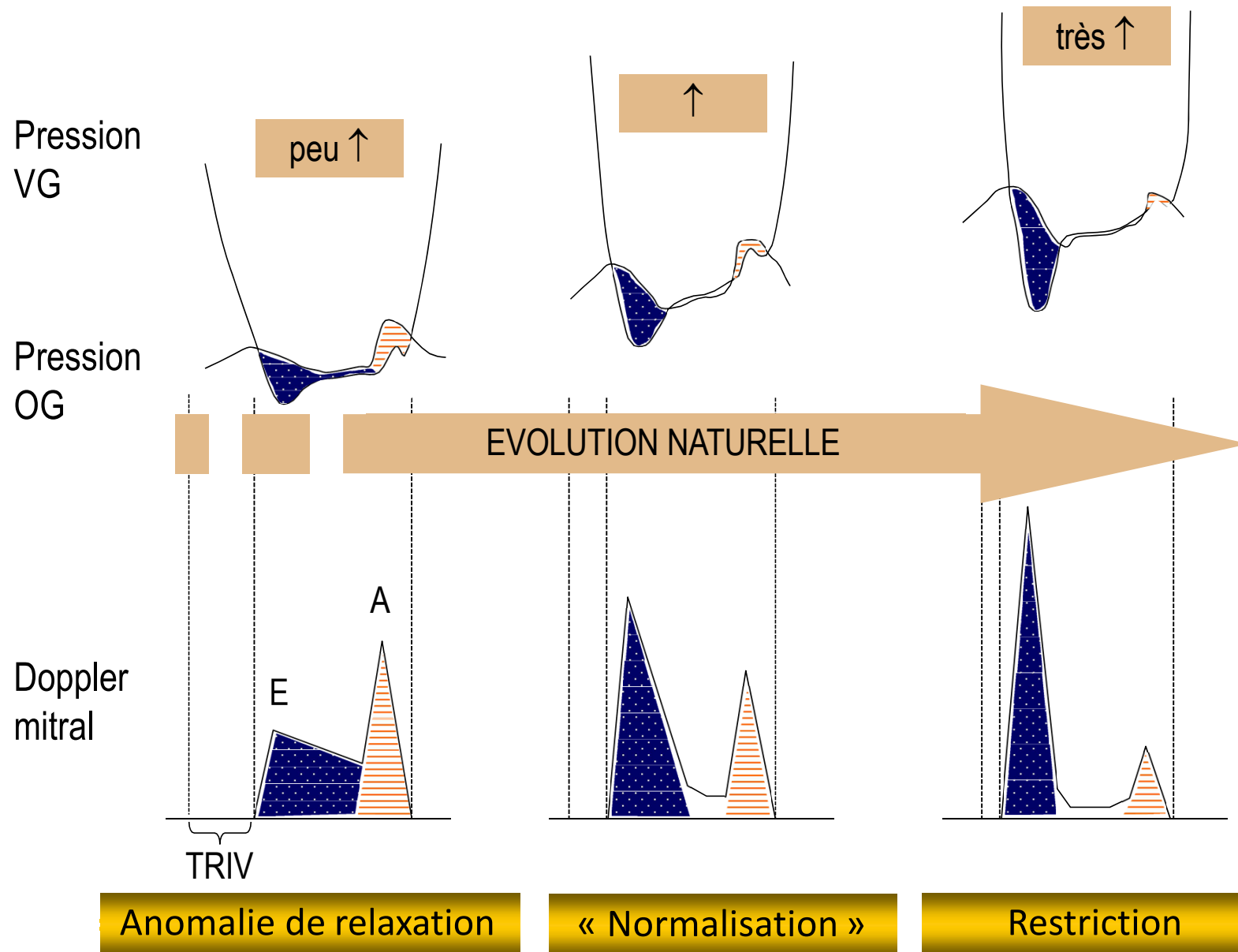


Paramètres simples et reproductibles :

- $V_{\max E} / V_{\max A}$
- Temps de décélération (TD) onde E

Vignon P et al. In: Hemodynamic monitoring in critically ill patients ; Springer (2008)

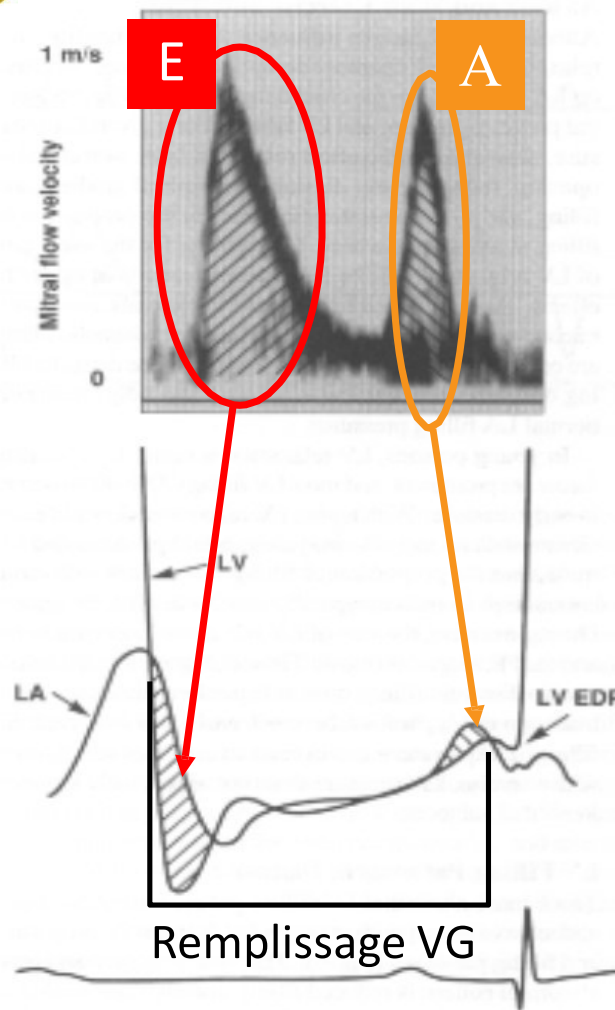
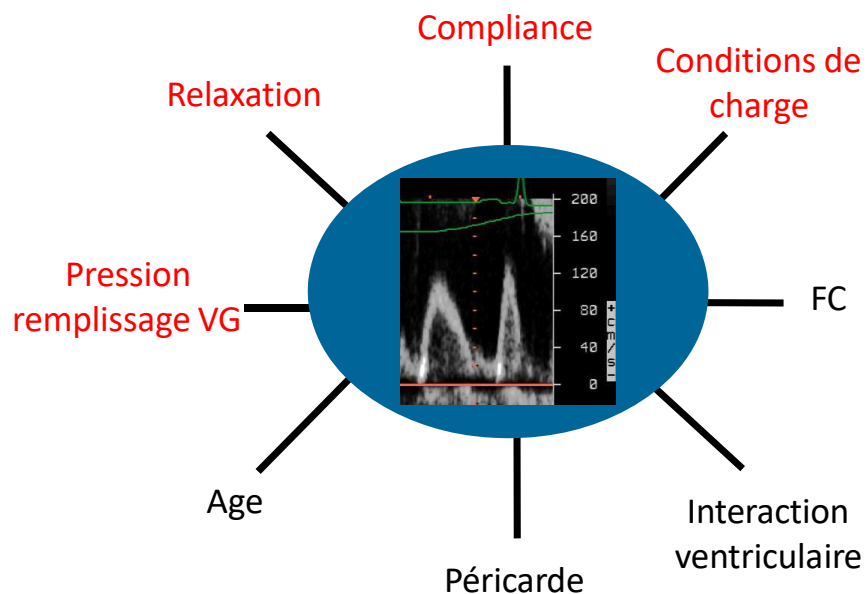
- ❖ Le temps de relaxation isovolumique (TRIV) reflète au mieux la relaxation
- ❖ Il est difficile à mesurer en ETT et non validé en ETO



Physio-  
pathologie

Outils  
diagnostique

Doppler  
pulsé mitral



ITV E : gradient de pression  
OG-VG pendant le remplissage  
ventriculaire précoce :  
**RELAXATION**

ITV A : gradient de pression  
OG-VG pendant la contraction  
auriculaire : **COMPLIANCE**

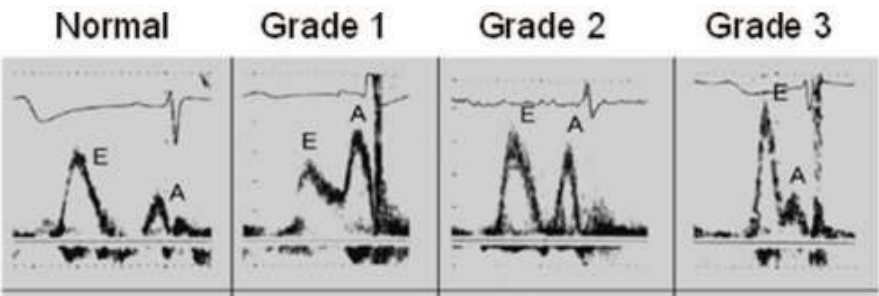
E / A : contribution relative  
du remplissage VG précoce  
et par contraction de l'OG  
(en l'absence de  
valvulopathie mitrale)



## Advances in Cardiovascular Imaging

### Established and Novel Clinical Applications of Diastolic Function Assessment by Echocardiography

Jae K. Oh, MD; Sung-Ji Park, MD; Sherif F. Nagueh, MD

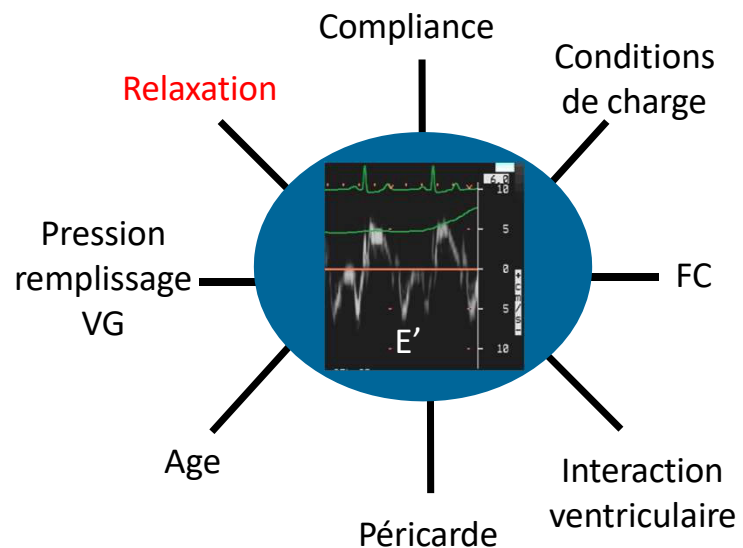


### New Doppler Echocardiographic Applications for the Study of Diastolic Function

MARIO J. GARCIA, MD, FACC, JAMES D. THOMAS, MD, FACC, ALLAN L. KLEIN, MD, FACC  
Cleveland, Ohio

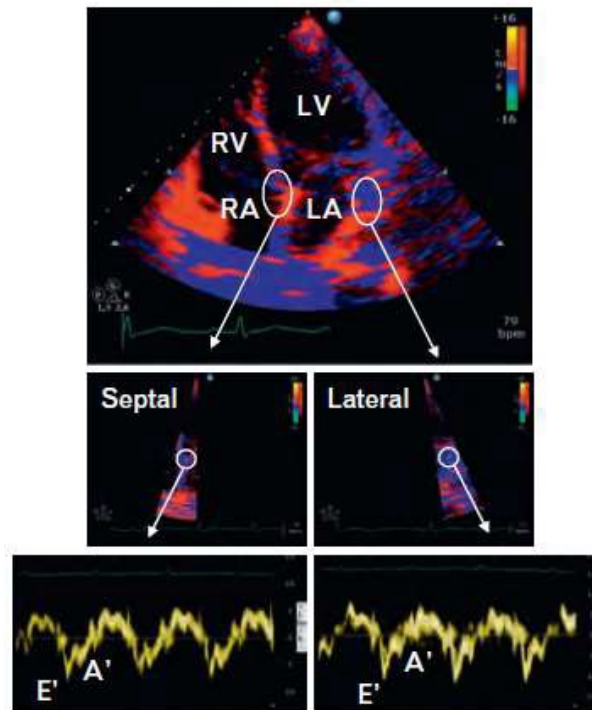
Table 1. Stages of Diastolic Dysfunction (see text for details)

	Normal (young)	Normal (adult)	Delayed Relaxation	Pseudonormal Filling	Restrictive Filling
E/A (cm/s)	>1	>1	<1	1-2	>2
DT (ms)	<220	<220	>220	150-200	<150
IVRT (ms)	<100	<100	>100	60-100	<60
S/D	<1	≥1	≥1	<1	<1
AR (cm/s)	<35	<35	<35	≥35*	≥25*
V <sub>p</sub> (cm/s)	>55	>45	<45	<45	<45
E <sub>m</sub> (cm/s)	>10	>8	<8	<8	<8



- ❖ E' est moins précharge-dépendant que les paramètres Doppler conventionnels
- ❖ Protodiastolique, il reflète mieux la relaxation VG

Tissue doppler (mitral annulus)



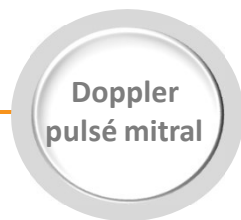
## VALEURS NORMALES

- E' latéral  $\geq 10$  cm/s
- E' septal  $\geq 7$  cm/s

E' non valide si :

- ❖ Valvulopathie mitrale
- ❖ Valve / anneau prothétique
- ❖ BBG, électro-entraîné
- ❖ Péricardite constrictive





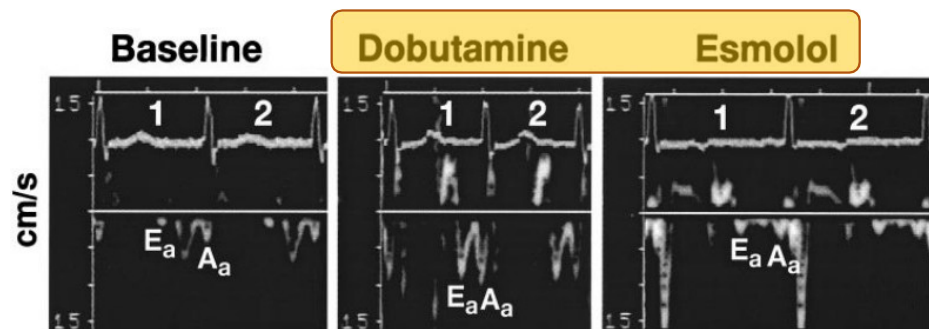
## Reproductibilité des mesures

Reproductibilité	TRIV	$V_{\max} E$	$V_{\max} A$	$DT_E$	$V_{\max} S$	$V_{\max} D$	$V_{\max} E'$ septal	$V_{\max} E'$ lateral	Vp
Inter-observateur	10%	1%	3%	13%	4%	5%	4%	5%	11%
Intra-observateur	6%	2%	2%	7%	4%	6%	2%	2%	7%

- ❖ DTI : E' aisée à obtenir même si imagerie 2D suboptimale
- ❖ TM couleur (Vp) : nécessite une bonne qualité d'image 2D et l'absence de déformation VG (courant entrant excentré et TM mal aligné)
- ❖ Vp : à éviter en réanimation car difficile à mesurer et peu reproductible.

## Hemodynamic Determinants of the Mitral Annulus Diastolic Velocities by Tissue Doppler

Sherif F. Nagueh, MD, FACC, Huabin Sun, MD, Helen A. Kopelen, RDMS, Katherine J. Middleton, RCT, Dirar S. Khoury, PhD  
Houston, Texas



E' peut varier sous traitement inotrope (lusinotrope) et après variations aiguës des conditions de charge du VG.

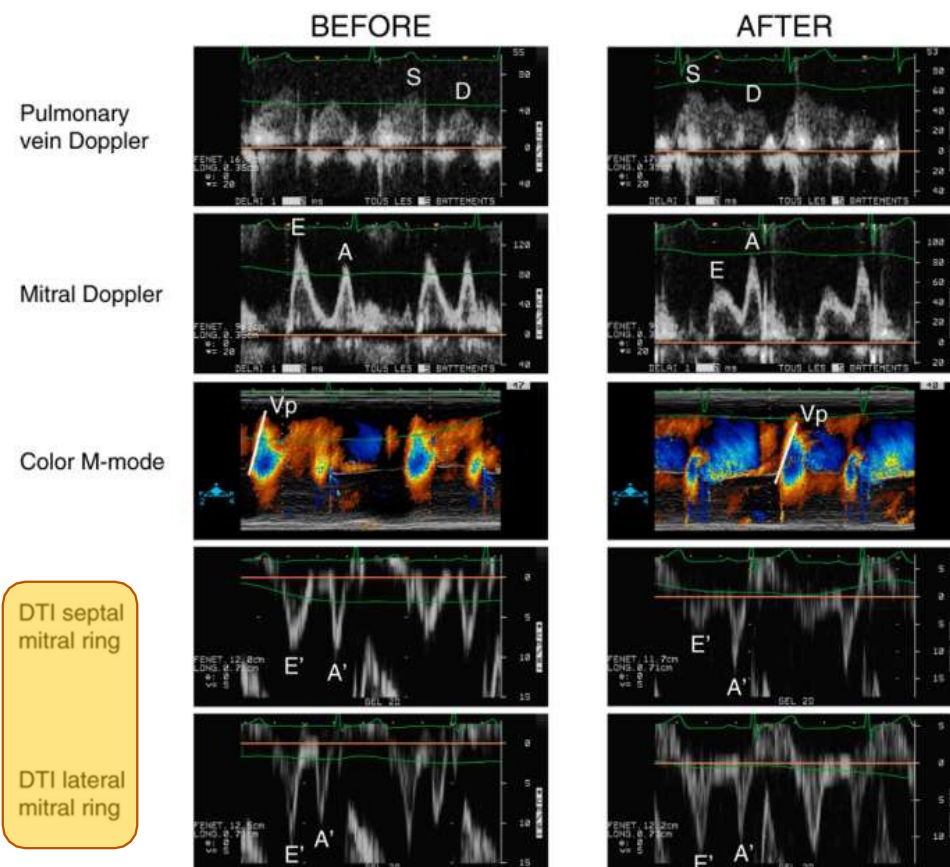
## Research

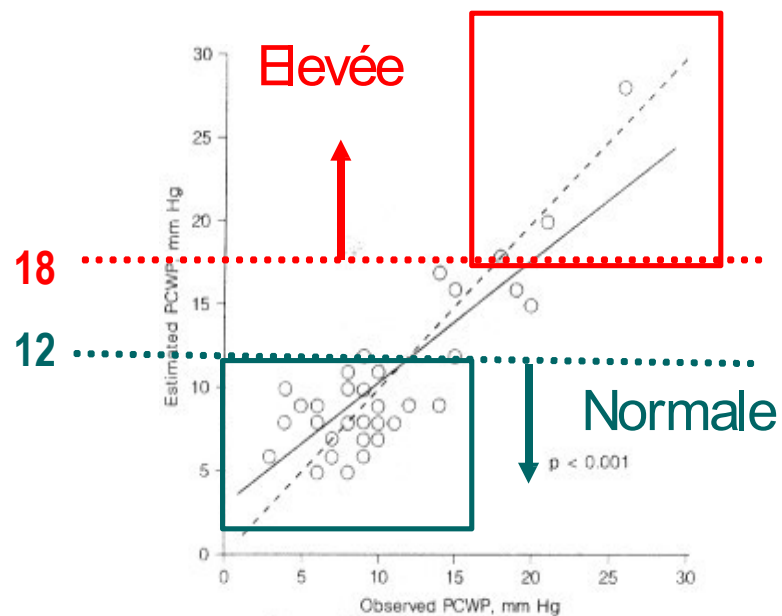
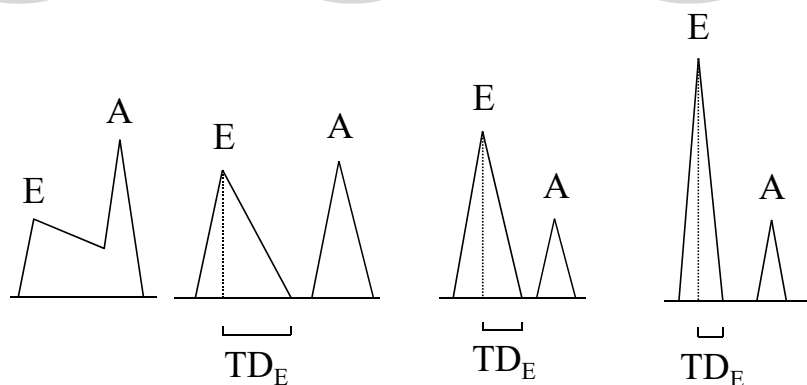
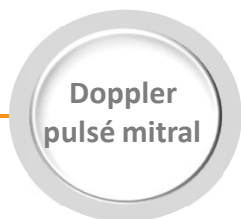
## Open Access

## Diagnosis of left ventricular diastolic dysfunction in the setting of acute changes in loading conditions

Philippe Vignon<sup>1,2,3</sup>, Vincent Allot<sup>4</sup>, Jérôme Lesage<sup>1</sup>, Jean-François Martailhé<sup>1</sup>, Jean-Claude Aldigier<sup>3,4</sup>, Bruno François<sup>1,2</sup> and Hervé Gastinne<sup>1,3</sup>

Critical Care 2007, 11:R43





Suwa et al. Am J Noninvas Cardiol 1994 ; 8 : 207-14

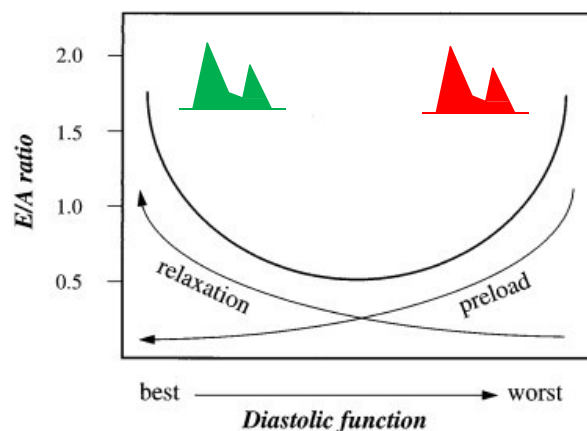
	Valeurs seuil	PAPO prédite
E/A	> 2	> 18 mmHg
TD <sub>E</sub>	< 120 ms	> 18 mmHg

Le Doppler mitral est performant pour estimer la PAPO lorsqu'elle est élevée



Bonne relaxation  
Pressions de remplissage basse  
Profil **normal**

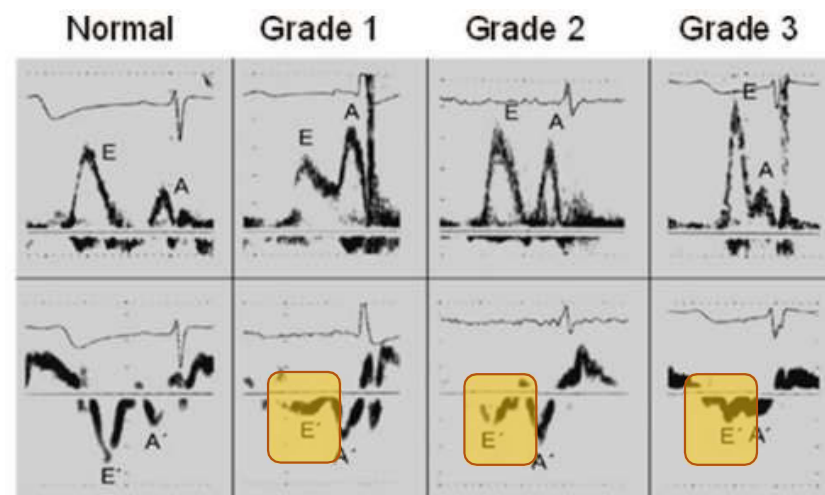
Anomalie de relaxation  
Pressions de remplissage élevées  
Profil **normalisé**



## Advances in Cardiovascular Imaging

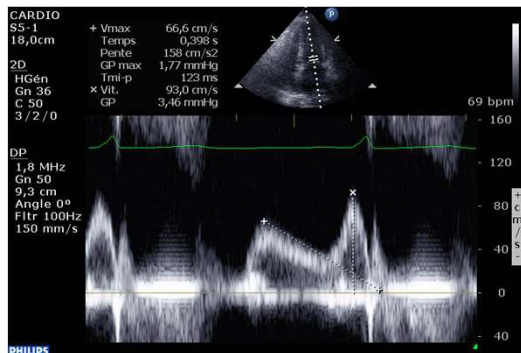
### Established and Novel Clinical Applications of Diastolic Function Assessment by Echocardiography

Jae K. Oh, MD; Sung-Ji Park, MD; Sherif F. Naguch, MD

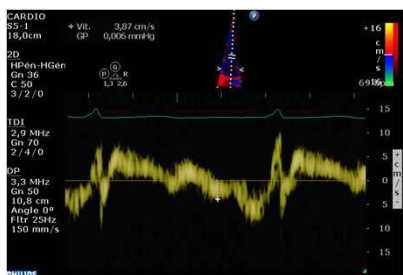


*Circ Cardiovasc Imaging* 2011 ; 4 : 444-455

Le Doppler mitral est moins performant pour estimer la PAPO en cas de cardiopathie associée : il faut alors lui associer le Doppler tissulaire

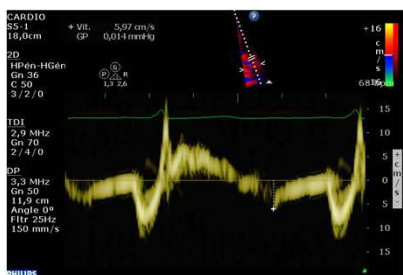


$E/A = 0,7$  et  $TDE = 400$  ms  
(Grade 1)

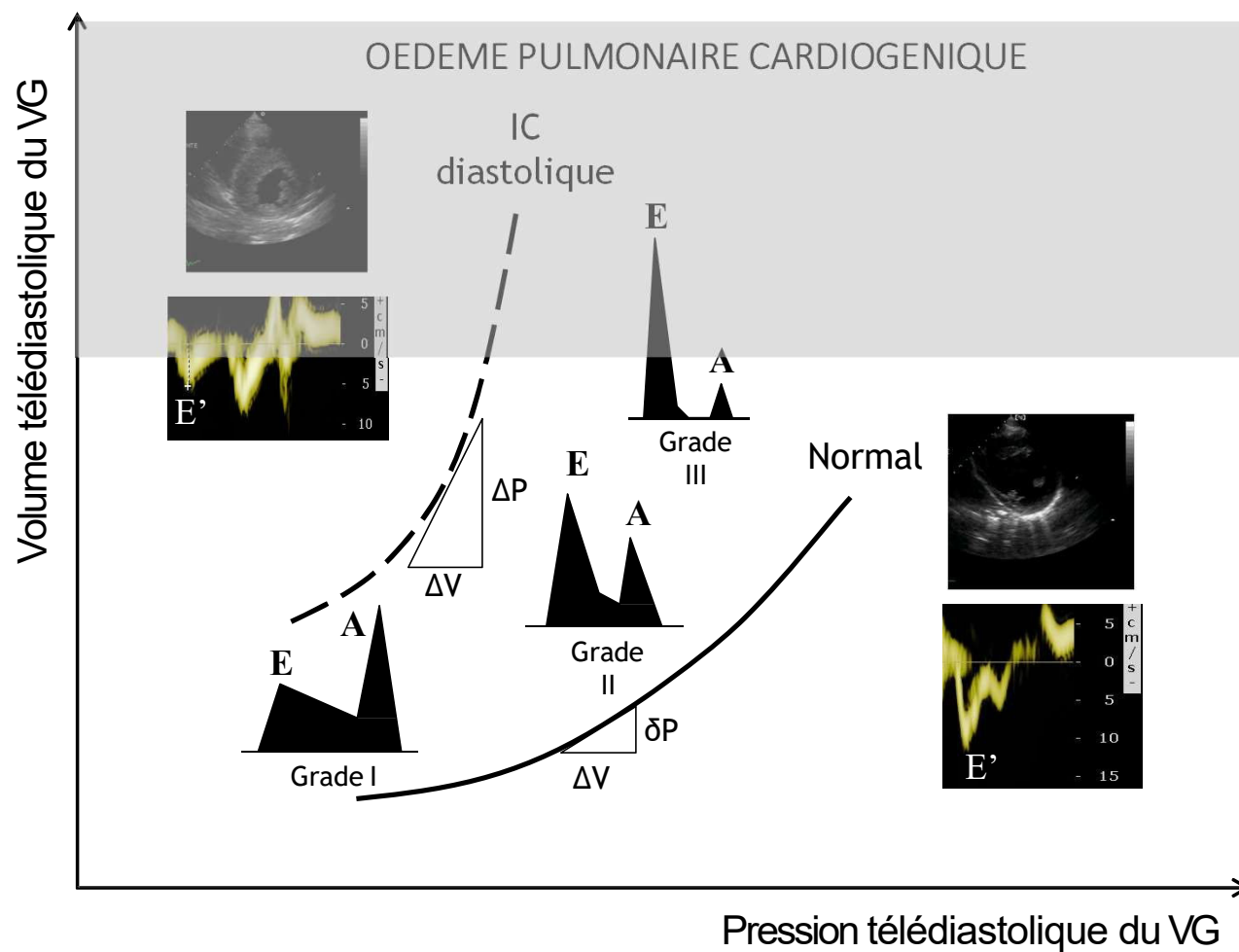


$E' \text{ septal} = 4 \text{ cm/s}$

$E/E' \text{ moyenné} : 14$



$E' \text{ lateral} = 6 \text{ cm/s}$





Physio-  
pathologie

Outils  
diagnostique

Doppler  
pulsé mitral

Doppler  
tissulaire  
anneau  
mitral

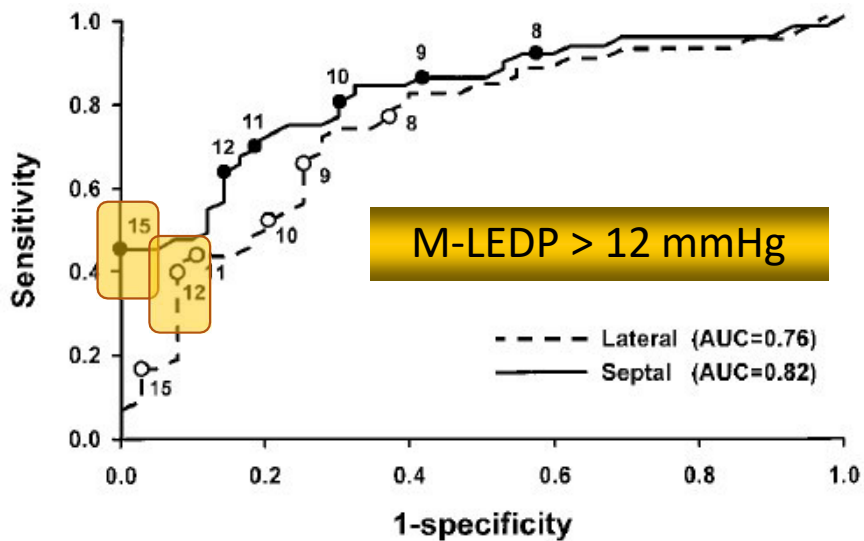
Evaluation  
pressions  
remplissage  
VG

## Cardiopathes en VS

### Clinical Utility of Doppler Echocardiography and Tissue Doppler Imaging in the Estimation of Left Ventricular Filling Pressures

A Comparative Simultaneous Doppler-Catheterization Study

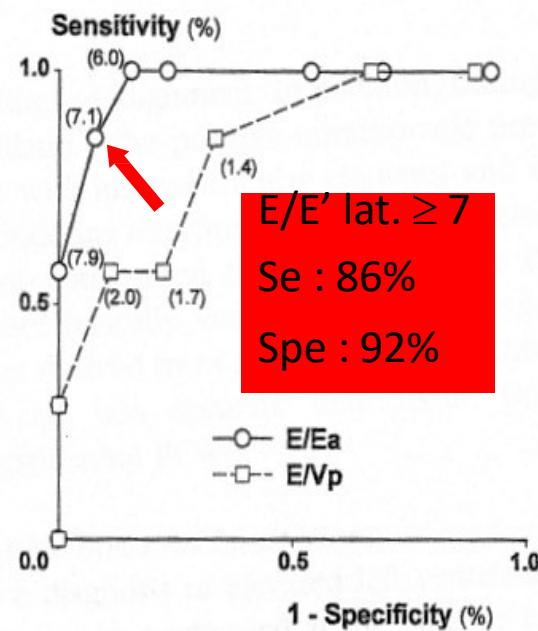
S.R. Ommen, MD; R.A. Nishimura, MD; C.P. Appleton, MD; F.A. Miller, MD; J.K. Oh, MD; M.M. Redfield, MD; A.J. Tajik, MD



Circulation 2000 ; 102 : 1788-94

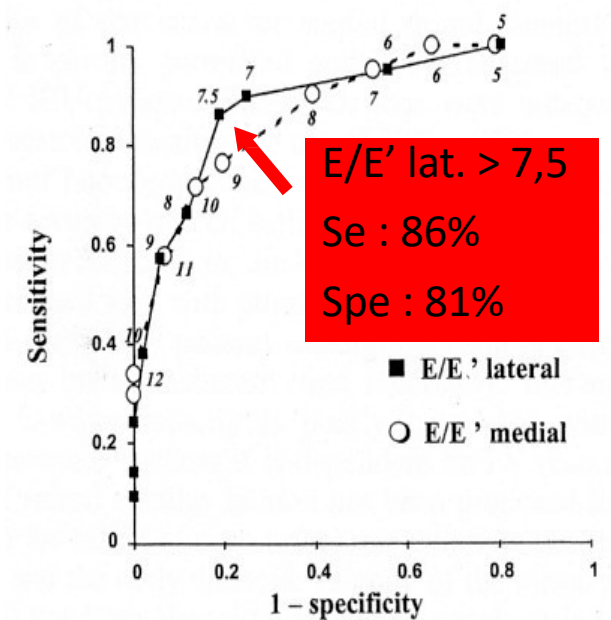
## Patients de réanimation en VAC

PAPO  $\geq 13$  mmHg



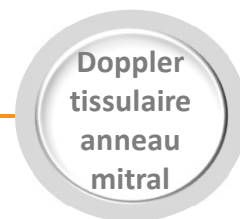
Bouhemad et al. Anesthesiology  
2003 ; 98: 1091-100

PAPO  $\geq 15$  mmHg



Combes et al. Intensive Care Med  
2004 ; 30 : 75-81





Research

Open Access

## Echocardiographic assessment of pulmonary artery occlusion pressure in ventilated patients: a transoesophageal study

Philippe Vignon<sup>1,2,3</sup>, Ali AitHssain<sup>4</sup>, Bruno François<sup>1,2</sup>, Pierre-Marie Preux<sup>3,5</sup>, Nicolas Pichon<sup>1,2</sup>, Marc Clavel<sup>1,2</sup>, Jean-Pierre Frat<sup>6</sup> and Hervé Gastinne<sup>1,3</sup>

*Crit Care* 2008 ; 12 : R18

E/E' lateral < 8,0 : PAPO < 18 mmHg

❖ Sensibilité : 83 %

❖ Spécificité : 88 %

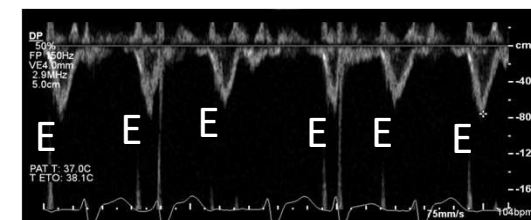
Doppler indices based on DTI of the lateral mitral ring and colour M-mode propagation velocity obtained in protocol B, according to the level of invasive PAOP measured during RHC

	PAOP ≤ 18 mmHg (n = 24)	PAOP > 18 mmHg (n = 8)	p Value	Dysfonction systolique VG : n = 7
Vp (cm/s)	45 ± 10	35 ± 8	0.05	
E' lateral (cm/s)	12.9 ± 3.9	9.2 ± 1.3	0.01	
E/Vp	1.7 ± 0.6	2.7 ± 0.5	0.0006	Fonction systolique VG normale : n = 49
E/E' lateral	5.9 ± 2.2	10.6 ± 3.3	0.0002	



## Patients en FA

Paramètres Doppler	Valeur seuil	PAPO prédite	Sensibilité	Spécificité
TD <sub>E</sub>	< 150 ms	> 15 mmHg	71%	100%
	< 120 ms	≥ 20 mmHg	100%	96%
E/E' septal	≥ 11	≥ 15 mmHg	75%	93%



### ASE/EACVI GUIDELINES AND STANDARDS

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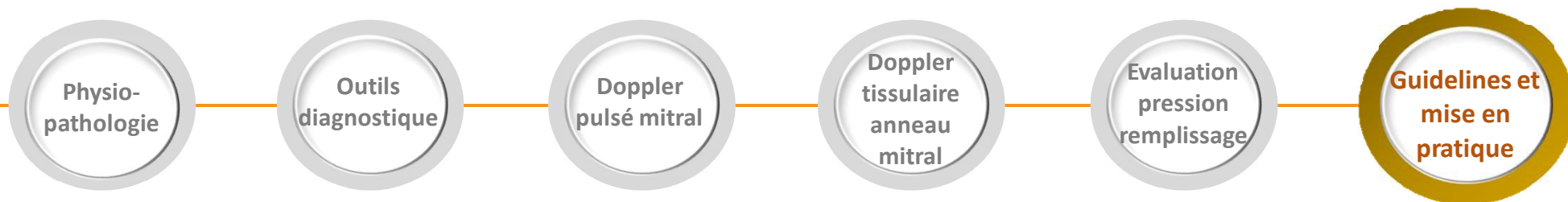
Sherif F. Nagueh, Chair, MD, FASE,<sup>1</sup> Otto A. Smiseth, Co-Chair, MD, PhD,<sup>2</sup> Christopher P. Appleton, MD,<sup>1</sup> Benjamin F. Byrd, III, MD, FASE,<sup>1</sup> Hisham Dokainish, MD, FASE,<sup>1</sup> Thor Edvardsen, MD, PhD,<sup>2</sup> Frank A. Flachskampf, MD, PhD, FESC,<sup>2</sup> Thierry C. Gillebert, MD, PhD, FESC,<sup>2</sup> Allan L. Klein, MD, FASE,<sup>1</sup> Patrizio Lancellotti, MD, PhD, FESC,<sup>2</sup> Paolo Marino, MD, FESC,<sup>2</sup> Jae K. Oh, MD,<sup>1</sup> Bogdan Alexandru Popescu, MD, PhD, FESC, FASE,<sup>2</sup> and Alan D. Waggoner, MHS, RDCS,<sup>1</sup> Houston, Texas; Oslo, Norway; Phoenix, Arizona; Nashville, Tennessee; Hamilton, Ontario, Canada; Uppsala, Sweden; Ghent and Liège, Belgium; Cleveland, Ohio; Novara, Italy; Rochester, Minnesota; Bucharest, Romania; and St. Louis, Missouri

(J Am Soc Echocardiogr 2016;29:277-314.)

**Table 6** Assessment of LV filling pressures in special populations

Disease	Echocardiographic measurements and cutoff values
AF <sup>43,94-99</sup>	Peak acceleration rate of mitral E velocity (≥1,900 cm/sec <sup>2</sup> ) IVRT (≤65 msec) DT of pulmonary venous diastolic velocity (≤220 msec) E/A ratio (≥1.4) Septal E/e' ratio (≥11)

Moyenne de 10 cycles cardiaques...  
...ou de 3 battements non consécutifs avec  
une durée de cycle dans les 10 à 20% de  
variation de fréquence cardiaque



## Recommandations internationales : pourquoi ?

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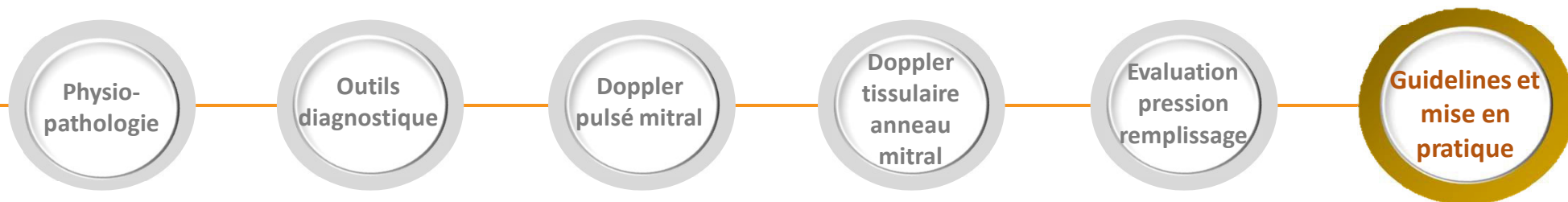
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(J Am Soc Echocardiogr 2016;29:277-314.)

when feasible, particularly in patients referred with symptoms of dyspnea or diagnosis of “heart failure.” In addition, the grade of LV diastolic dysfunction should be included in the reports along with the estimated LV filling pressures. The rationale for this recommendation comes from several single center and epidemiologic studies showing the independent and incremental prognostic information provided by LV diastolic dysfunction grade in several settings including HFrEF, HFpEF and acute myocardial infarction.<sup>72-87</sup> Finally, when feasible,

with heart failure. In patients with AF, Doppler assessment of LV diastolic function is limited by the variability in cycle length, the absence of organized atrial activity, and the frequent occurrence of LA enlargement regardless of filling pressures. In general, when





### ASE/EACVI GUIDELINES AND STANDARDS

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(J Am Soc Echocardiogr 2016;29:277-314.)

- ❖ Les critères diagnostiques de dysfonction diastolique du VG associent l'anomalie de relaxation ( $E'$  bas), l'augmentation des pressions de remplissage du VG ( $E/E'$  moyenné élevé et dilatation de l'OG), et l'HTAP postcapillaire en résultant ( $V_{\max}$  IT qualifiante)
- ❖ La dysfonction systolique ( $FEVG$  basse) est toujours considérée comme étant associée à une dysfonction diastolique
- ❖ Lorsque la  $FEVG$  est normale, la dysfonction diastolique doit être cherchée si dyspnée / IRA
- ❖ Une fois la dysfonction diastolique établie, sa sévérité doit être déterminée (3 grades).

Physio-  
pathologie

Outils  
diagnostique

Doppler  
pulsé mitral

Doppler  
tissulaire  
anneau  
mitral

Evaluation  
pression  
remplissage

Guidelines et  
mise en  
pratique

# ASE / EACVI recommendations : 2025 update pour FEVG conservée

## GUIDELINES AND STANDARDS

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography and for Heart Failure With Preserved Ejection Fraction Diagnosis: An Update From the American Society of Echocardiography

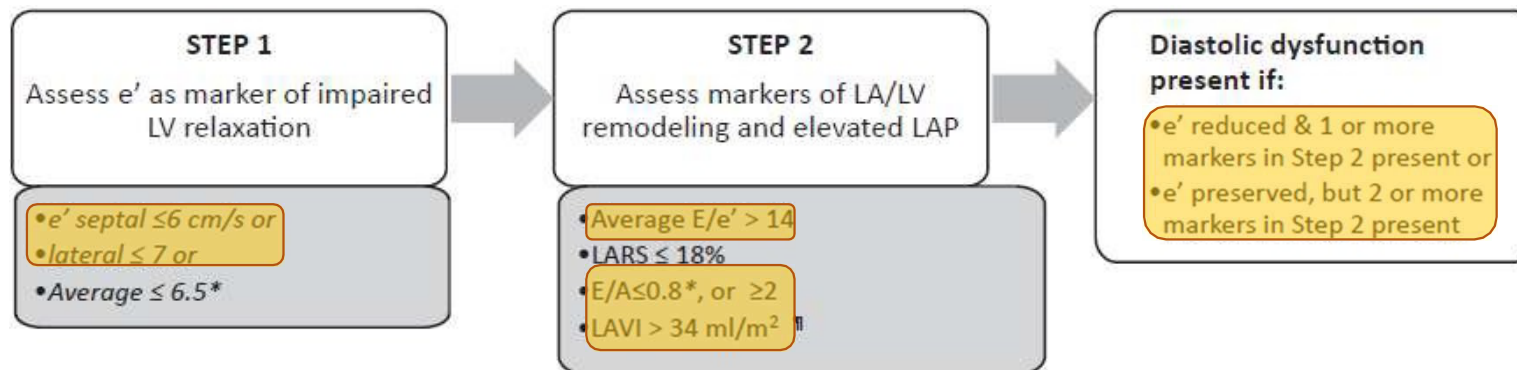


Sherif F. Nagueh, MD, FASE (Chair), Danita Y. Sanborn, MD, FASE (Co-Chair), Jae K. Oh, MD, FASE, Bonita Anderson, MAppSc, DMU, ACS, FASE, FASA, Kristen Billick, BS, ACS, RCS, RDMS, FASE, Genevieve Derumeaux, MD, PhD, Allan Klein, MD, FASE, Konstantinos Koulgiannis, MD, FASE, Carol Mitchell, PhD, ACS, RDMS, RDCS, RVT, RT(R), FASE, Amil Shah, MD, Kavita Sharma, MD, Otto A. Smiseth, MD, PhD, Honorary FASE, and Teresa S. M. Tsang, MD, FASE, *Houston and Dallas, Texas; Boston, Massachusetts; Rochester, Minnesota; Brisbane, Australia; San Diego, California; Creteil, France; Cleveland, Ohio; Morristown, New Jersey; Madison, Wisconsin; Baltimore, Maryland; Oslo, Norway; and Vancouver, British Columbia, Canada*

(J Am Soc Echocardiogr 2025;38:537-69.)

Table 6 Mitral annular e' velocity values for diagnosis of impaired LV relaxation

	20-39 y	40-65 y	>65 y
1. Septal e', cm/s	<7	<6	<6
2. Lateral e', cm/s	<10	<8	<7
3. Average e', cm/s	<9	<7	<6.5



Physio-  
pathologie

Outils  
diagnostique

Doppler  
pulsé mitral

Doppler  
tissulaire  
anneau  
mitral

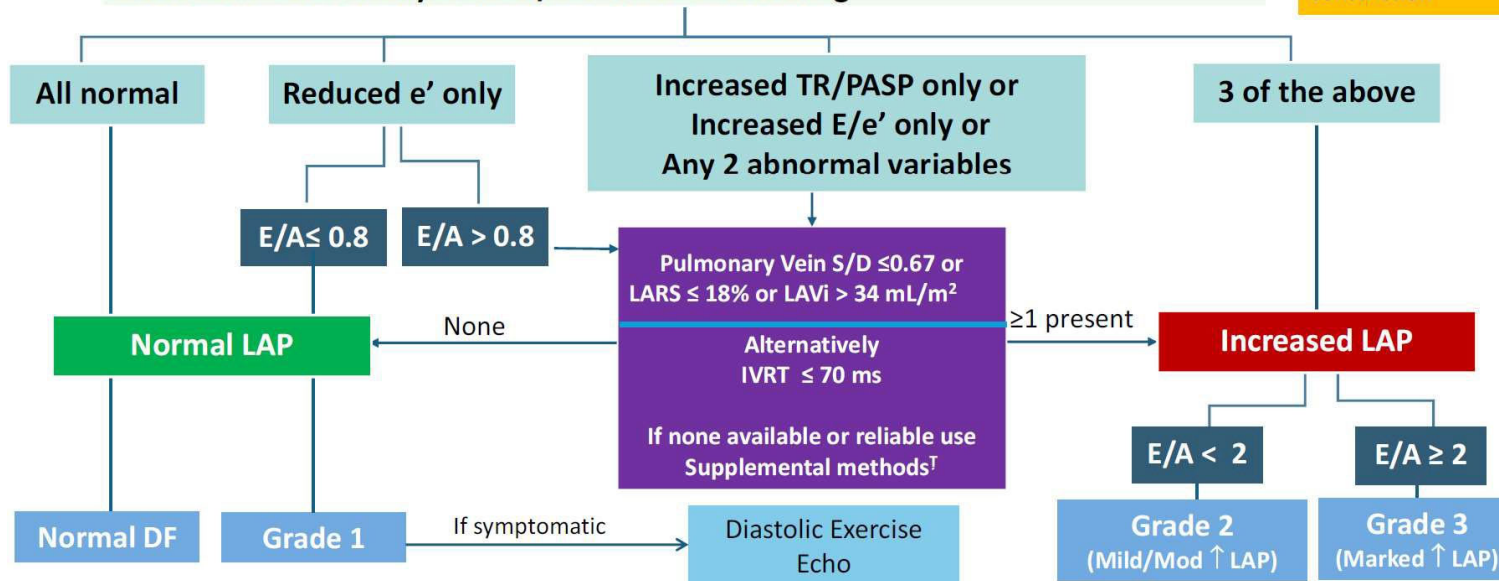
Evaluation  
pression  
remplissage

Guidelines et  
mise en  
pratique

## LV Diastolic Function Grading & LAP Estimation

1. Reduced  $e'$  velocity: septal  $\leq 6$  or lateral  $\leq 7$  or average  $\leq 6.5$  cm/s \*
2. Increased  $E/e'$ : septal  $\geq 15$  or lateral  $\geq 13$  or average  $\geq 14$
3. Increased TR velocity  $\geq 2.8$  m/s or PASP  $\geq 35$  mm Hg

Except in  
MAC, MR, MS<sup>†</sup>  
Atrial Fibrillation  
LVAD  
Non-cardiac PH  
HTX  
Pericardial  
constriction





Physio-  
pathologie

Outils  
diagnostique

Doppler  
pulsé mitral

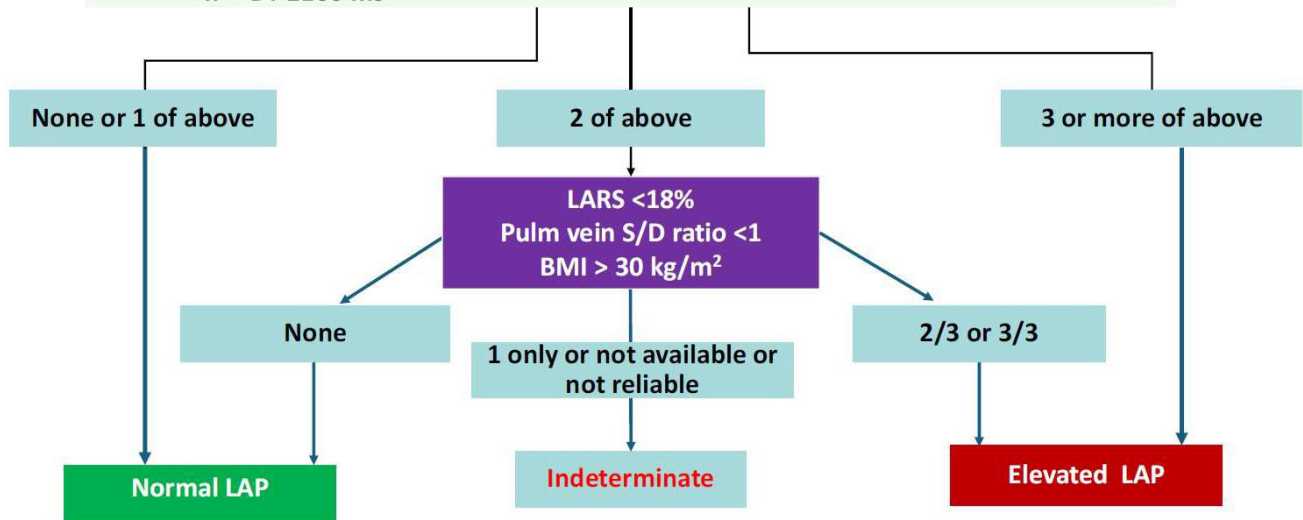
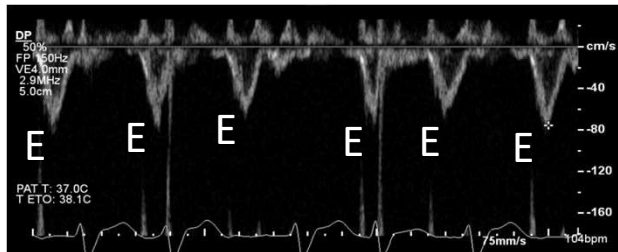
Doppler  
tissulaire  
anneau  
mitral

Evaluation  
pression  
remplissage

Guidelines et  
mise en  
pratique

## LAP Estimation in Atrial Fibrillation

1. Mitral E velocity  $\geq 100$  cm/s
2. Septal E/e' ratio  $> 11$
3. TR velocity  $> 2.8$  m/s or PASP  $> 35$  mm Hg
4. DT  $\leq 160$  ms



Physio-  
pathologie

Outils  
diagnostique

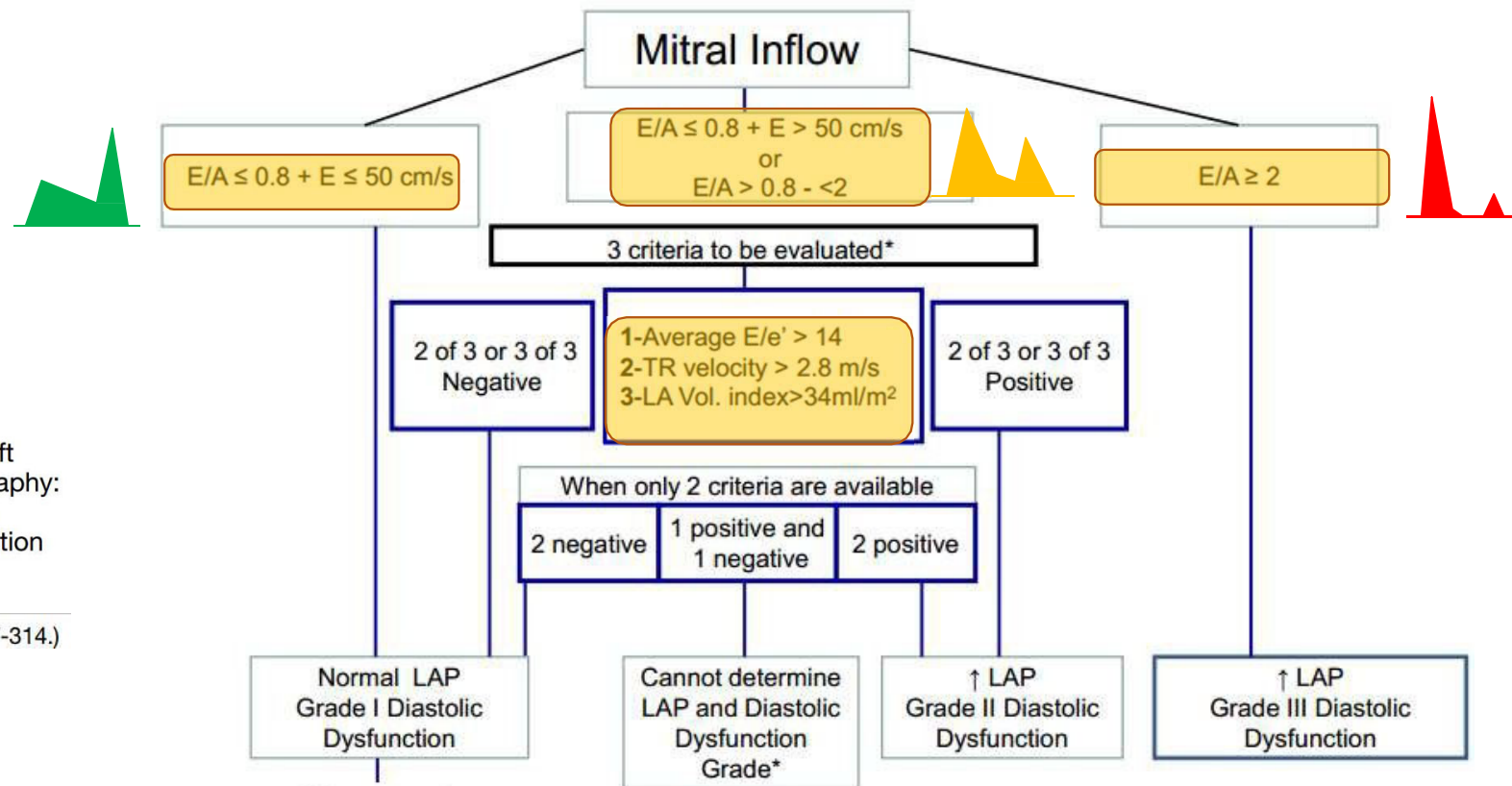
Doppler  
pulsé mitral

Doppler  
tissulaire  
anneau  
mitral

Evaluation  
pression  
remplissage

Guidelines et  
mise en  
pratique

## ASE / EACVI 2016 recommendations : FEVG basse



ASE/EACVI GUIDELINES AND STANDARDS

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Physio-  
pathologie

Outils  
diagnostique

Doppler  
pulsé mitral

Doppler  
tissulaire  
anneau  
mitral

Evaluation  
pression  
remplissage

Guidelines et  
mise en  
pratique

## Absence de dysfonction diastolique du VG

REVIEW



### Ventricular diastolic abnormalities in the critically ill

Philippe Vignon<sup>a,b,c</sup>

Vignon P Curr Opin Crit Care 2013 ; 19 : 242-9

Echocardiographic findings allowing to rule out a relevant LV diastolic dysfunction

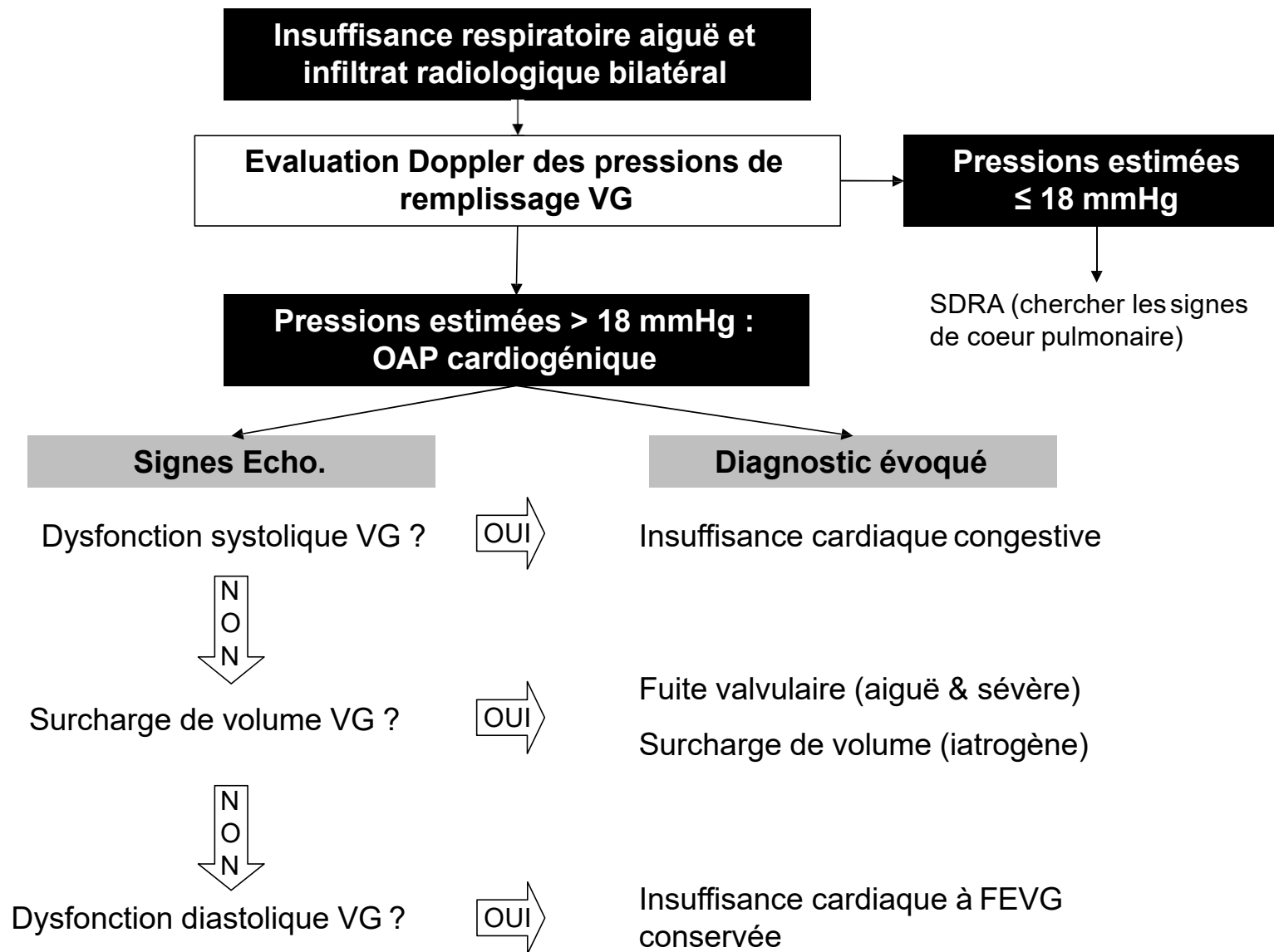
No LV morphological abnormality

Normal left-atrial size

Homogeneous pattern of LV contraction

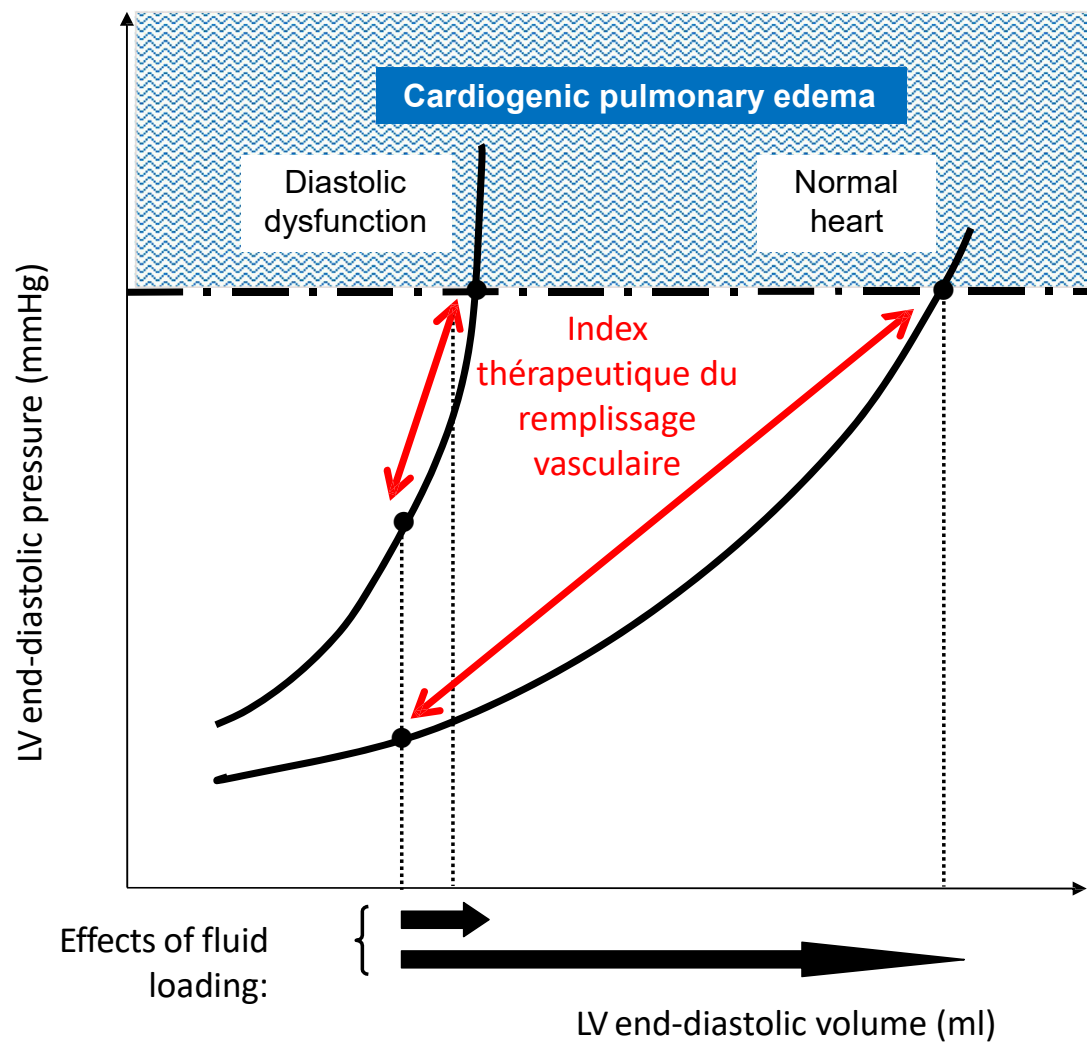
Normal or abnormal relaxation (grade I) pattern according to age, and no cardiac disease

$E/E' < 8$

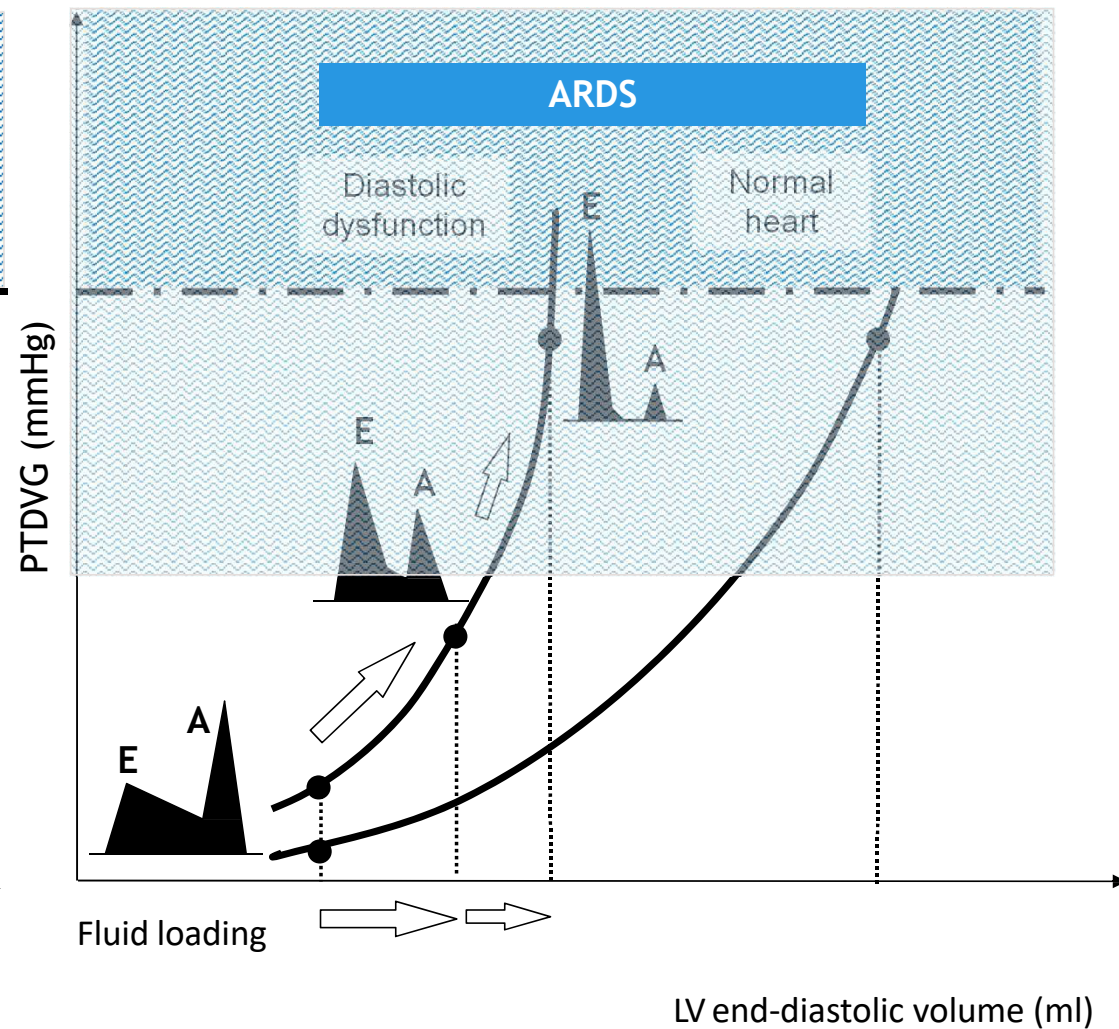




## OAP cardiogénique



## OAP lésionnel



Physio-  
pathologie

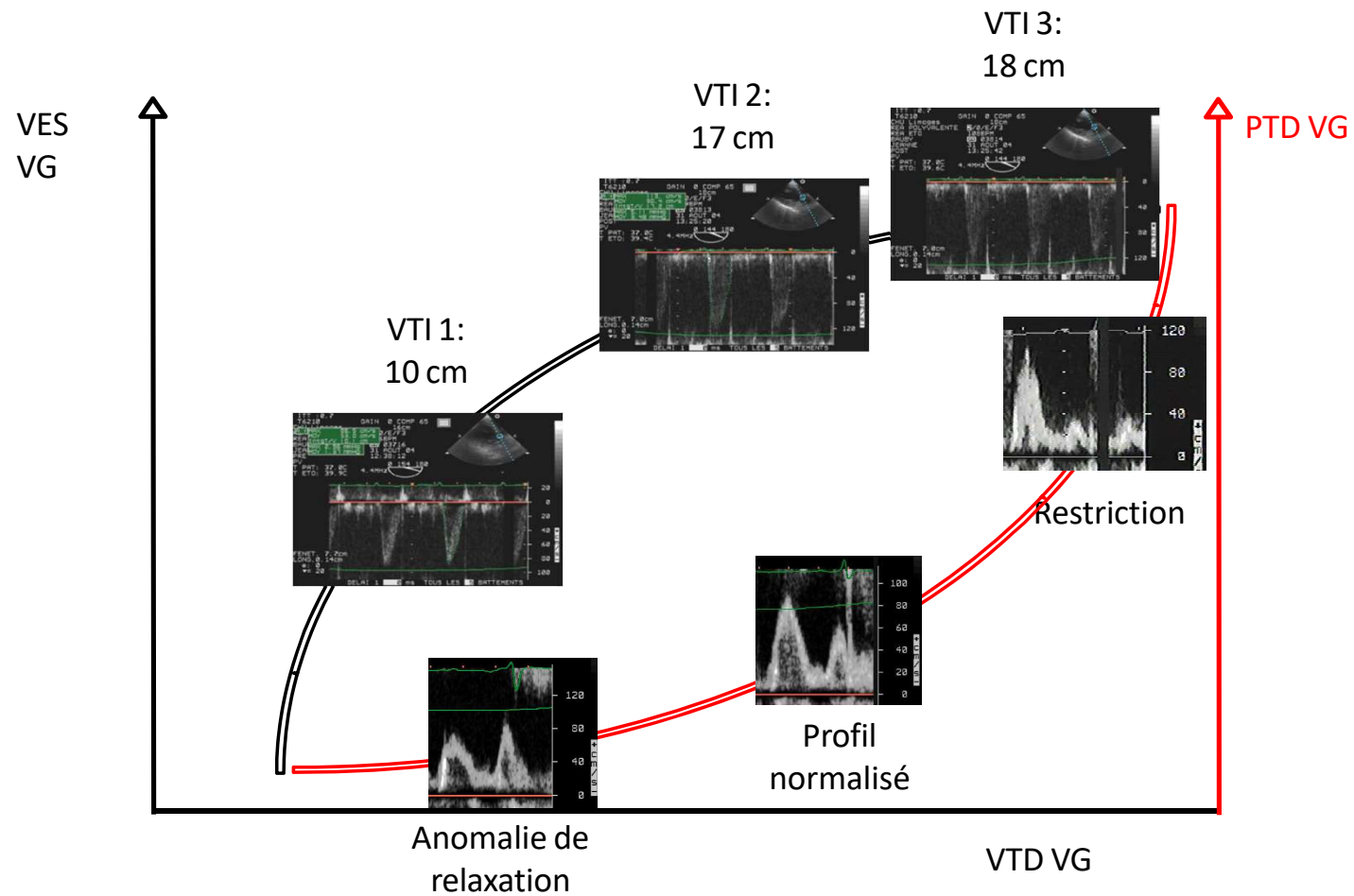
Outils  
diagnostique

Doppler  
pulsé mitral

Doppler  
tissulaire  
anneau mitral

Evaluation  
pression  
remplissage

Guidelines et  
mise en  
pratique





Physio-  
pathologie

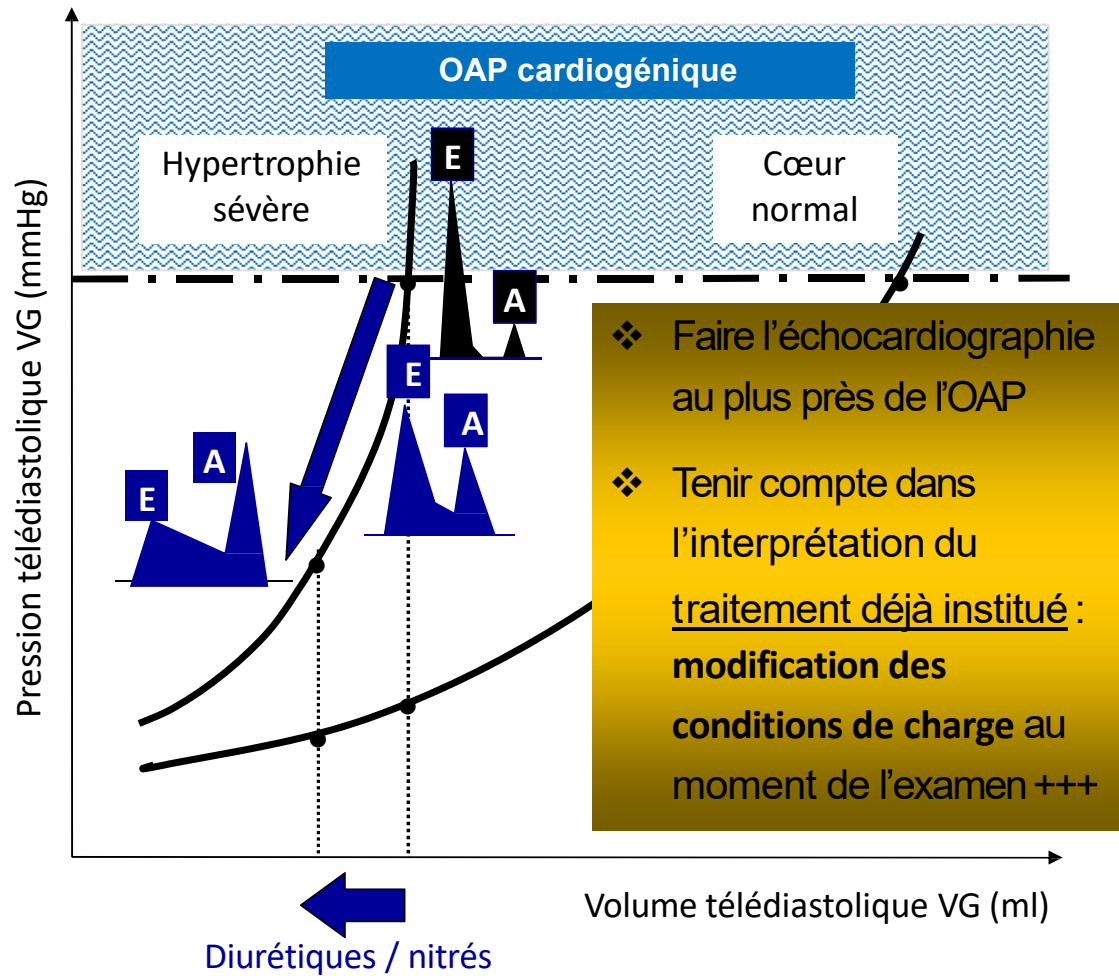
Outils  
diagnostique

Doppler  
pulsé mitral

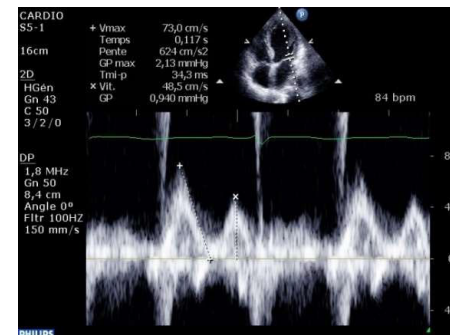
Doppler  
tissulaire  
anneau  
mitral

Evaluation  
pression  
remplissage

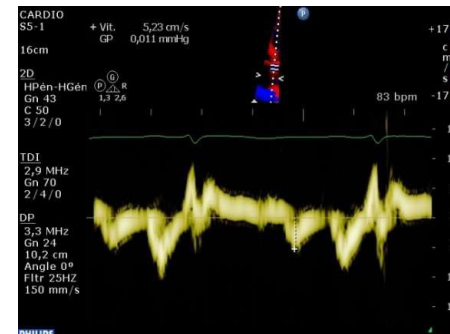
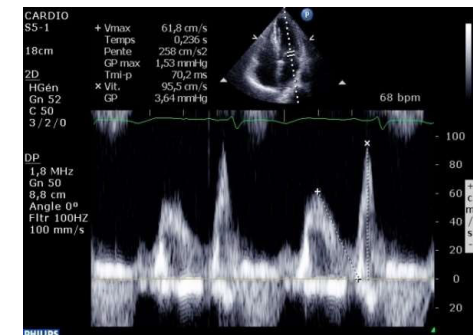
Guidelines et  
mise en  
pratique



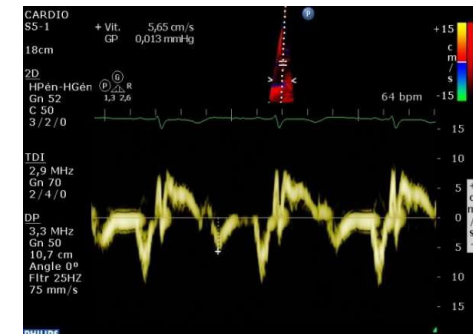
Admission  
(pulmonary edema)



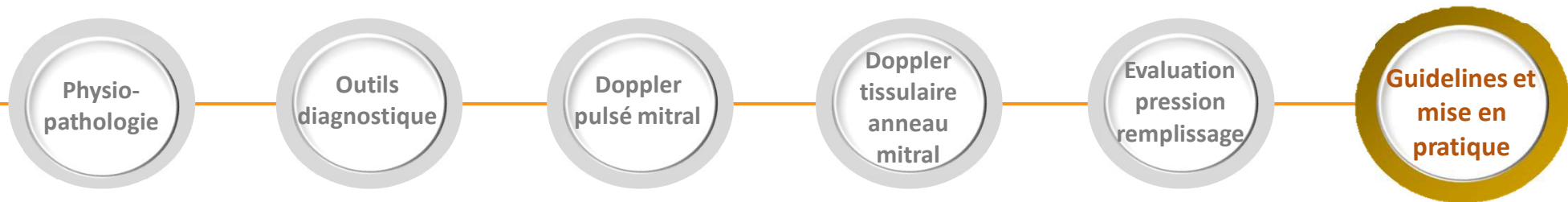
After treatment  
(vasodilators & diuretics)



E/E': 14



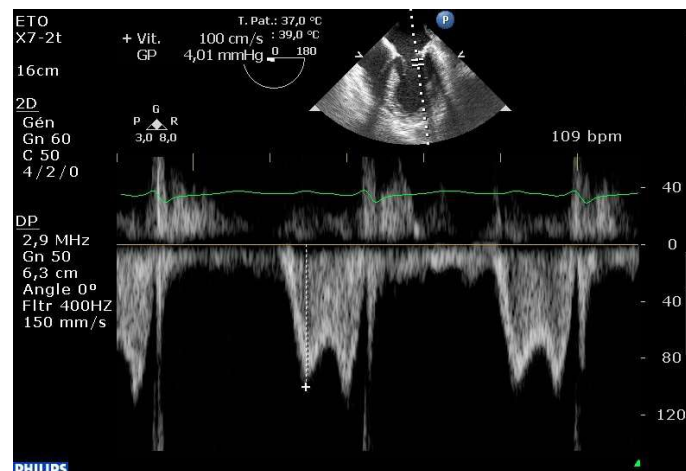
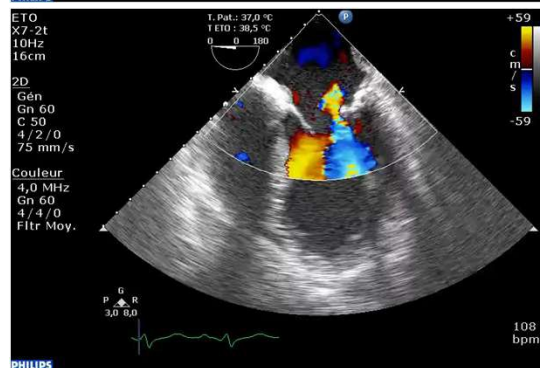
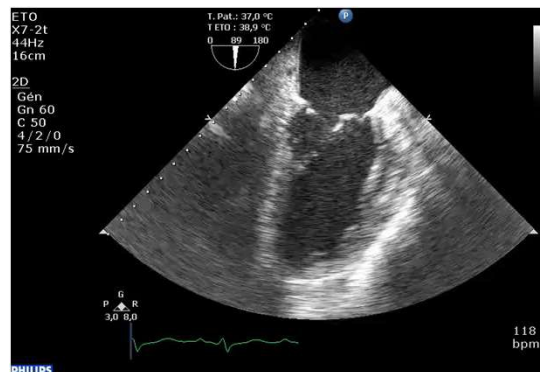
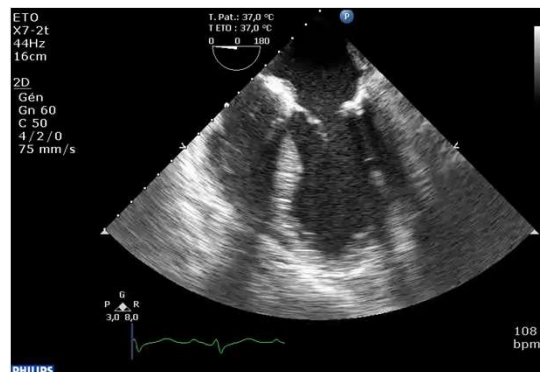
E/E': 11



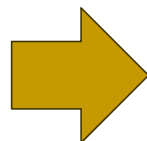
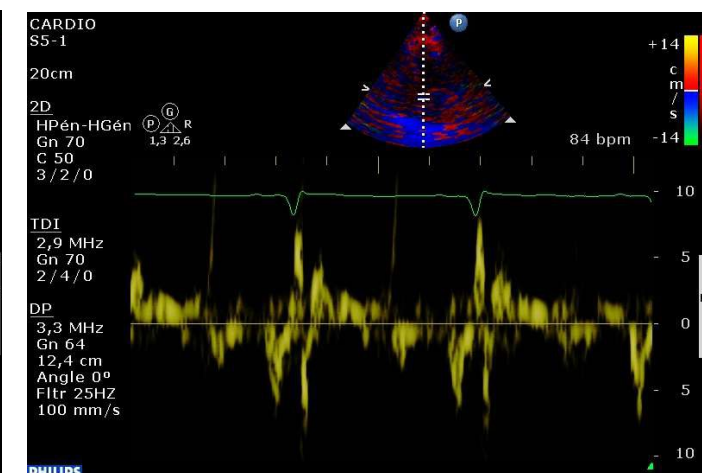
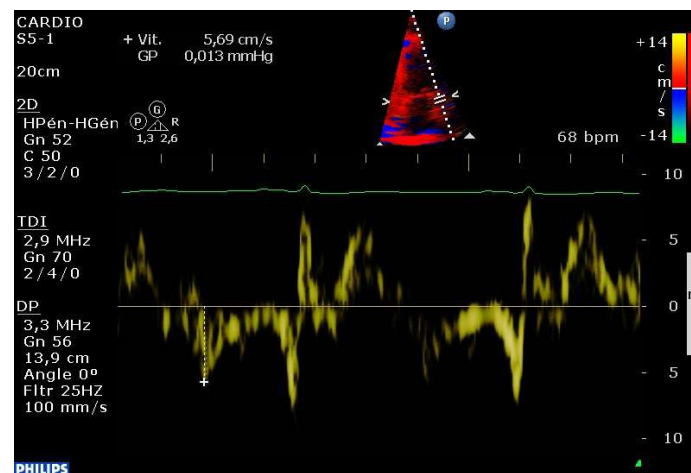
## Cas Clinique : échec de sevrage du respirateur

- ❖ Homme de 76 ans, hypertendu, cardiomyopathie ischémique avec FEVG à 45%
- ❖ Pontages aorto-coronaire sans CEC (pas de problèmes peropératoires)
- ❖ Transfert pour sevrage difficile après 2 échecs d'épreuve de VS sur tube en T
- ❖ ETT: fonction systolique VG normale (FEVG à 55%), E/E' moyenné à 10, IM minime
- ❖ Bilan hydrique négatif (- 6 kgs sous diurétiques) : échec de l'épreuve de VS sur tube à 10 min
- ❖ Patient immédiatement reconnecté au respirateur et ETO en volume contrôlé.

Echec pièce en T: PA= 210 / 115 mmHg

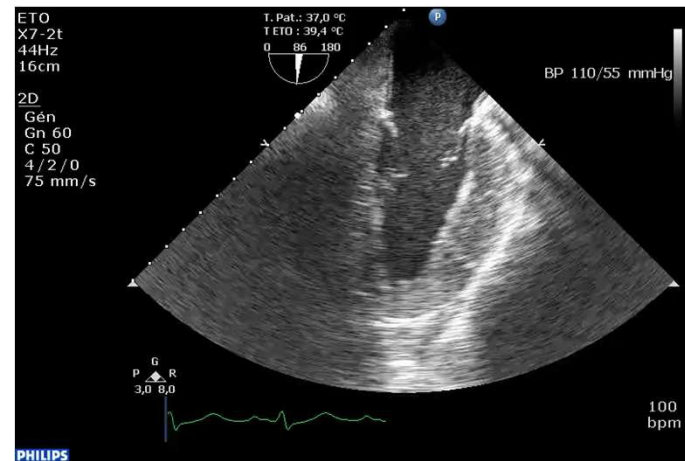
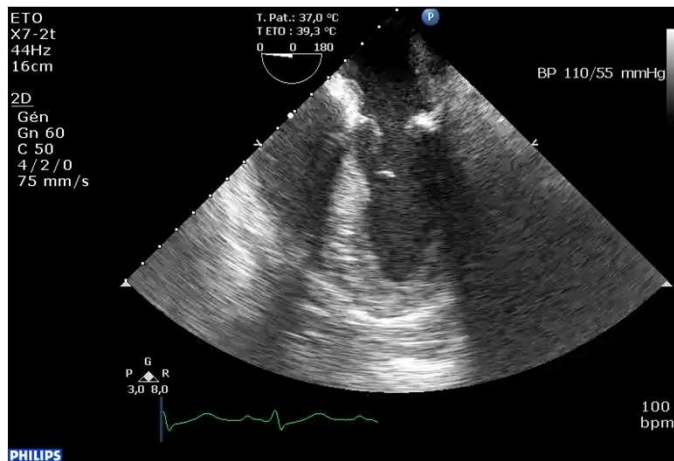


Vmax E: 100 cm/s  
E/E' moyenné : 17

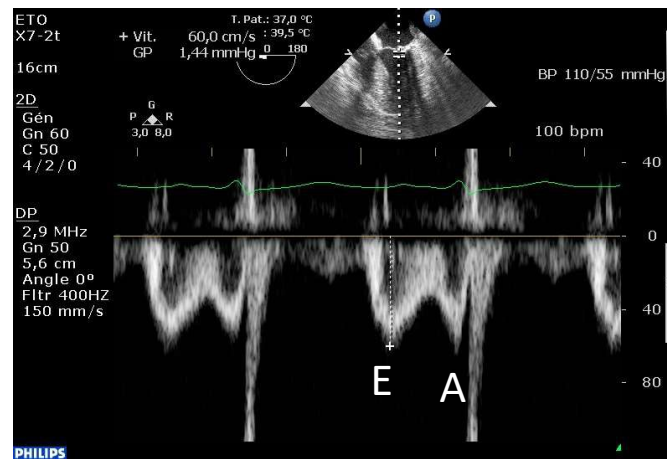


Traitement antihypertenseur IV

## VAC& Nicardipine IV : PA= 110 / 55 mmHg



Vmax E: 60 cm/s  
E/E' moyenné : 10





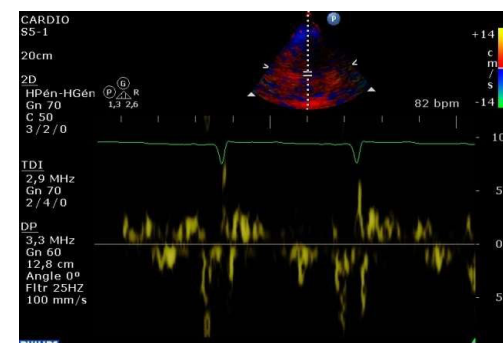
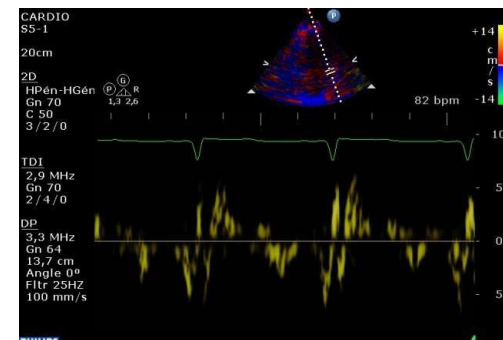
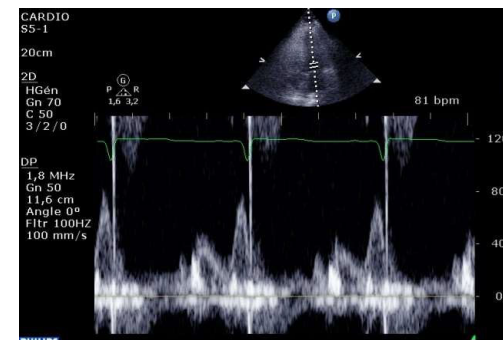
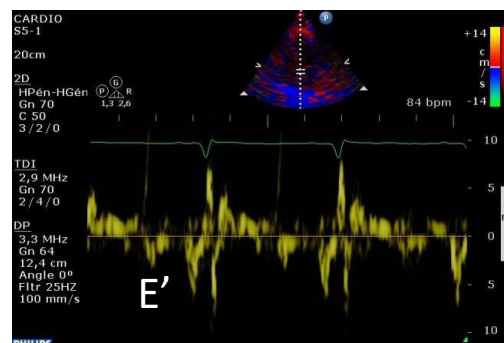
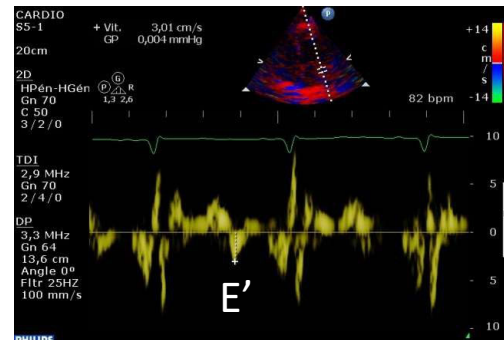
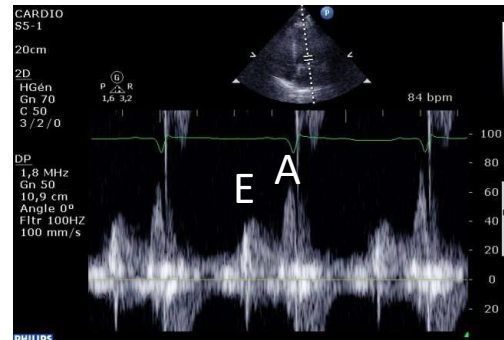
Vmax E: 40 cm/s  
E/E' moyenné : 10

Before SBT

SBT

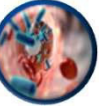
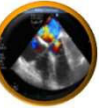
Vmax E: 40 cm/s  
E/E' moyenné : 10

TTT personnalisé



Epreuve de VS+ / extubation

# Fonction diastolique et pression de remplissage du VG



- ❖ Propriétés diastoliques et pressions de remplissage du VG sont étroitement liées
- ❖ En cas de dysfonction diastolique, la fonction systolique peut être conservée ou non
- ❖ Le diagnostic d'**OAP cardiogénique** repose sur la mise en évidence d'une **élévation des pressions de remplissage du VG** à l'instant  $t$ , souvent associée à une dysfonction diastolique (sévère) & cardiopathie
- ❖ Les recommandations internationales ne sont pas adaptées au patient en état critique
- ❖ **L'élévation des pressions de remplissage** est l'information pertinente pour le réanimateur
- ❖ OAP à FEVG conservée : documenter **au plus près de l'épisode** pour éviter les diagnostics par excès.

