DIU TUSAR

Bordeaux – Mardi 16 décembre 2025

Exploration du coeur droit et de la voie pulmonaire

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Anatomie

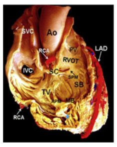
Ventricule droit

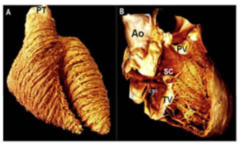
- Pyramide tronquée enroulée en croissant autour du VG
- Antérieur dans le thorax (position rétrosternale)
- Chambre d'admission (sinus) et chambre de chasse (infundibulum)
- Trabéculations apicales marquées
- Paroi libre mince :
  - ✓ Compliance > VG : fonction diastolique « tolérante »
  - ✓ Contractilité < VG : fonction systolique « sensible » aux conditions de charge (post-charge +++)
- Ejection selon le mode d'un soufflet & interaction avec le VG
- Contraction de l'infundibulum difficile à explorer.

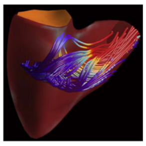
Anatomie

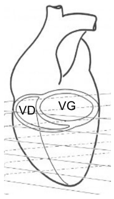
Ventricule droit : anatomie complexe

- OD connectée aux veines caves : éjection du VD directement dépendant du retour veineux
- Forme de soufflet, enroulé autour du VG ; mesure des volumes non modélisable (recours à la 3D)
- Fibres longitudinales développées ; contraction complexe (rôle de l'infundibulum).





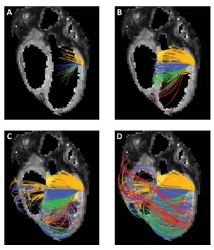


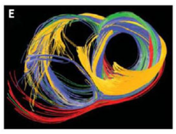


Sanz J et al. JACC 2019

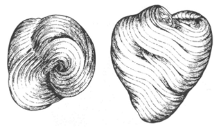
Anatomie

Ventricule droit : interdépendance avec le VG





Friedberg MK et al. Circulation 2014

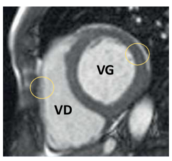


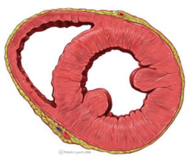
Streeter 1957

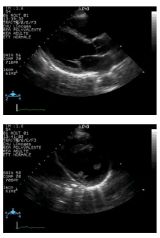
- L'éjection VD dépend de la fonction systolique VG (fibres communes)
- Interdépendance avec VG : septum interventriculaire commun.

Anatomie

Ventricule droit : paroi libre fine



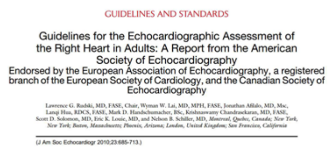




- Rôle du VD : éjecter la totalité du débit sanguin dans le système artériel pulmonaire en maintenant une POD basse pour faciliter le retour veineux
- Paroi libre fine adaptée aux RVP basses.

Anatomie

Etude morphologique



GUIDELINES AND STANDARDS

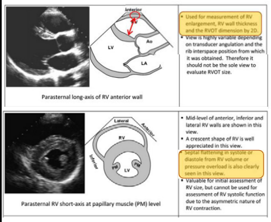
Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography
Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

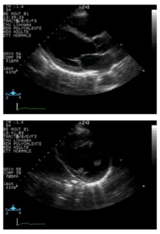
Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afilalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, *Montreal, Quebec, Canada; New York, New York; Boston, Massachusetts; Phoenix, Arizona; London, United Kingdom; San Francisco, California*

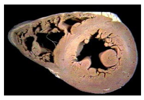
(J Am Soc Echocardiogr 2010;23:685-713.)

Anatomie
Etude morphologique

VD : vues parasternales



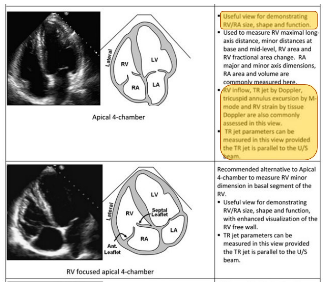


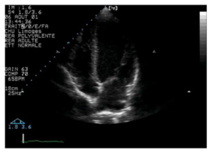


J Am Soc Echocardiogr 2010 ; 12 : 685-713

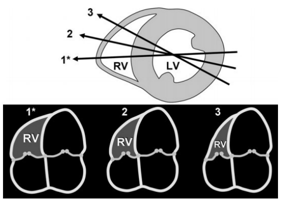
Anatomie
Etude morphologique

VD : vue apicale 4 cavités





Incidence de l'angle de coupe sur le rapport des surfaces télédiastoliques VD/VG

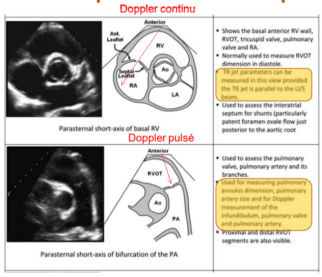


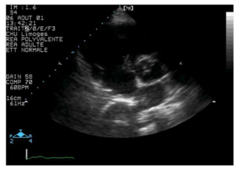
1* : coupe recommandée
2,3 : risque de sous-estimation

Anatomie
Etude morphologique

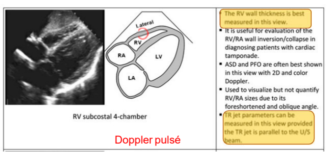
VD et voie pulmonaire : vues parasternales petit axe de la base

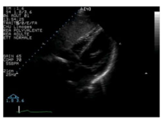
Doppler continu



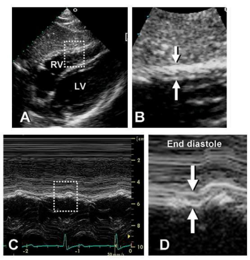


VD et voie pulmonaire : vues sous-costales (1)





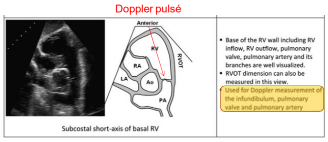
Nle < 5 mm (télédiastole)

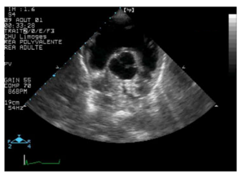


Anatomie
Etude morphologique

VD et voie pulmonaire : vues sous-costales (2)

Doppler pulsé





Anatomie

Etude morphologique

Vue sous-costale de la VCI

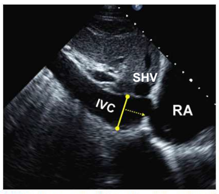
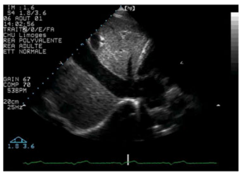


Figure 4 Inferior vena cava (IVC) view. Measurement of the IVC. The diameter *(solid line)* is measured perpendicular to the long axis of the IVC at end-expiration, just proximal to the junction of the hepatic veins that lie approximately 0.5 to 3.0 cm proximal to the ostium of the right atrium (RA).



Anatomie

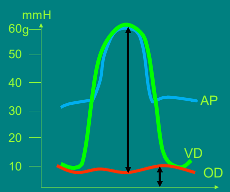
Etude morphologique

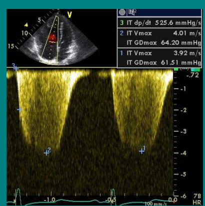
Etude hémodynamique

Etude hémodynamique : *VD et voie pulmonaire*

- Doppler spectral (pulsé et continu)
- Utiliser différentes vues pour un alignement optimal du tir Doppler
- Estimation de la pression artérielle pulmonaire (PAP)
- Estimation du volume d'éjection systolique du VD
- Retentissement d'une insuffisance VD sur la circulation veineuse systémique.

Evaluation de la PAPs





- Equation de Bernoulli : **ΔP = 4 V²**

  (PVD syst - POD syst = 4 Vmax IT², ou PAP syst - POD syst = 4 Vmax IT²)
- En l'absence de sténose pulmonaire.

Assessment of Pulmonary Arterial Pressure Using Critical Care Echocardiography: Dealing With the Yin and the Yang?*

Philippe Vignon, MD, PhD
Medical-Surgical Intensive Care Unit, and Inserm CIC 1435
Dupuytren Teaching Hospital; and
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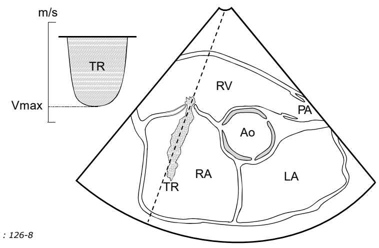
Limoges, France



Crit Care Med 2019 ; 47 : 126-8

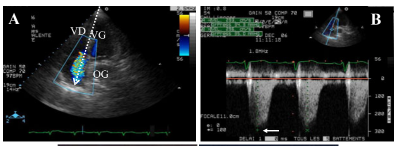
Anatomie

Etude morphologique

Etude hémodynamique

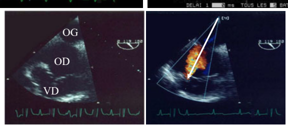
Evaluation de la PAPs

ETT



PAPs ≈ 4 • (Vmax IT)² + POD

ETO



Typiquement :
40 à 60°

Anatomie

Etude morphologique

Etude hémodynamique

Evaluation de la PAPs

TABLE 1. Technical Prerequisites and Potential Limitations of Advanced Critical Care Echocardiography for Quantitative Estimation of Pulmonary Artery Pressure

Technical Prerequisites for Each Successive Step	Potential Limitations of Critical Care Echocardiography
Adequate acoustic windows[a]	Feasibility in the targeted population (e.g., chronic lung diseases) and in the ICU setting (e.g., dressings, mechanical ventilation with PEEP, supine position)
Identifiable TR using color Doppler flow mapping	No correlation between TR jet area and right atrioventricular pressure gradient
	The absence of TR fails to exclude pulmonary artery hypertension
High-quality continuous-wave Doppler signal with clear delineation of TR envelope	Inadequate alignment of Doppler beam with TR jet leading to underestimation of maximal velocity, hence peak RV systolic pressure
Well-identified TR peak velocity	Any measurement error is squared, leading to even higher imprecision of peak RV systolic pressure estimate
Multiple[b] measurements evenly performed throughout the respiratory cycle	Confounding effects of heart-lung interactions, especially in ventilated patients with high PEEP levels
Identification of potential sources of inaccuracy of simplified Bernouilli's equation[c]	Inaccurate quantitative estimation of pulmonary artery pressure due to imperfect transformation of potential to kinetic energy
Invasive measurement of CVP (equivalent to right atrial pressure)[d]	Inaccurate estimation of CVP using the size and respirophasic variations of inferior vena cava[e]

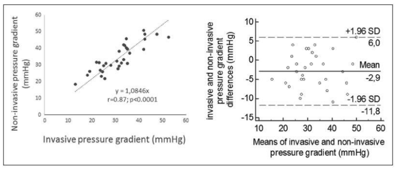
Crit Care Med 2019 ; 47 : 126-8

Anatomie · Etude morphologique · Etude hémodynamique

Evaluation du gradient de pression OD-VD

Reassessment of the Accuracy of Cardiac Doppler Pulmonary Artery Pressure Measurements in Ventilated ICU Patients: A Simultaneous Doppler-Catheterization Study*

Pablo Mercado, MD[1]; Julien Maizel, MD, PhD[1,2]; Christophe Beyls, MD[1]; Loay Kontar, MD[1]; Sam Orde, MD[3]; Stephen Huang, MD, PhD[3]; Anthony McLean, MD, PhD[3]; Christophe Tribouilloy, MD, PhD[1,2]; Michel Slama, MD, PhD[1,2]



Crit Care Med 2019 ; 47 : 41-8

Anatomie · Etude morphologique · Etude hémodynamique

Evaluation de la PVC / POD

Reappraisal of the Use of Inferior Vena Cava for Estimating Right Atrial Pressure

J. Matthew Brennan, MD, John E. Blair, MD, Sascha Goonewardena, MD, Adam Ronan, MD, Dipak Shah, MD, Samip Vasaiwala, MD, James N. Kirkpatrick, MD, and Kirk T. Spencer, MD, *Chicago, Illinois*

Diamètre de la VCI	Variations respiratoires du diamètre de la VCI en VENTILATION SPONTANEE	POD prédite
< 20 mm	Diminution inspiratoire > 50%	5 mmHg
	Diminution inspiratoire < 50%	10 mmHg
> 20 mm	Diminution inspiratoire > 50%	15 mmHg
	Diminution inspiratoire < 50%	20 mmHg

Brennan JM et al. J Am Soc Echocardiogr 2007; 20: 857-61

PVC : 5 mmHg

PVC : 18 mmHg

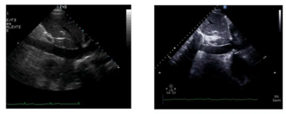


Table 3 Estimation of RA pressure on the basis of IVC diameter and collapse

Variable	Normal (0-5 [3] mm Hg)	Intermediate (5-10 [8] mm Hg)		High (15 mm Hg)
IVC diameter	≤2.1 cm	≤2.1 cm	>2.1 cm	>2.1 cm
Collapse with sniff	>50%	<50%	>50%	<50%

JASE 2010 ; 23 : 685-713

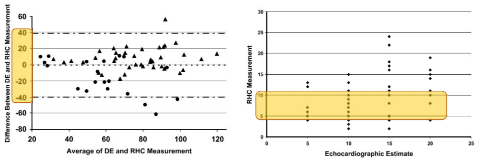
Anatomie · Etude morphologique · Etude hémodynamique

Précision de l'évaluation de la PAPs

Accuracy of Doppler Echocardiography in the Hemodynamic Assessment of Pulmonary Hypertension

Micah R. Fisher[1*], Paul R. Forfia[2], Elzbieta Chamera[2], Traci Housten-Harris[1], Hunter C. Champion[2], Reda E. Girgis[1], Mary C. Corretti[2], and Paul M. Hassoun[1]

[1]Division of Pulmonary and Critical Care Medicine; [2]Division of Cardiology, Department of Medicine, Johns Hopkins University, Baltimore, Maryland



Manque de précision liée à la mauvaise évaluation PVC : la mesurer sur KTC !

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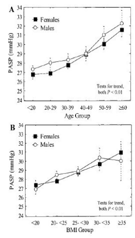
Limites de normalité de la PAPs (1)



Mc Quillan BM. Circulation 2001 ; 104 : 2797-2802

CHEST Original Research

PULMONARY VASCULAR DISEASE

Echocardiography of the Pulmonary Circulation and Right Ventricular Function

Exploring the Physiologic Spectrum in 1,480 Normal Subjects

Results: PASP and mean pulmonary artery pressure values were significantly higher in subjects aged >50 years and in those with a BMI >30 kg/m². In particular, a PASP >40 mm Hg was found in 118 subjects (8%) of those aged >50 years and in 103 (7%) of those with a BMI >30 kg/m².

Table 4—Significant Independent Relation of PASP in the Overall Population With Clinical Variables and Echocardiography Variables by Multivariate Analysis

Dependent Variable	Independent Variables	β Coefficient	P Value
PASP	Age	0.41	<.001
	Male sex	0.21	NS
	BMI	0.44	<.001
	LV E/e′	0.46	<.001
	LV mass index	0.26	NS
	LV stroke volume	0.36	<.01

D'Andrea A. Chest 2014 ; 145 : 1071-8

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Limites de normalité de la PAPs (2)

- HTAP : PAPs > 30 mmHg ou PAPm > 20 mmHg
- En fait : PAPs jusqu'à 38 mmHg (adulte normal non obèse) et 47 mmHg (adulte normal obèse)[1]

  et PAP élevée chez les hypertendus âgés[2]
- HTAP si Vmax IT > 3 m/s en l'absence d'obésité et d'HTA
- Vmax IT > 2.9 m/s : un des 4 critères de dysfonction diastolique VG.

[1] : Abergel E et al. Am J cardiol 1996 ; 77 : 767-9
[2] : Finkelhor RS et al. Chest 2003 ; 123 : 711-5

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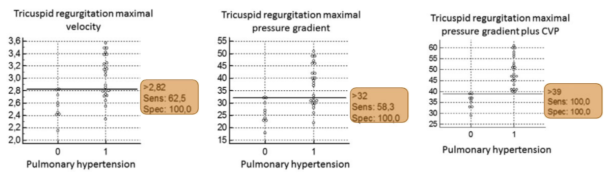
Limites de normalité de la PAPs (3)

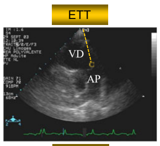


Mercado P et al. Crit Care Med 2019 ; 47 : 41-8

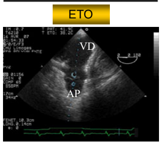
Anatomie | Etude morphologique | **Etude hémodynamique**

Doppler pulmonaire
Doppler pulsé

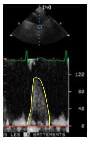
ETT



ETO

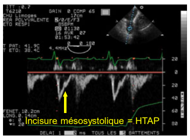


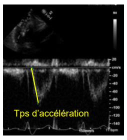
ETO base 0°



Mesure de l'ITV pulmonaire ~ volume d'éjection systolique VD

Transgastrique profonde 0°





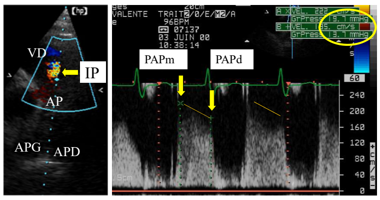
Mesure du temps d'accélération et profil de l'ITV pulmonaire

Anatomie | Etude morphologique | **Etude hémodynamique**

Doppler pulmonaire
Doppler continu

PAPm ~ 4 • (Vmax IP protodiastolique)² + POD

PAPd ~ 4 • (Vmax IP télédiastolique)² + POD

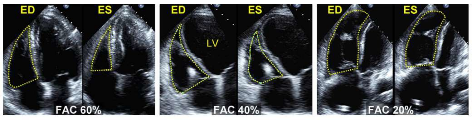


Pressions (mmHg) :

PVC = 14
PAPm = 34
PAPd = 28

Anatomie | Etude morphologique | Etude hémodynamique | **Fonction VD**

Fraction de réduction de surface du VD



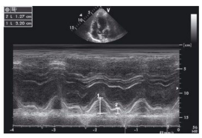
Normale : 40 à 70 % (Jardin), 30 à 60% (Weyman)

JASE 2010 ; 23 : 685-713

Anatomie | Etude morphologique | Etude hémodynamique | **Fonction VD**

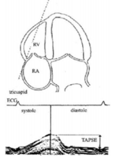
Fonction systolique des fibres longitudinale du VD

TAPSE
Tricuspid Annulus Plane Systolic Excursion

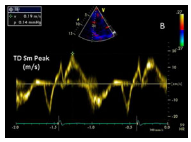


Mode TM

Normale : 16 à 30 mm



Onde S'



Doppler tissulaire pulsé

Normale : 10 à 19 cm/s

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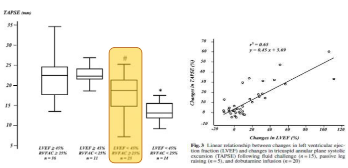
Limites du TAPSE

ORIGINAL

Relationship between the tricuspid annular plane systolic excursion and right and left ventricular function in critically ill patients



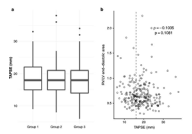
Critical Care

RESEARCH

Right ventricular failure in septic shock: characterization, incidence and impact on fluid responsiveness

Groupe 1 : STDVD/VG < 0.6
Groupe 2 : STDVD/VG ≥ 0.6 et PVC < 8 mmHg
Groupe 3 : STDVD/VG ≥ 0.6 et PVC ≥ 8 mmHg.

282 patients ventilés en choc septique



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GUIDELINES AND STANDARDS

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography
Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

Valeurs normales

Table 4 Systolic function

Variable	Studies	n	LRV (95% CI)	Mean (95% CI)	URV (95% CI)
TAPSE (mm) (Figure 17)	46	2320	16 (15-18)	23 (22-24)	30 (29-31)
Pulsed Doppler velocity at the annulus (cm/s)	43	2139	10 (9-11)	15 (14-15)	19 (18-20)
Color Doppler velocities at the annulus (cm/s)	5	281	6 (5-7)	10 (9-10)	14 (12-15)
Pulsed Doppler MPI (Figures 16 and 18)	17	686	0.15 (0.10-0.20)	0.28 (0.24-0.32)	0.40 (0.35-0.45)
Tissue Doppler MPI (Figure 18)	8	590	0.24 (0.16-0.32)	0.39 (0.34-0.45)	0.55 (0.47-0.63)
FAC (%) (Figure 8)	36	1276	35 (32-38)	49 (47-51)	63 (60-65)
RV EF (%) (Figure 8)	12	596	44 (38-50)	58 (53-63)	71 (66-77)
3D RV EF (%)	9	524	44 (39-49)	57 (53-61)	69 (65-74)
IVA (m/s²)	12	389	2.2 (1.4-3.0)	3.7 (3.0-4.4)	5.2 (4.4-5.9)

CI, Confidence interval; *EF*, ejection fraction; *FAC*, fractional area change; *IVA*, isovolumic acceleration; *LRV*, lower reference value; *MPI*, myocardial performance index; *RV*, right ventricular; *TAPSE*, tricuspid annular plane systolic excursion; *3D*, three-dimensional; *URV*, upper reference value.

J Am Soc Echocardiogr 2010 ; 12 : 685-713

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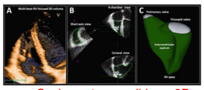
Valeurs pathologiques

Journal of the American Society of Echocardiography
January 2015



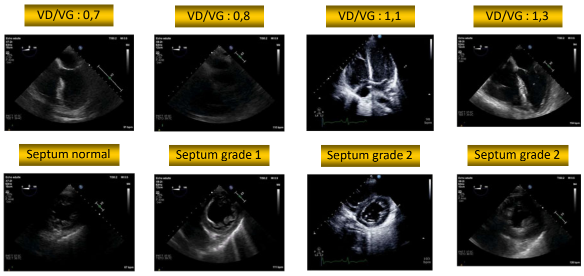
Seulement accessible en 3D
(validé contre IRM)

Table 10 Normal values for parameters of RV function

Parameter	Mean ± SD	Abnormality threshold
TAPSE (mm)	24 ± 3.5	<17
Pulsed Doppler S wave (cm/sec)	14.1 ± 2.3	<9.5
Color Doppler S wave (cm/sec)	9.7 ± 1.85	<6.0
RV fractional area change (%)	49 ± 7	<35
RV free wall 2D strain* (%)	−29 ± 4.5	>−20 (<20 in magnitude with the negative sign)
RV 3D EF (%)	58 ± 6.5	<45
Pulsed Doppler MPI	0.26 ± 0.085	>0.43
Tissue Doppler MPI	0.38 ± 0.08	>0.54
E wave deceleration time (msec)	180 ± 31	<119 or >242
E/A	1.4 ± 0.3	<0.8 or >2.0
e′/a′	1.18 ± 0.33	<0.52
e′	14.0 ± 3.1	<7.8
E/e′	4.0 ± 1.0	>6.0

MPI, Myocardial performance index.
*Limited data; values may vary depending on vendor and software version.

Evolution de l'atteinte du VD (découplage VD / AP)



Exploration du coeur droit et de la voie pulmonaire

- Echocardiographie : information triple (morphologie, hémodynamique et fonction systolique VD)
- Pas de modélisation géométrique simple du VD à la différence du VG
- ***Pas*** de superposition fonctionnelle avec le VG
- **Sensibilité** du VD aux conditions de charge **(post-charge).**

CHU Limoges — Inserm — CIC Limoges

Anatomie — Etude morphologique — **Etude hémodynamique**

Evaluation des résistances vasculaires pulmonaires

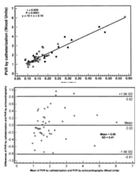
Pulmonary Hypertension

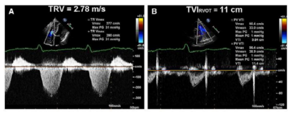
A Simple Method for Noninvasive Estimation of Pulmonary Vascular Resistance

Based on our results, we propose a simplified equation for noninvasive calculation of PVR:

$PVR(WU) = 10 \times TRV/TVI_{RVOT}$

We also propose that in patients with increased PASP on Doppler echocardiography and $TRV/TVI_{RVOT} > 0.2$, an elevated PVR is suggested, and these patients may require further invasive workup. However, in patients with $TRV/TVI_{RVOT} < 0.2$, PVR values are likely to be normal, even in the presence of Doppler evidence of increased PASP.





- V max IT / ITV pulm > 0,20 : pathologique (= 0,25)
- RVP estimées = 10 (V max IT / ITV pulm) + 0,16 (= 2,68 UW)