DIU TUSAR
Bordeaux – Mardi 17 décembre 2019

Exploration du CŒUR DROIT et de la voie pulmonaire

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Réanimation Polyvalente ; CIC 1435 - CHU Limoges

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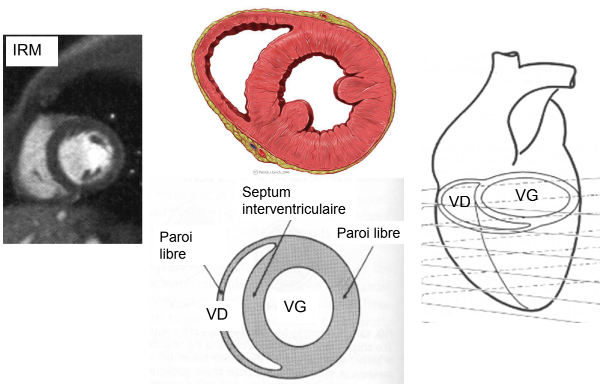
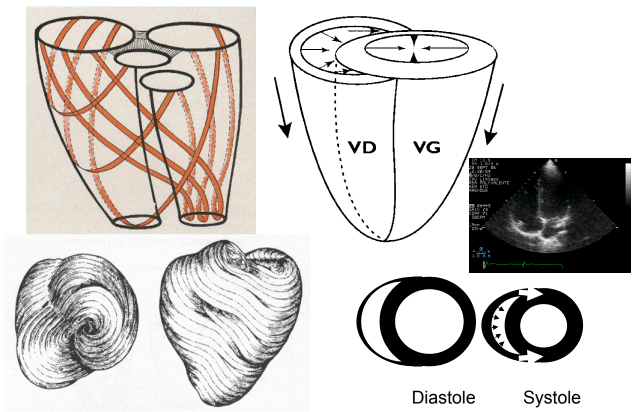
Conflit d'intérêt

Rappels anatomiques

Ventricule droit (VD)

- 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.





Etude morphologique

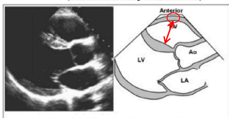
GUIDELINES AND STANDARDS

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

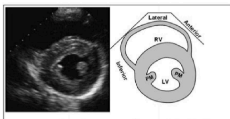
Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afilalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, *Montreal, Quebec, Canada; New York, New York; Boston,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

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



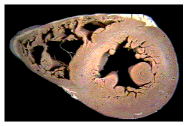
Parasternal long-axis of RV anterior wall

- Used for measurement of RV enlargement, RV wall thickness and the RVOT dimension by 2D.
- View is highly variable depending on transducer angulation and the rib interspace position from which it was obtained. Therefore it should not be the sole view to evaluate RVOT size.



Parasternal RV short-axis at papillary muscle (PM) level

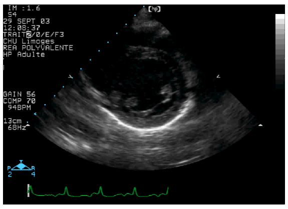
- Mid-level of anterior, inferior and lateral RV walls are shown in this view.
- A crescent shape of RV is well appreciated in this view.
- Septal flattening in systole or diastole from RV volume or pressure overload is also clearly seen in this view.
- Valuable for initial assessment of RV size, but cannot be used for assessment of RV systolic function due to the asymmetric nature of RV contraction.



Ventricule droit normal

Petit axe

ETT



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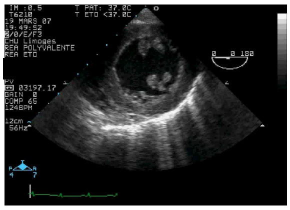
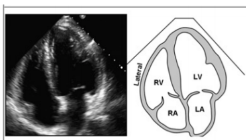
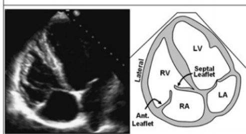




Apical 4-chamber

- Useful view for demonstrating RV/RA size, shape and function.
- Used to measure RV maximal long-axis distance, minor distances at base and mid-level, RV area and RV fractional area change. RA major and minor axis dimensions, RA area and volume are commonly measured here.
- RV inflow, TR jet by Doppler, tricuspid annulus excursion by M-mode and RV strain by tissue Doppler are also commonly assessed in this view.
- TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.



RV focused apical 4-chamber

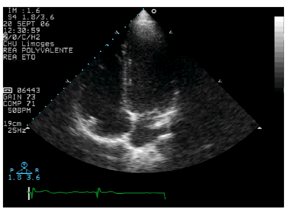
Recommended alternative to Apical 4-chamber to measure RV minor dimension in basal segment of the RV.

- Useful view for demonstrating RV/RA size, shape and function, with enhanced visualization of the RV free wall.
- TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.

Ventricule droit normal

Grand axe

ETT



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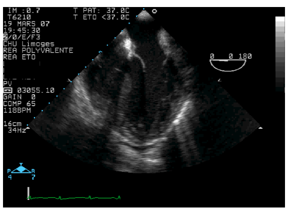
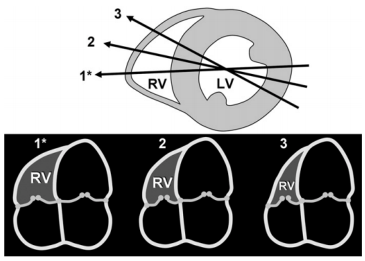
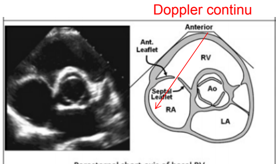
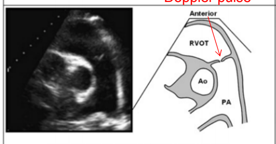
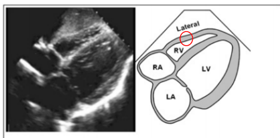
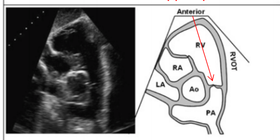


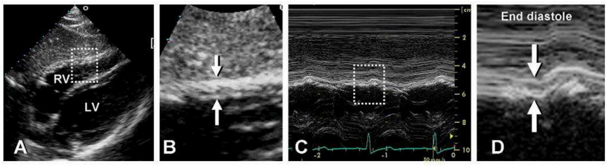


1* : coupe recommandée
2,3 : risque de sous-estimation

Doppler continu	
 Parasternal short-axis of basal RV	▪ Shows the basal anterior RV wall, RVOT, tricuspid valve, pulmonary valve and RA. ▪ Normally used to measure RVOT dimension in diastole. ▪ TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam. ▪ Used to assess the interatrial septum for shunts (particularly patent foramen ovale flow just posterior to the aortic root
Doppler pulsé  Parasternal short-axis of bifurcation of the PA	▪ Used to assess the pulmonary valve, pulmonary artery and its branches. ▪ Used for measuring pulmonary annulus dimension, pulmonary artery size and for Doppler measurement of the infundibulum, pulmonary valve and pulmonary artery. ▪ Proximal and distal RVOT segments are also visible.

 RV subcostal 4-chamber	▪ The RV wall thickness is best measured in this view. ▪ It is useful for evaluation of the RV/RA wall inversion/collapse in diagnosing patients with cardiac tamponade. ▪ ASD and PFO are often best shown in this view with 2D and color Doppler. ▪ Used to visualize but not quantify RV/RA sizes due to its foreshortened and oblique angle. ▪ TR jet parameters can be measured in this view provided the TR jet is parallel to the U/S beam.
Doppler pulsé  Subcostal short-axis of basal RV	▪ Base of the RV wall including RV inflow, RV outflow, pulmonary valve, pulmonary artery and its branches are well visualized. ▪ RVOT dimension can also be measured in this view. ▪ Used for Doppler measurement of the infundibulum, pulmonary valve and pulmonary artery

Epaisseur paroi libre VD



- Vue sous-costale, zoom sur la paroi libre
- TM strictement perpendiculaire à la paroi, mesure en télédiastole
- Normale ≤ 5 mm

Veine cave inférieure (VCI)

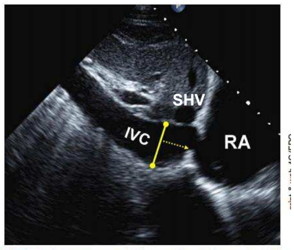
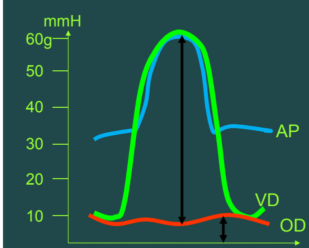


Figure 4 Inferior vena cava (IVC) view. Measurement of the IVC. The diameter *(solid line)* is measured perpendicular to the long axis of the IVC at end-expiration, just proximal to the junction of the hepatic veins that lie approximately 0.5 to 3.0 cm proximal to the ostium of the right atrium (RA).

JASE 2010 ; 23 : 685-713

Evaluation hémodynamique

Evaluation de la PAPs



- Equation de Bernoulli : $\Delta P = 4\ V^2$

(PVD syst - POD syst = 4 Vmax IT², 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?*

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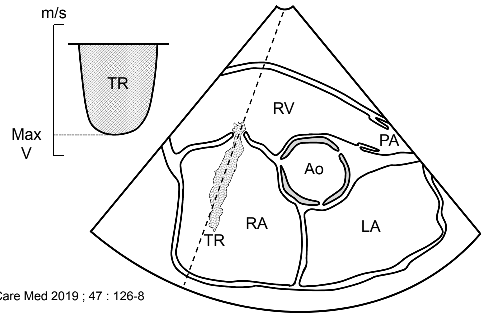
Dupuytren Teaching Hospital; and
University of Limoges
Limoges, France

maximal Doppler velocity of the tricuspid regurgitation (TR) flow had a perfect diagnostic accuracy to identify PAH when using a threshold value of 26 mm Hg, but not when estimated from Doppler pulmonary vein flow (4). Nevertheless, both the accurate Doppler estimation of PAP and identification of PAH in ventilated ICU patients with shock or acute respiratory failure reported in the present study (4) should not conceal substantial



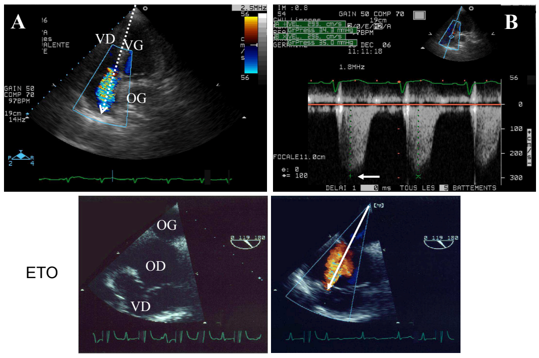
Crit Care Med 2019 ; 47 : 126-8

Insuffisance tricuspide : ETT > ETO

$PAPs \sim 4 \bullet (Vmax\ IT)^2 + POD$

ETT

ETO



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

Philippe Vignon, MD, PhD

Crit Care Med 2019 ; 47 : 126-8

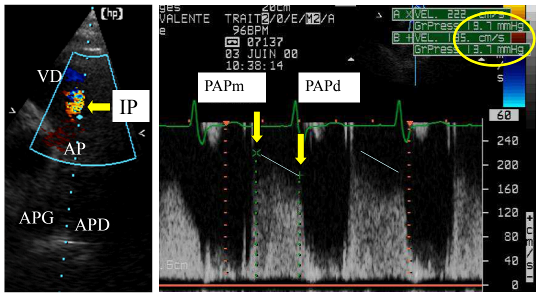
TABLE 1. Technical Prerequisites and Potential Limitations of Advanced Critical Care Echocardiography for Quantitative Estimation of Pulmonary Artery Pressure

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]

CVP = central venous pressure, PEEP = positive end-expiratory pressure, RV = right ventricle, TR = tricuspid regurgitation.
[a]Only applies for transthoracic echocardiography and specifically for the apical four-chamber, the upper parasternal short-axis, and eventually the subcostal view of heart.
[b]At least three measurements.
[c]For example, pulmonary valve stenosis or tricuspid valvular disease, severe polycythemia or anemia, eccentric TR, small right atrial size (see text for details).
[d]Most of ICU patients have inserted central venous catheter allowing this invasive measurement.
[e]Frequent overestimation in spontaneously breathing patients; the relationship of inferior vena cava size and CVP is adversely altered by intra-abdominal hypertension in ventilated ICU patients.

Insuffisance pulmonaire : ETT > ETO

$PAPm \sim 4 \bullet (Vmax\ IP\ protodiastolique)^2 + POD$
$PAPd \sim 4 \bullet (Vmax\ IP\ télédiastolique)^2 + POD$



Pressions (mmHg)
PVC = 14
PAPm = 34
PAPd = 28

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*

J Am Soc Echocardiogr 2007

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

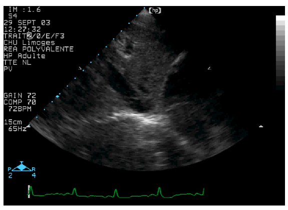
Evaluation de la pression auriculaire droite

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

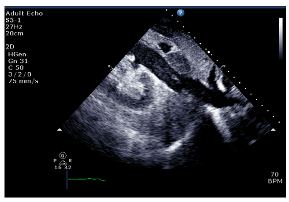
Variable	Normal (0-5 [3] mm Hg)	Intermediate (5-10 [8] mm Hg)		High (15 mm Hg)
IVC diameter	≤2.1 cm	≤2.1 cm	>2.1 cm	>2.1 cm
Collapse with sniff	>50%	<50%	>50%	<50%

JASE 2010 ; 23 : 685-713

POD : 5 mmHg



POD : 18 mmHg



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

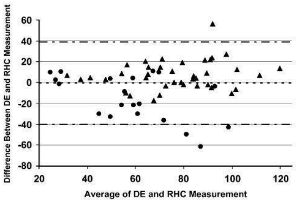


Figure 1. Bland-Altman plot of Doppler echocardiographic estimates of pulmonary artery pressure and right-heart catheterization measurements. The bias was −0.6 mm Hg and the 95% limits of agreement were +38.8 and −40.0 mm Hg. *Triangles* represent excellent- and good-quality Doppler signal; *circles* = fair- and poor-quality Doppler signal; *dotted line* = bias; *dash/dotted line* = upper and lower limits of agreement. Abbreviations: DE = Doppler echocardiography; PASP = pulmonary artery systolic pressure; RHC = right-heart catheterization.

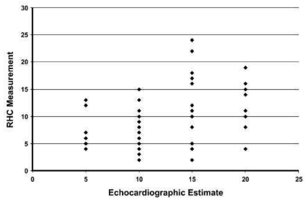
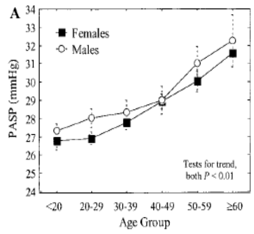
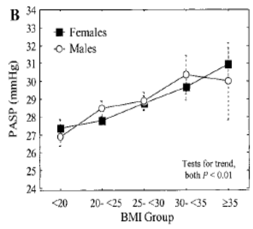


Figure 2. Comparison of right atrial pressure as estimated by Doppler echocardiography and right-heart catheterization. RHC = right-heart catheterization.

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

Valeurs normales de PAPs





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

Antonello D'Andrea, MD; Robert Naeije, MD; Ekkehard Grünig, MD; Pio Caso, MD; Michele D'Alto, MD; Enza Di Palma, MD; Luigi Nunziata, MD; Lucia Riegler, MD; Raffaella Scarafile, MD; Rosangela Cocchia, MD; Olga Vriz, MD; Rodolfo Citro, MD; Raffaele Calabrò, MD; Maria Giovanna Russo, MD; and Eduardo Bossone, MD, PhD, FCCP

CHEST 2014; 145(5):1071–1078

1480 sujets normaux

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

Valeurs normales de PAPs

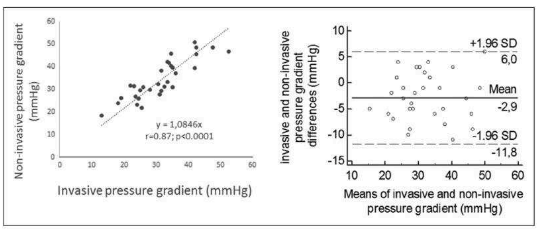
- HTAP : PAPs > 30 mmHg ou PAPm > 20 mmHg
- En fait : PAPs jusqu'à 38 mmHg (adulte normal non obèse) et 47 mmHg (adulte normal obèse)[1]et PAP élevée chez les hypertendus âgés[2]
- HTAP si Vmax IT > 3 m/s en l'absence d'obésité et d'HTA
- Vmax IT > 2.9 m/s : un des 4 critères de dysfonction diastolique VG.

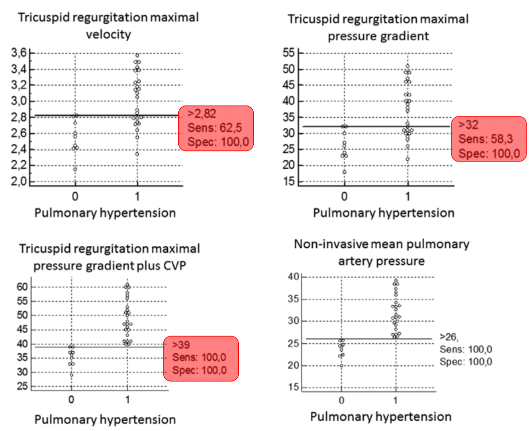
[1] : Abergel E et al. Am J cardiol 1996 ; 77 : 767-9
[2] : Finkelhor RS et al. Chest 2003 ; 123 : 711-5

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]

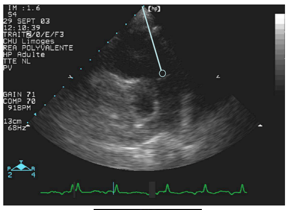
Crit Care Med 2019; 47:41–48





Doppler pulmonaire

ETT



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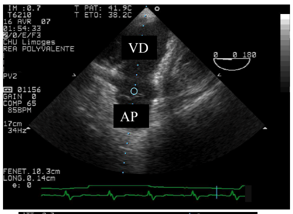
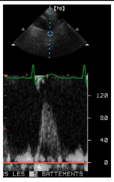
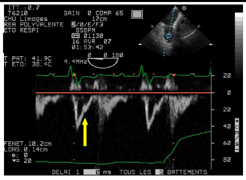


PAP normale :



HTAP :



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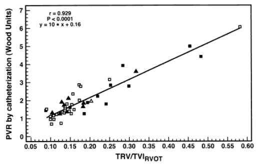
Pulmonary Hypertension

A Simple Method for Noninvasive Estimation of Pulmonary Vascular Resistance

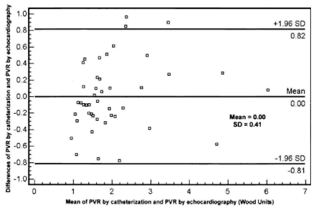
Amr E. Abbas, MD,* F. David Fortuin, MD,* Nelson B. Schiller, MD, FACC,† Christopher P. Appleton, MD, FACC,* Carlos A. Moreno, BS,* Steven J. Lester, MD, FACC*
San Francisco, California; and Scottsdale, Arizona



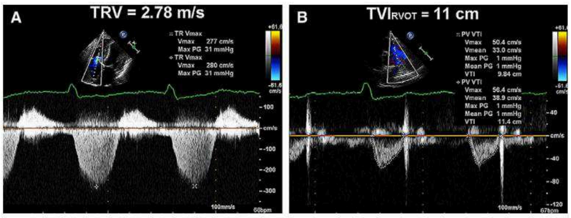
Based on our results, we propose a simplified equation for noninvasive calculation of PVR:

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

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.



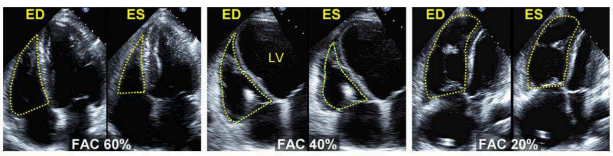
Evaluation des résistances vasculaires pulmonaires (RVP)



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

Evaluation de la fonction systolique VD

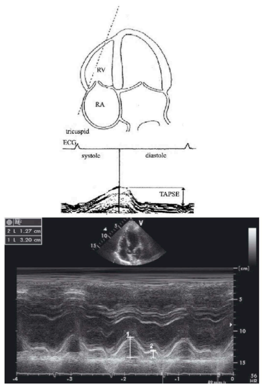
Fraction de réduction de surface du VD



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

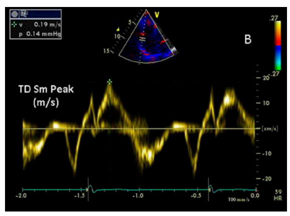
JASE 2010 ; 23 : 685-713

TAPSE



Onde S DTI

Même site de mesure avec le DTI en mode pulsé



Intensive Care Med (2007) 33:2143–2149
DOI 10.1007/s00134-007-0881-y

ORIGINAL

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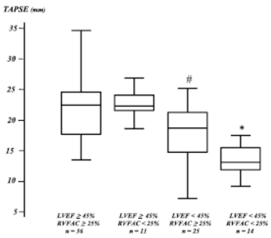
Relationship between the tricuspid annular plane systolic excursion and right and left ventricular function in critically ill patients



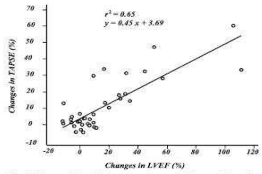


Fig. 3 Linear relationship between changes in left ventricular ejection fraction (LVEF) and changes in tricuspid annular plane systolic excursion (TAPSE) following fluid challenge ($n = 15$), passive leg raising ($n = 5$), and dobutamine infusion ($n = 20$)

Paramètres de fonction systolique VD

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/s^2)	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.

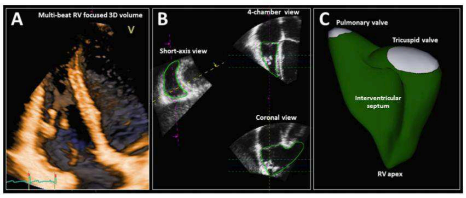
JASE 2010 ; 23 : 685-713

Fraction d'éjection du VD

Seulement accessible en 3D !! (validé contre IRM)

Lang et al

Journal of the American Society of Echocardiography
January 2015



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

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

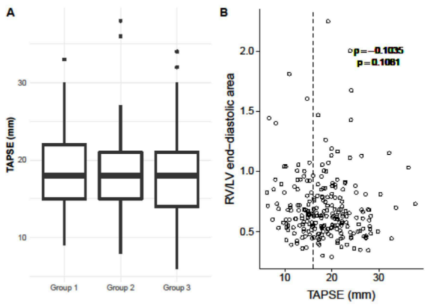
Table 10 Normal values for parameters of RV function

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.

Groupe 1 : STDVD/VG < 0.6 (pas de dilatation VD)
Groupe 2 : STDVD/VG ≥ 0.6 (dilatation VD) et PVC < 8 mmHg (*pas* de congestion veineuse systémique)
Groupe 3 : STDVD/VG ≥ 0.6 (dilatation VD) et PVC ≥ 8 mmHg (congestion veineuse systémique).

282 patients ventilés avec choc septique



Soumis à publication

Conclusion

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