# IRM dans l'HTAP

Damien Mandry

# Introduction

- Évaluation fonctionnelle cardiaque
- Analyse parenchymateuse pulmonaire et vasculaire

# IRM cardiaque

- Mouvements cardiaques et respiratoires

-> Imagerie rapide

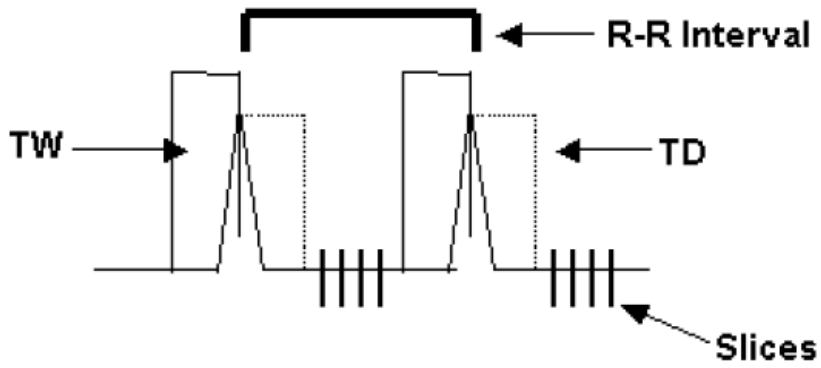
-> Apnée

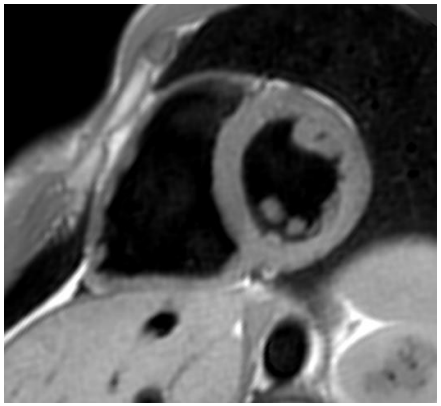
durée examen

  - ~1 coupe / apnée
  - 10 à 20s / apnée
    - selon résolutions spatiale et temporelle
  - Expiration = la plus reproductible

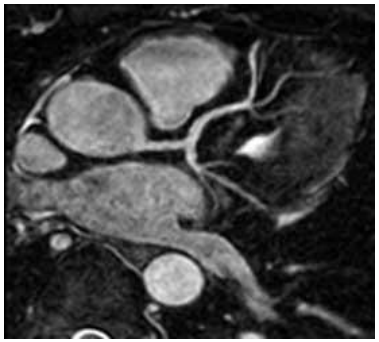
-> Synchronisation à l'ECG

- Prospective ou rétrospective
- Imagerie statique (diastole)
- ou « ciné »

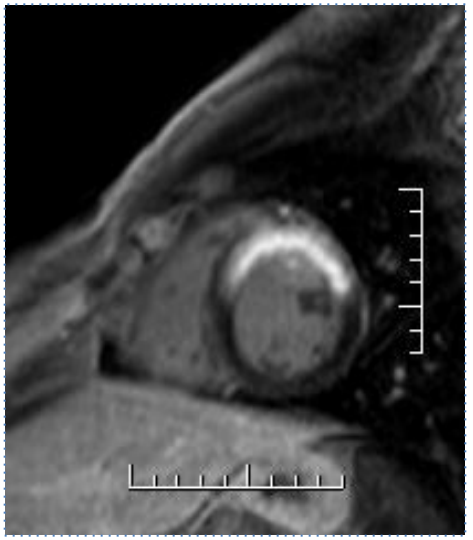




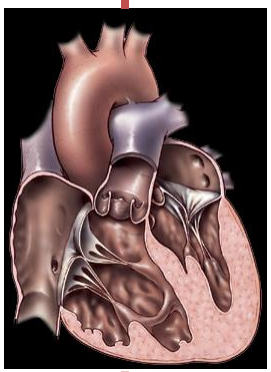
Séquences morphologiques en « sang noir »

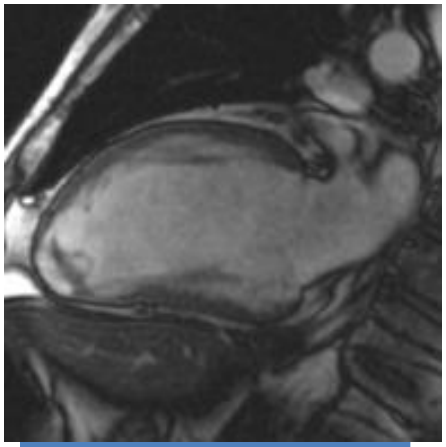


Imagerie des coronaires

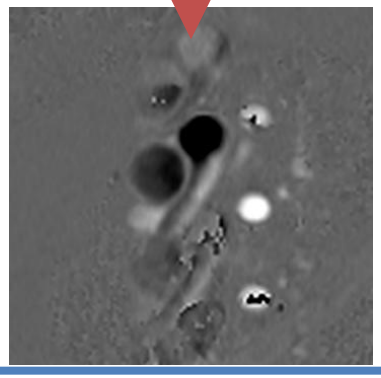


Séquences de viabilité

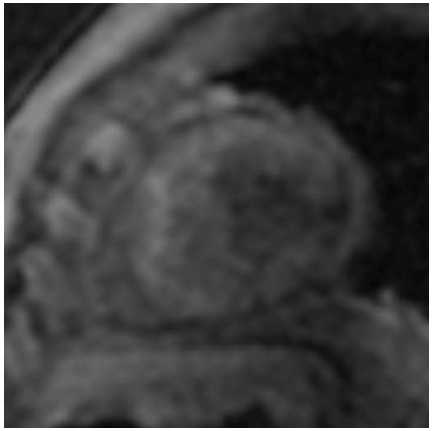




Séquences dynamiques en sang blanc « ciné »



« ciné » PC (Quantification de flux)



Séquences de perfusion

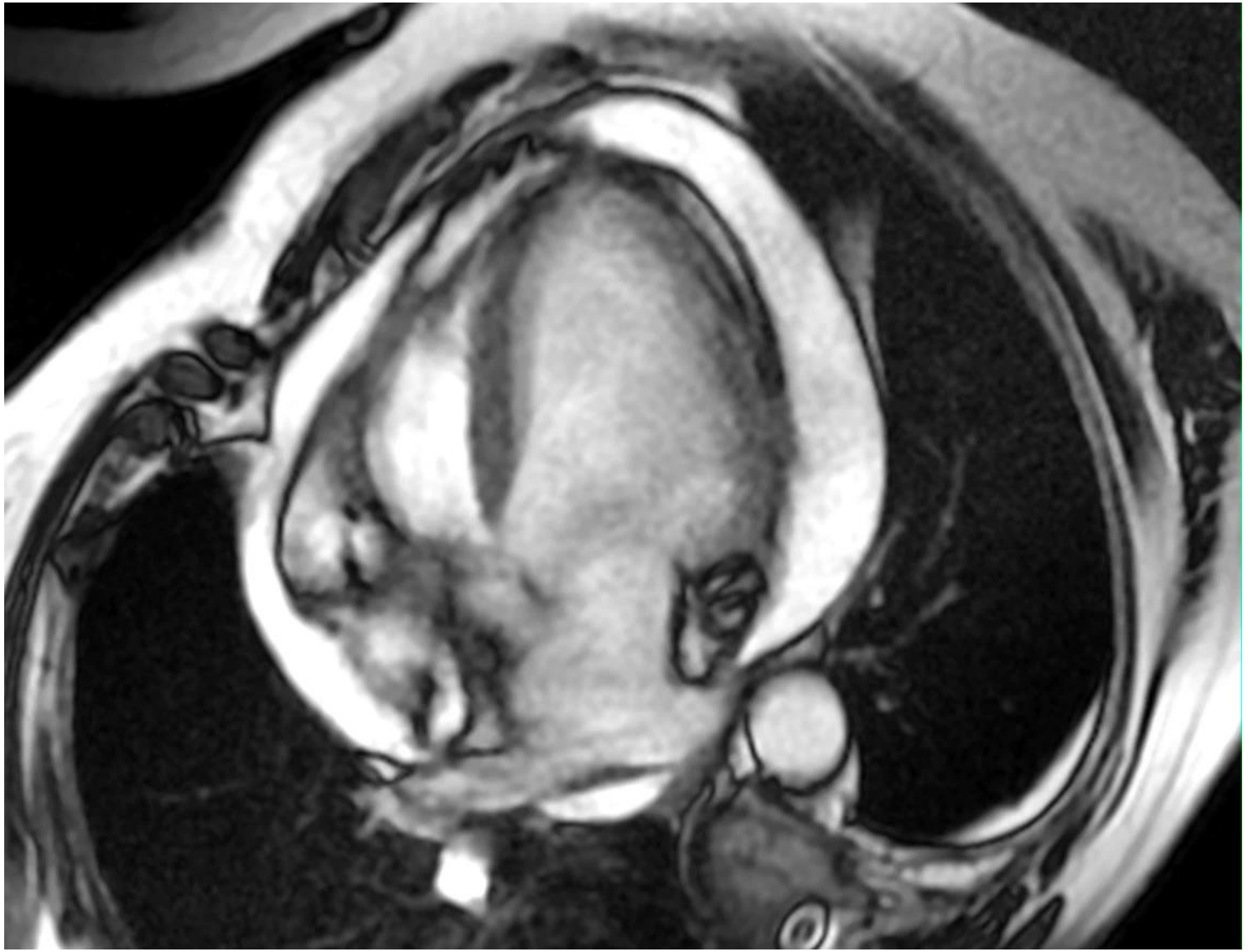
# Principes des séquences « ciné »

- Synchronisation à l'ECG : onde R
- Acquisition (presque) continue

- Acquisition « segmentée »
  - Sur plusieurs cycles cardiaques
  - > rythme régulier +++

  - Compromis entre durée de l'acquisition et pas de segmentation

# IRM : FA

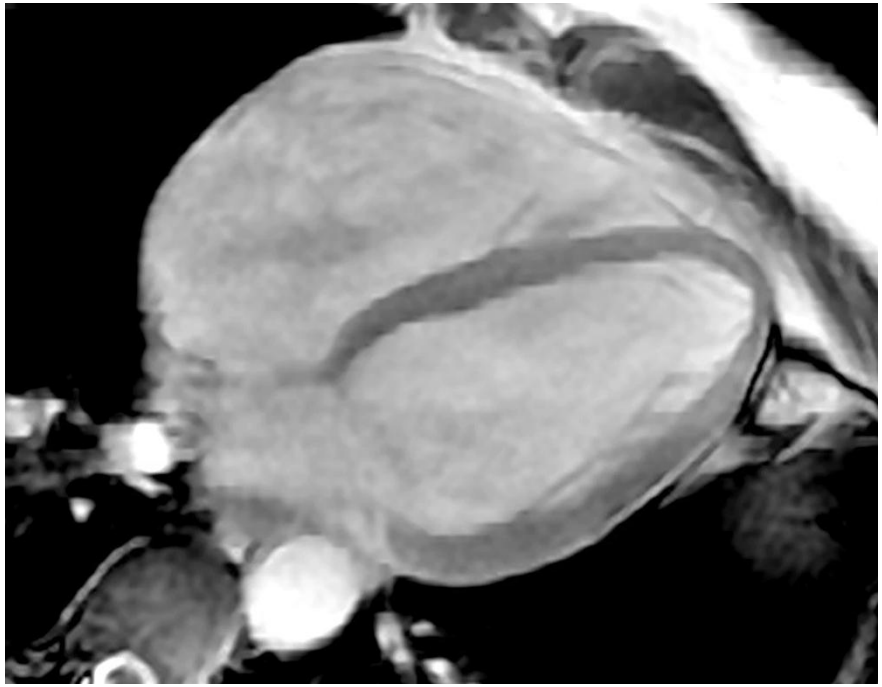


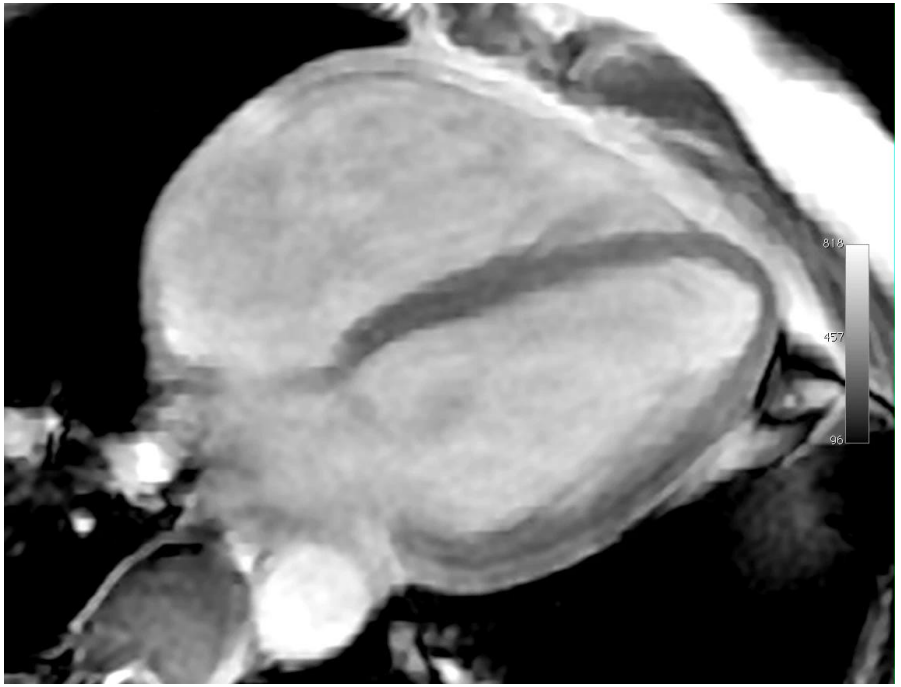
# Ciné « sang blanc »

- Balanced - Steady State Free Precession
  - Précession libre à l'état d'équilibre
- Pondération naturelle en T2/T1

- Résolution temporelle ++

# Segmentation de l’acquisition



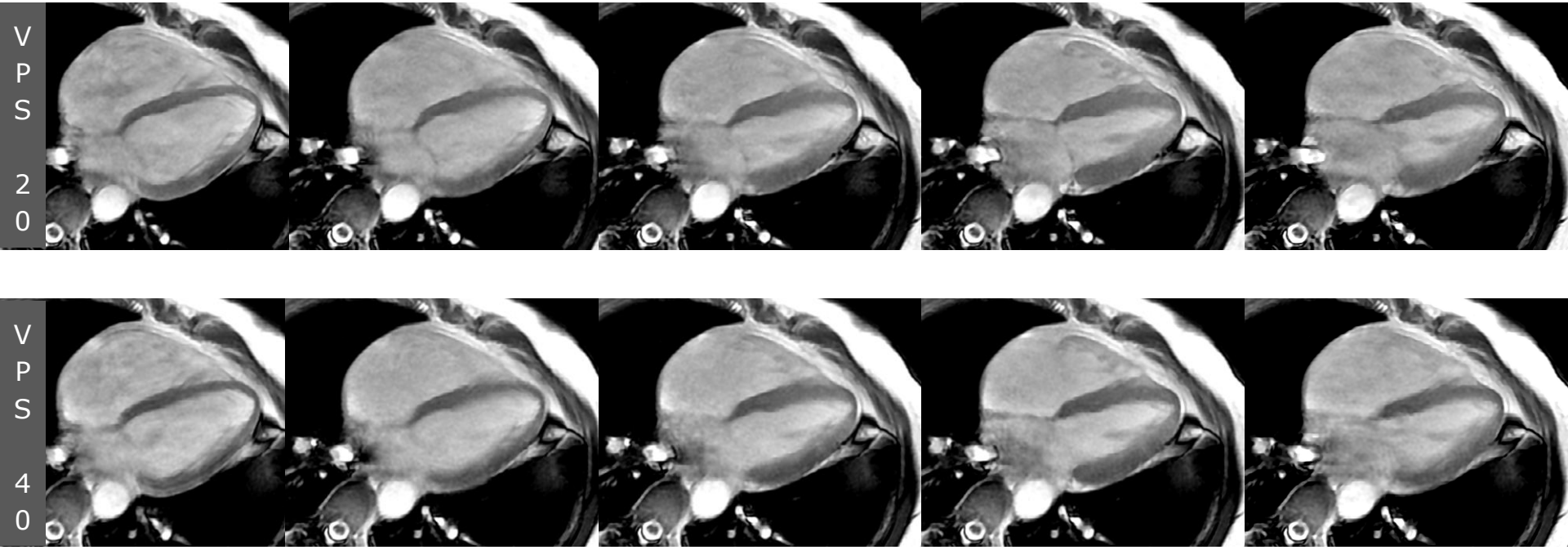



**SSFP**
**TR 3,8**

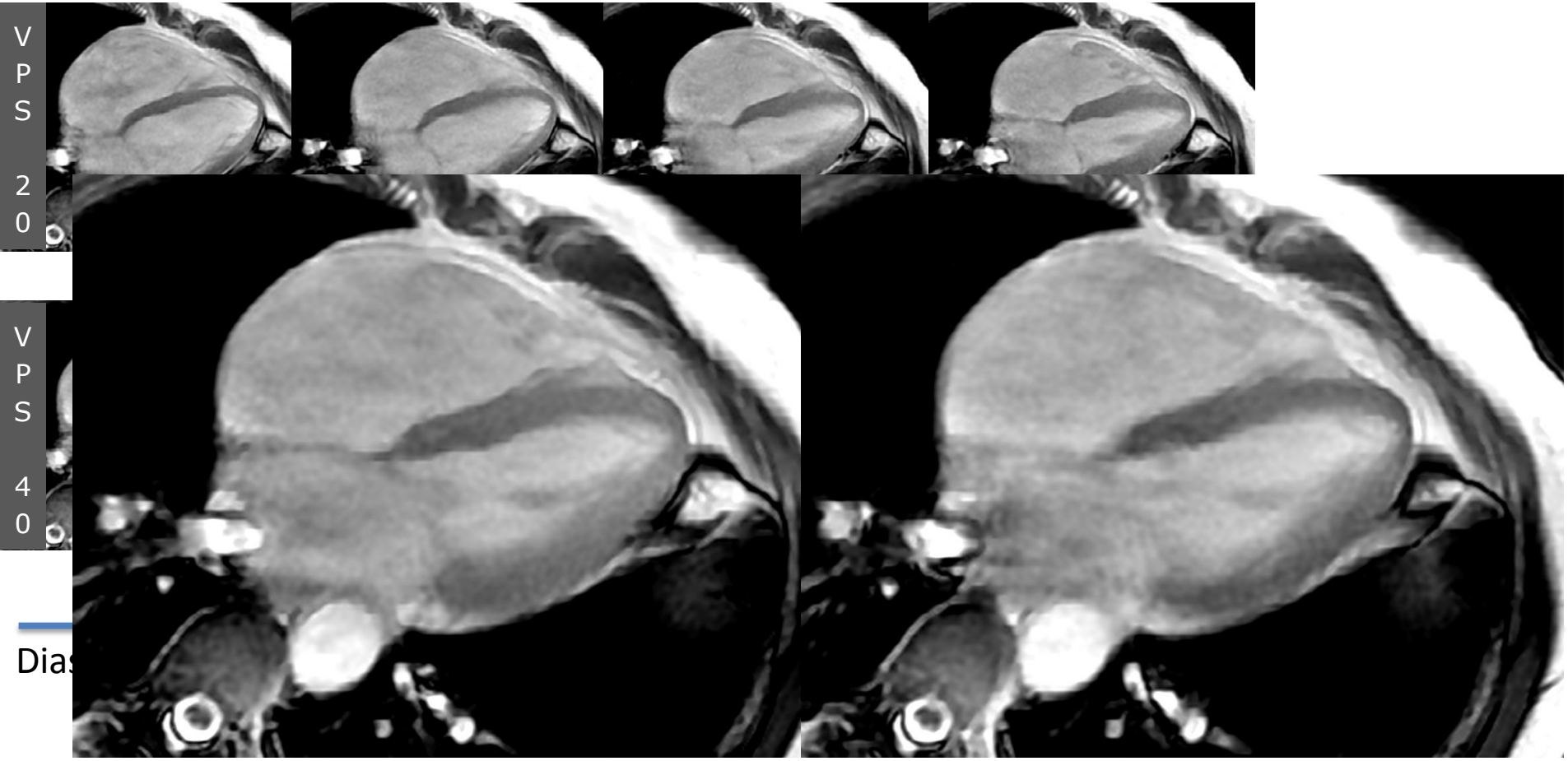
VPS 20
Temp Res 76

VPS 40
Temp Res 152

# Segmentation de l’acquisition

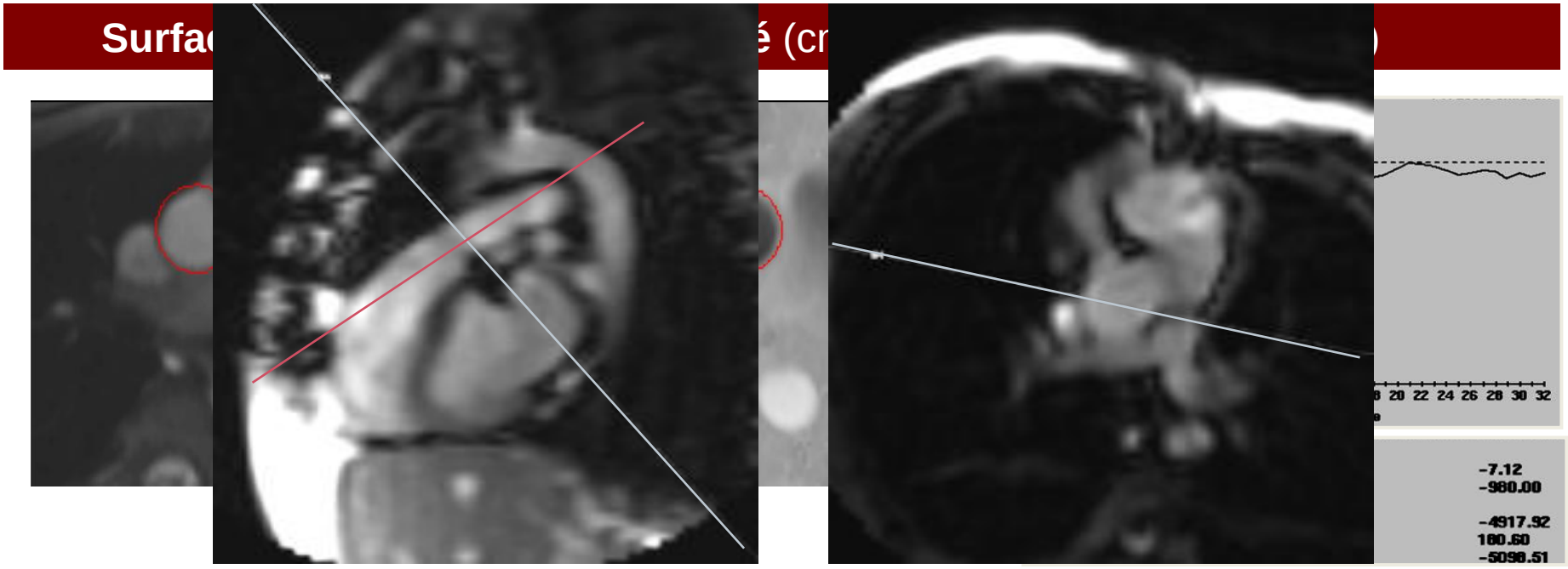


# Segmentation de l’acquisition

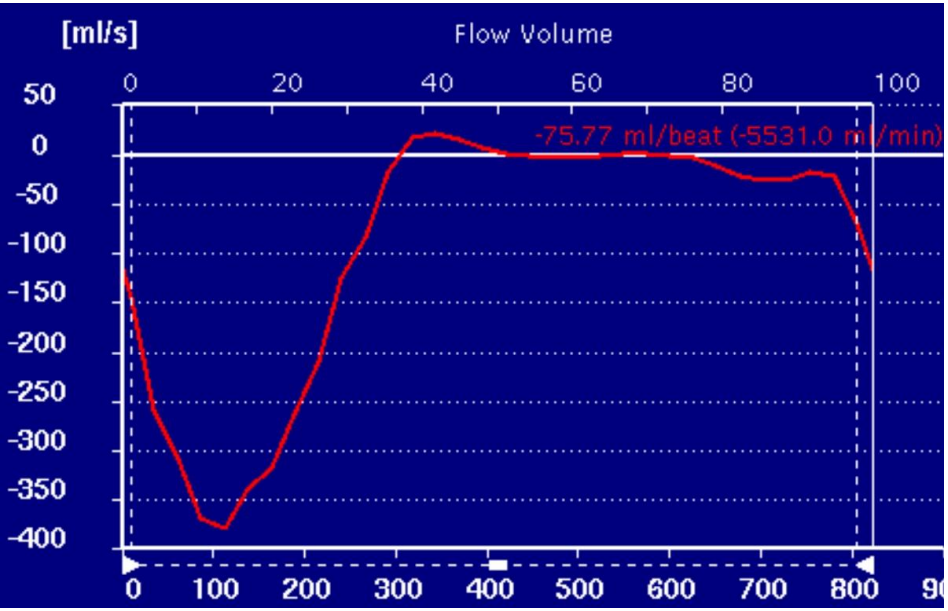


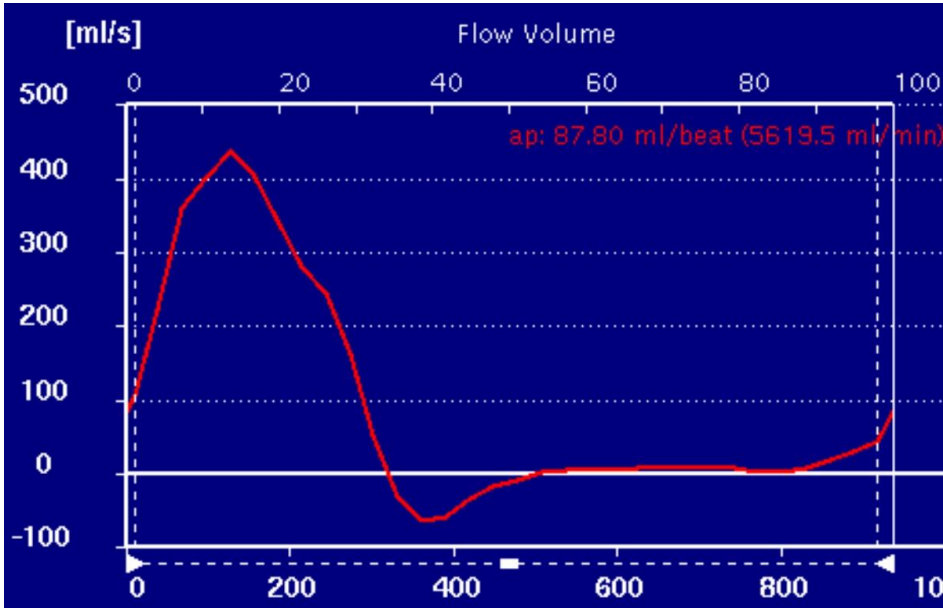
# « Ciné » contraste de phase (PC)

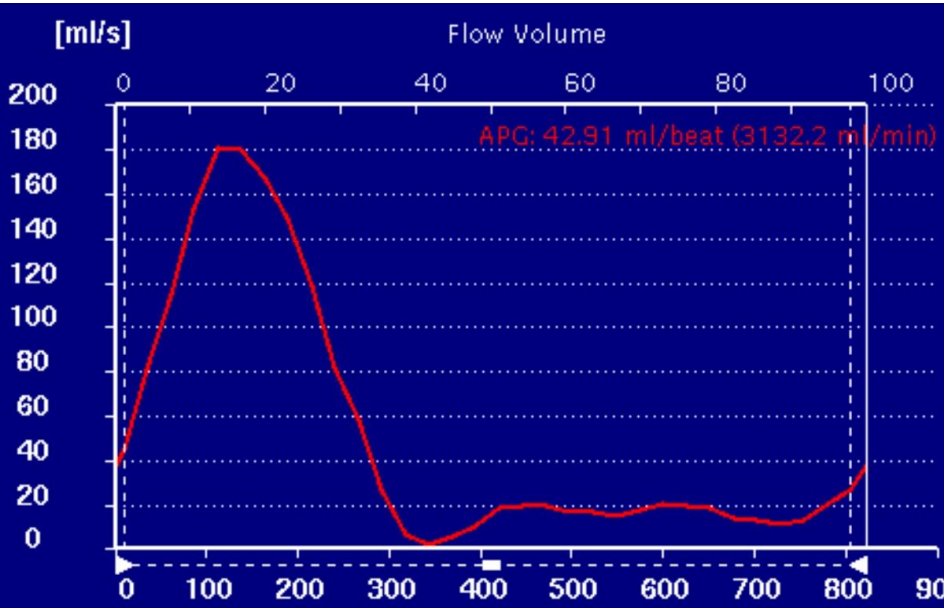
- 2 acquisitions avec application de gradients de sens opposés
  - > cartographie de vitesses des protons

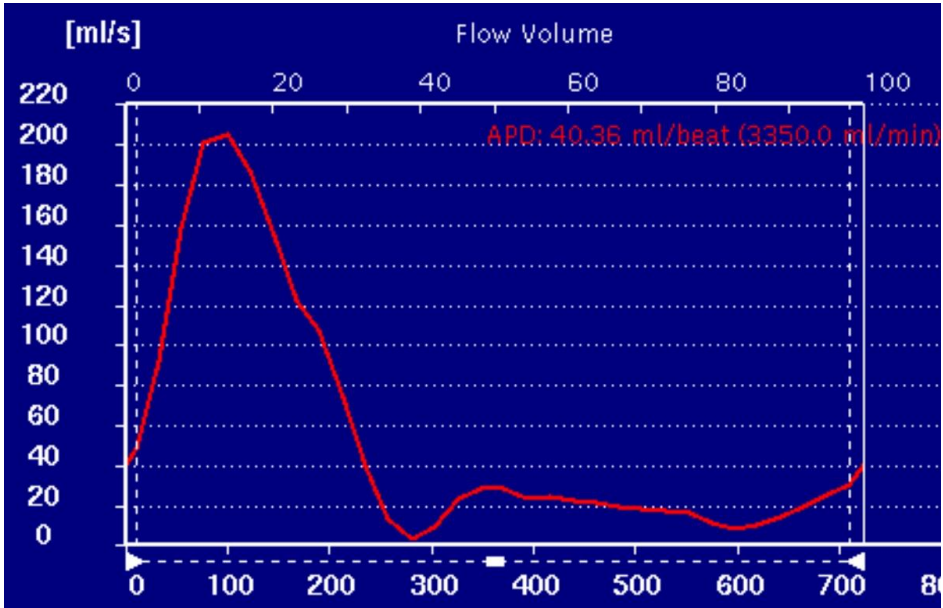


# Mesure des débits

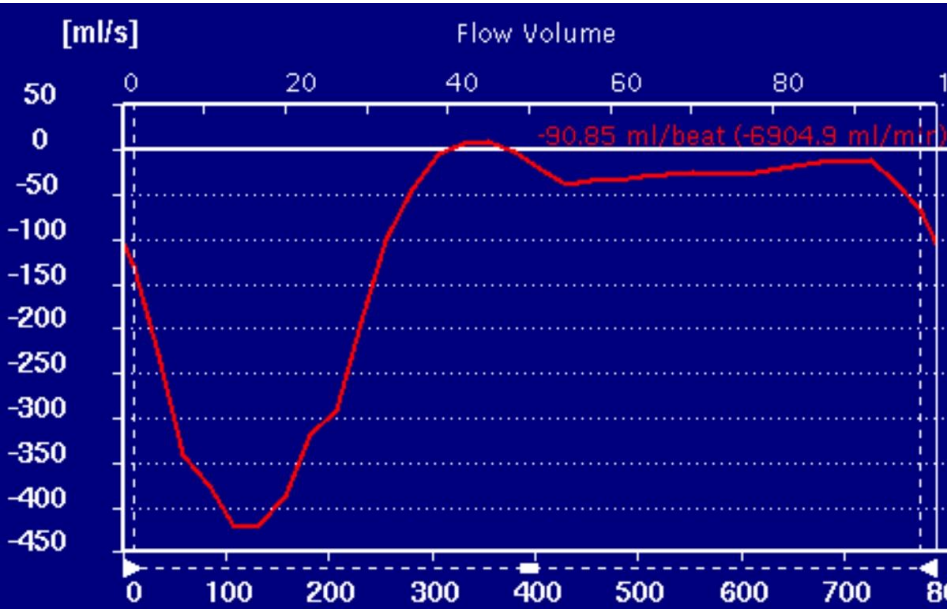


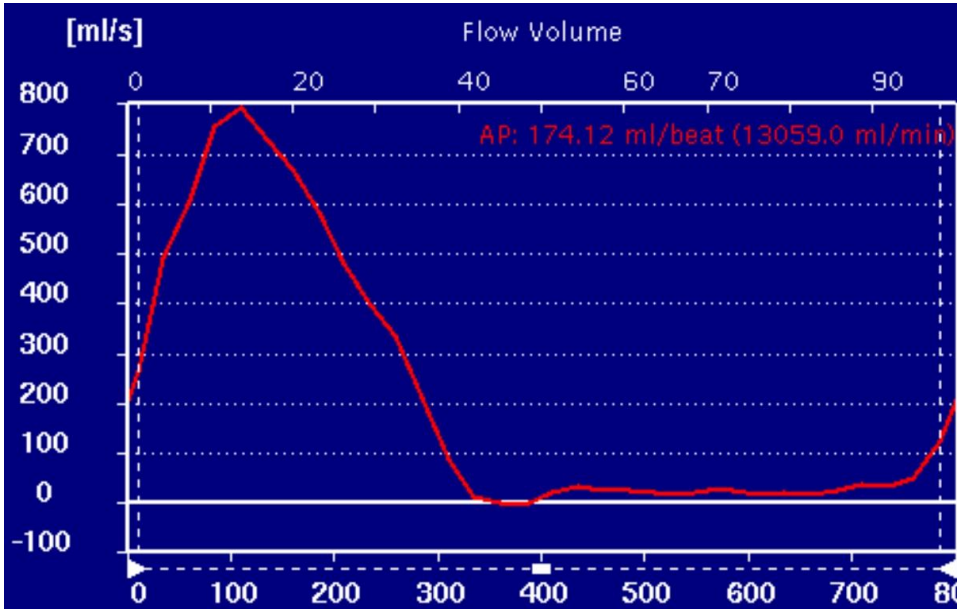



# Shunts




Qs = 6,9 l/min




Qp = 13,1 l/min

**Qp/Qs = 1,9**


1
W 897 : L 376

# Diamètres / Surfaces

- Distensibilité
  - $(D_{systole} - D_{diastole}) / D_{diastole}$
- Compliance
  - $\Delta V / \Delta P$

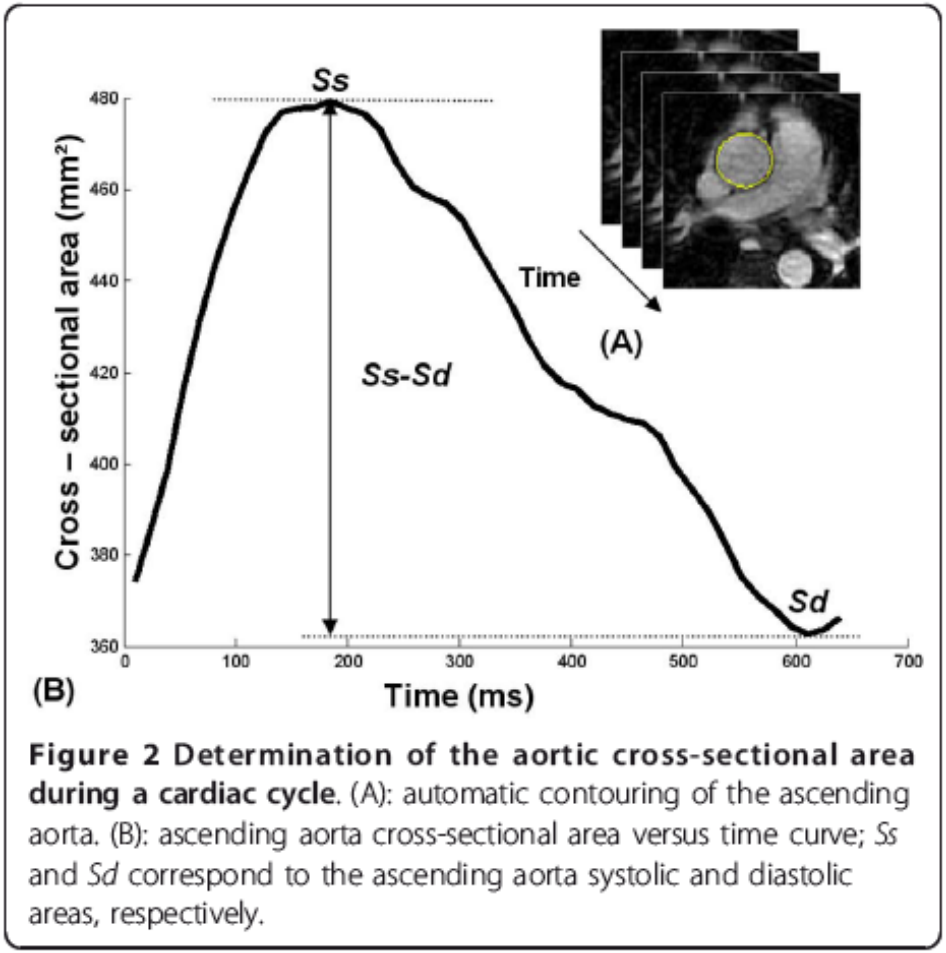



**Figure 2 Determination of the aortic cross-sectional area during a cardiac cycle.** (A): automatic contouring of the ascending aorta. (B): ascending aorta cross-sectional area versus time curve; *Ss* and *Sd* correspond to the ascending aorta systolic and diastolic areas, respectively.


1. Dogui A, Kachenoura N, Frouin F, Lefort M, De Cesare A, Mousseaux E, et al. Consistency of aortic distensibility and pulse wave velocity estimates with respect to the Bramwell-Hill theoretical model: a cardiovascular magnetic resonance study. Journal of Cardiovascular Magnetic Resonance. 2011 Jan 27;13(1):11.

# Vélocités

**Table 6**

**Diagnostic Performance of Two Parameters for Detection of PAH at Phase-Contrast MR Imaging**

| Parameter and Definition* | Cutoff Value | Sensitivity† | Specificity† | *P* Value‡ |
|---|---|---|---|---|
| Average velocity | | | | |
| mPAP (>25 mm Hg) | 11.7 | 39/42 (92.9) [80.5, 98.4] | 14/17 (82.4) [56.6, 96] | <.001 |
| sPAP (>35 mm Hg) | 11.7 | 39/44 (88.6) [75.4, 96.2] | 12/15 (80) [51.9, 95.4] | <.001 |
| PVRI (>3 Wood units × $m^2$) | 11.7 | 41/45 (91.1) [78.8 ,97.5] | 13/14 (92.9) [75.1, 100] | <.001 |
| Minimum PA area | | | | |
| mPAP (>25 mm Hg) | 6.6 | 39/42 (92.9) [80.5, 98.4] | 15/17 (88.2) [64, 98.2] | <.001 |
| sPAP (>35 mm Hg) | 6.6 | 39/44 (88.6) [75.4, 96.2] | 13/15 (85.7) [57.2, 97.8] | <.001 |
| PVRI (>3 Wood units × $m^2$) | 6.0 | 43/45 (95.6) [84.8, 99.3] | 12/14 (84.6) [55, 97.6] | <.001 |

* Different definitions of PAH are employed.

† Data are raw numbers, with percentages in parentheses and 95% CIs in brackets.

‡ At receiver operating characteristic curve analysis.

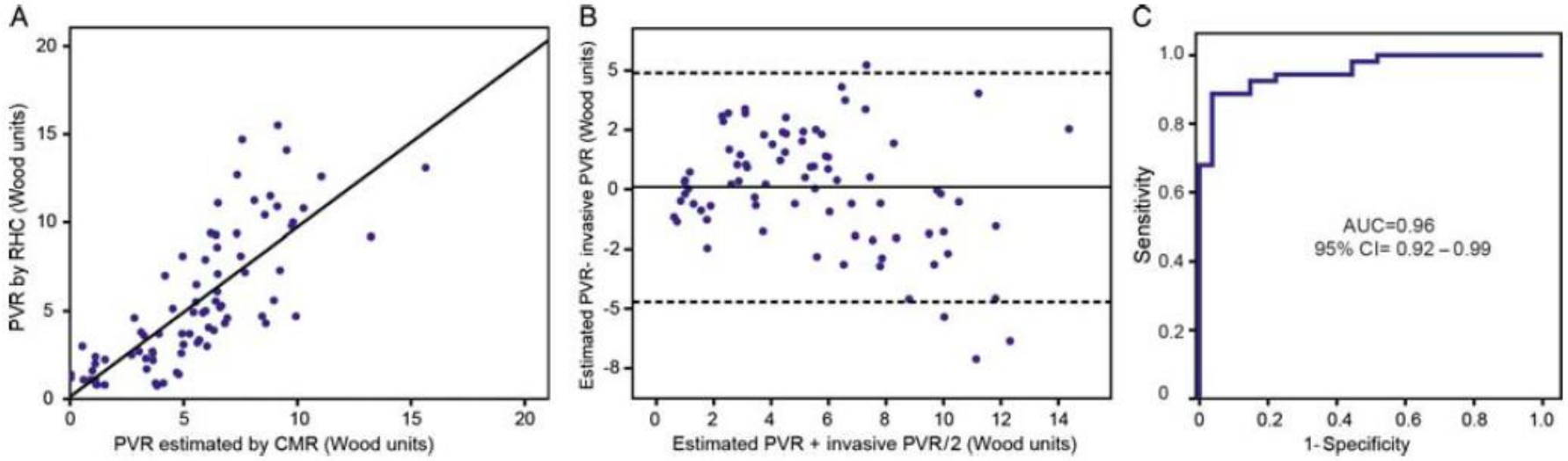
1. Sanz J, Kuschnir P, Rius T, Salguero R, Sulica R, Einstein AJ, et al. Pulmonary Arterial Hypertension: Noninvasive Detection with Phase-Contrast MR Imaging. Radiology. 2007 Apr 1;243(1):70–9.

# Non-invasive estimation of pulmonary vascular resistance with cardiac magnetic resonance

**Ana García-Alvarez[1,2,3], Leticia Fernández-Friera[1], Jesús G. Mirelis[1,2], Simonette Sawit[1], Ajith Nair[1], Jill Kallman[1], Valentin Fuster[1,2], and Javier Sanz[1]***

[1]The Zena and Michael A. Wiener Cardiovascular Institute and Marie-Josee and Henry R. Kravis Center for Cardiovascular Health, Mount Sinai School of Medicine, New York, USA; [2]Centro Nacional de Investigaciones Cardiovasculares (CNIC), Madrid, Spain; and [3]Thorax Institute. Cardiology Department, Hospital Clinic, Barcelona, Spain

$$\text{estimated PVR (in WU)} = 19.38 - [4.62 \times \text{Ln PA average velocity (in cm/s)}] - [0.08 \times \text{RVEF (in \%)}]$$

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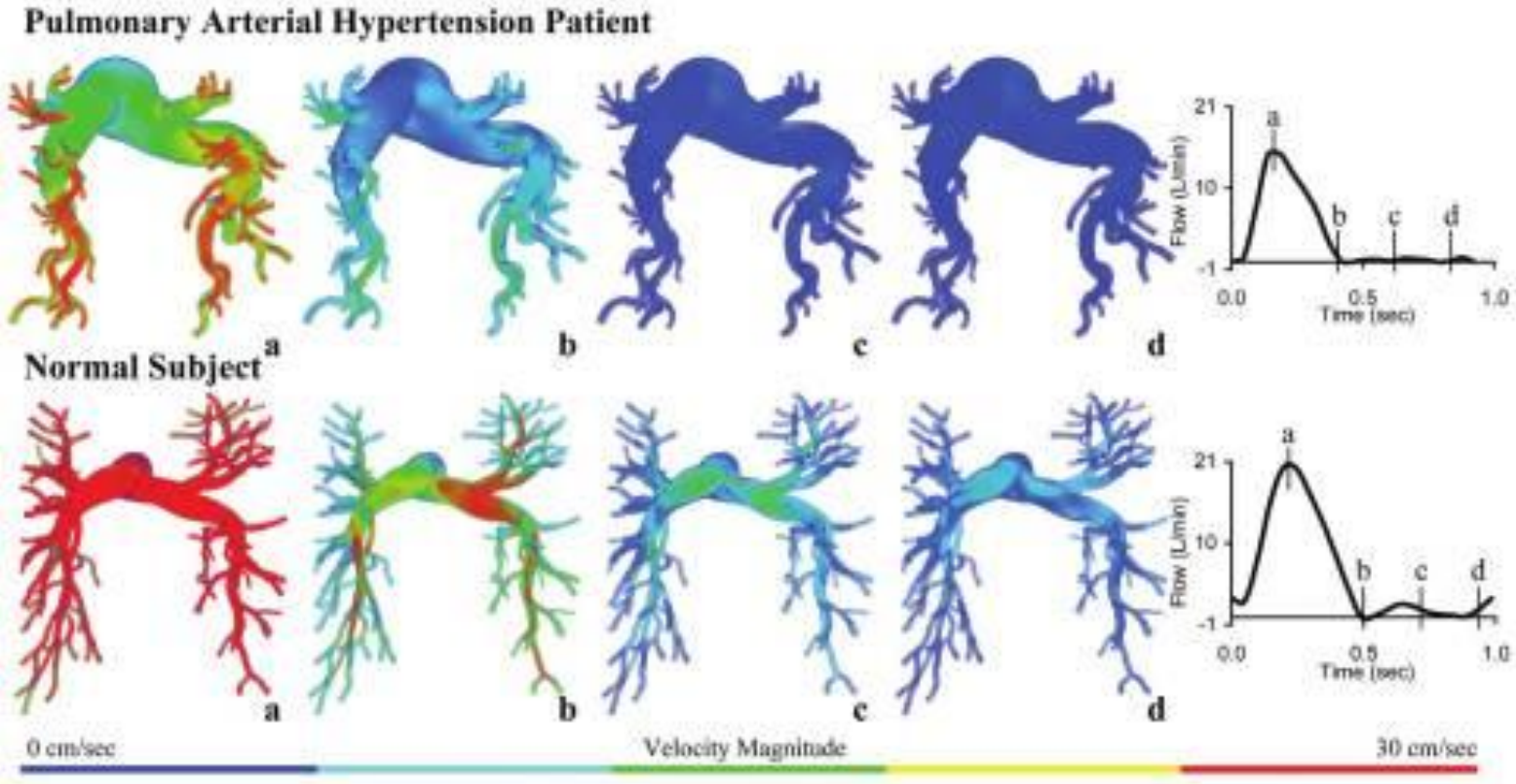
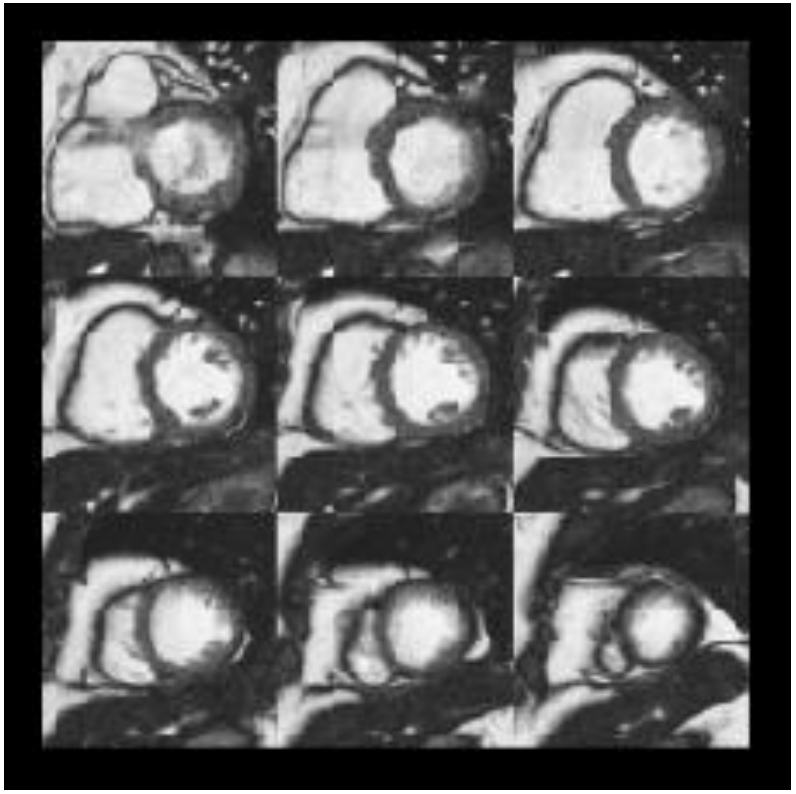
European Heart Journal (2011) **32**, 2438–2445
doi:10.1093/eurheartj/ehr173

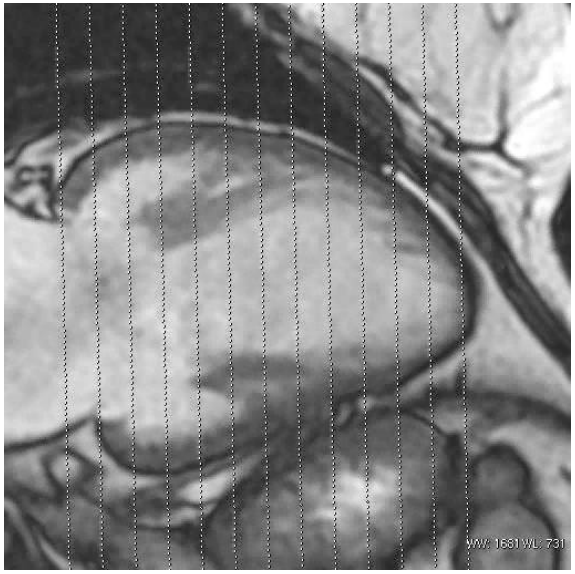



1. Tang BT, Pickard SS, Chan FP, Tsao PS, Taylor CA, Feinstein JA. Wall shear stress is decreased in the pulmonary arteries of patients with pulmonary arterial hypertension: An image-based, computational fluid dynamics study. Pulm Circ. 2012 Oct;2(4):470–6.

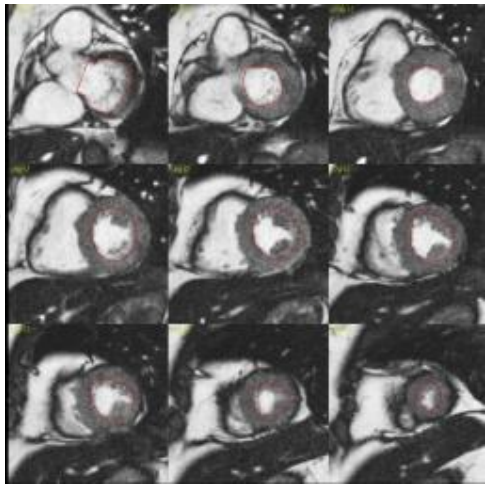
# Ciné « sang blanc »

- Balanced - Steady State Free Precession
  - Précession libre à l'état d'équilibre
- Pondération naturelle en T2/T1
- Résolution temporelle ++
- Fonction globale et segmentaire

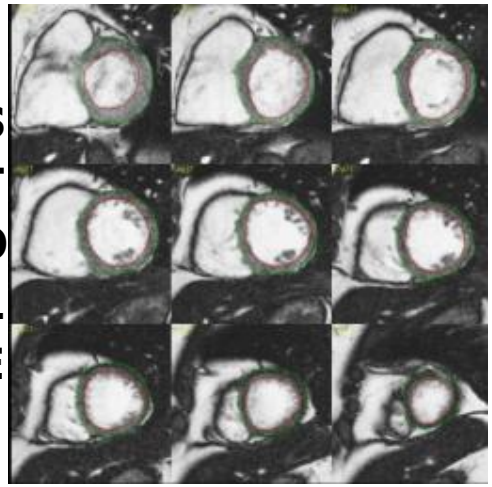





TELESYS TOLE



TELEDIA STOLE



# Ciné et HTAP chronique

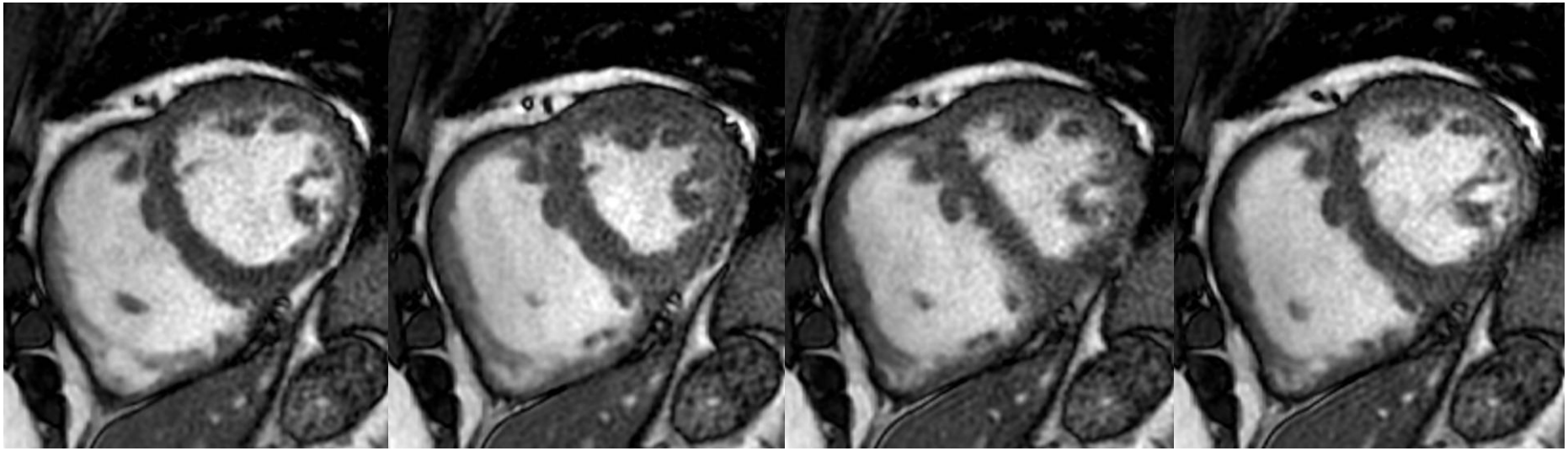
- Critères morphologiques :
  - Similaires à échocardiographie
    - Dilatation AP
    - Dilatation cavités droites
    - Hypertrophie VD
    - Septum paradoxal

- Analyse fonctionnelle :
  - TAPSE
  - Masse VD
  - VTD et VTS -> FEVD


1
W 414 : L 272

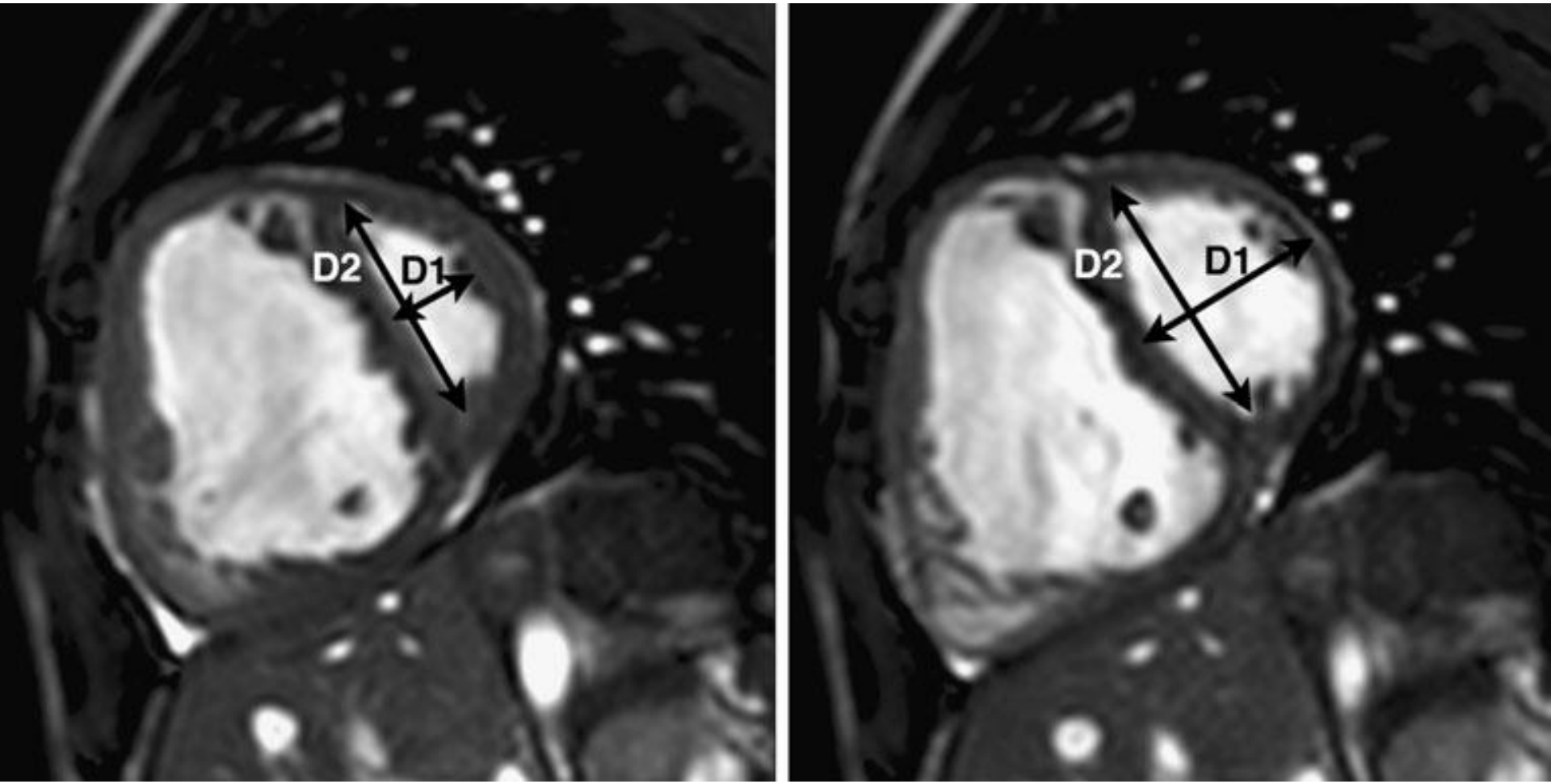

1
W 447 : L 294


181
W 441 : L 253



| Paradoxical septal motion | | |
|---|---|---|
| Systolic | Systolic and diastolic | Diastolic |
| Left bundle branch block | RV volume overload (left to right shunts, tricuspid and pulmonary regurgitation) | Pericardial constriction |
| Antero-septal infarction<br>Post-open heart surgery | RV pressure overload (RVOT obstruction, pulmonary hypertension, D-TGA after atrial switch procedures and ccTGA end systole) | Arrhythmogenic RV cardiomyopathy |

1. Méndez C, Soler R, Rodriguez E, López M, Álvarez L, Fernández N, et al. Magnetic resonance imaging of abnormal ventricular septal motion in heart diseases: a pictorial review. Insights Imaging. 2011 Apr 17;2(4):483–92.

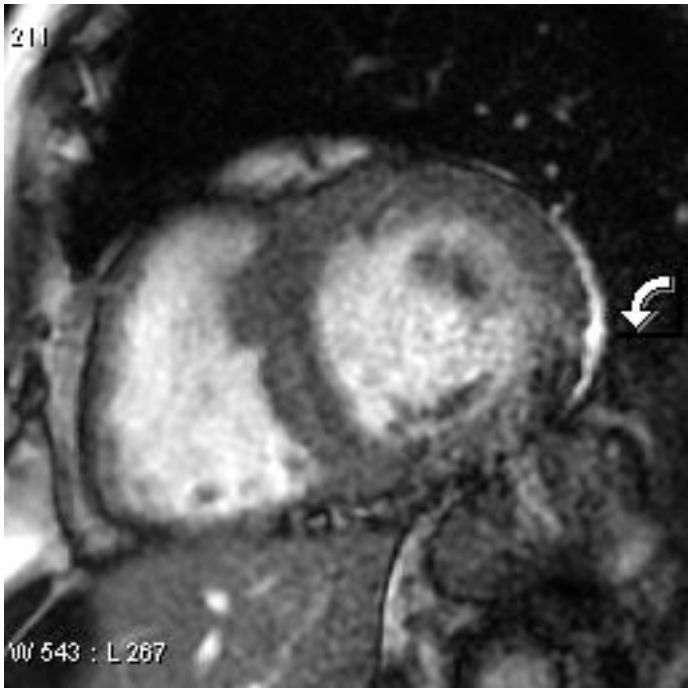



**Indice d’excentricité**
**Normalement = 1**

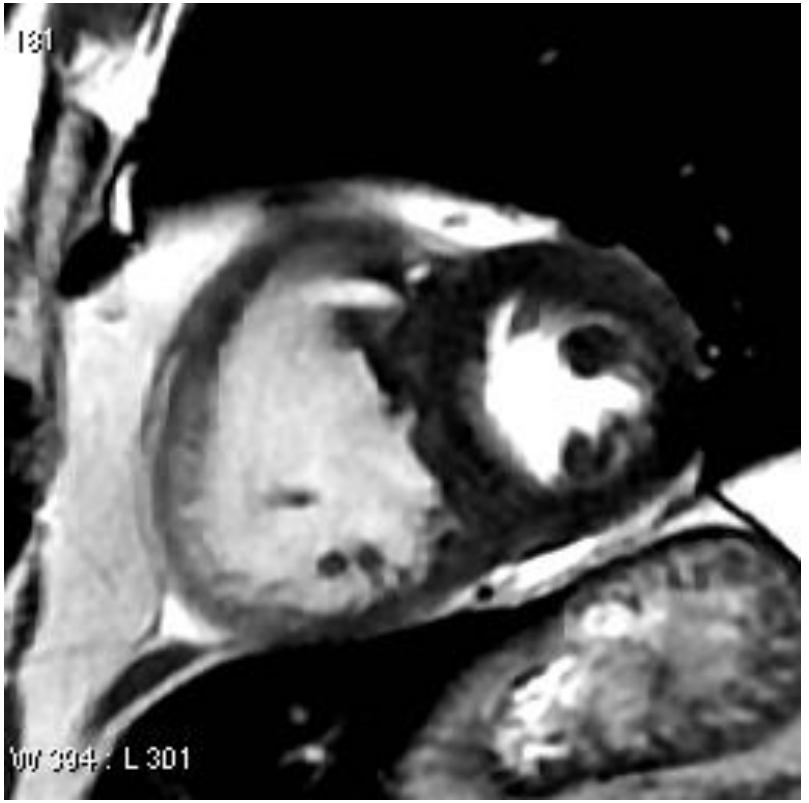

1
W 528 : L 357


151
W 496 : L 272


W 450 : L 281

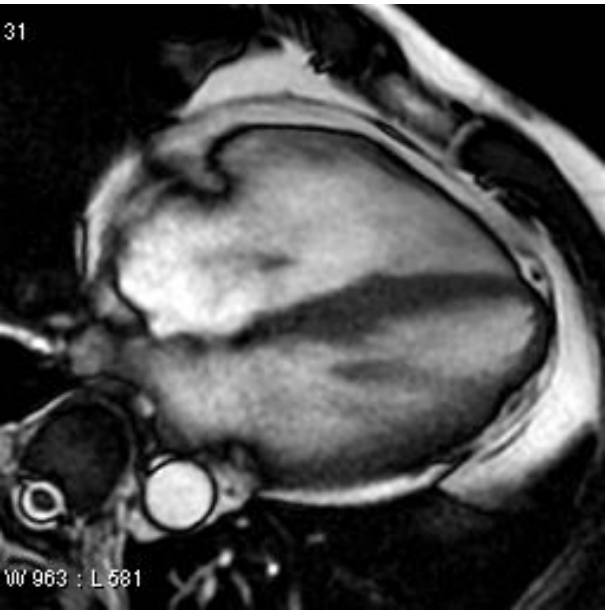

W 543 : L 267


1
W 585 : L 446


181
W 394 : L 301


1
W 1254 : L 653


31
W 1559 : L 723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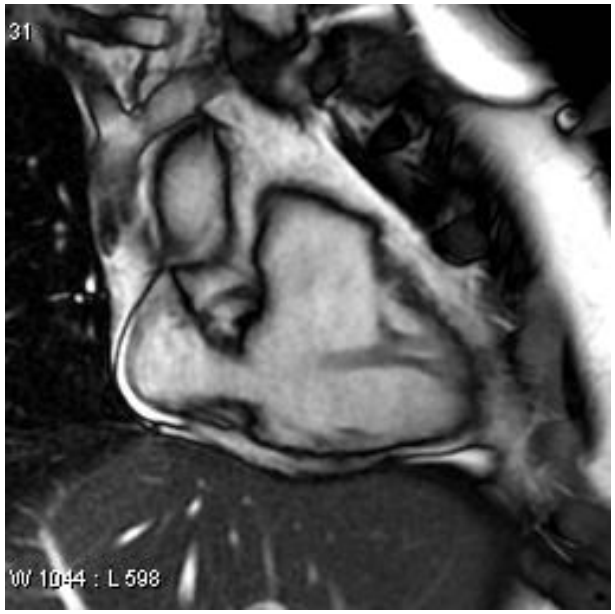
W 963 : L 581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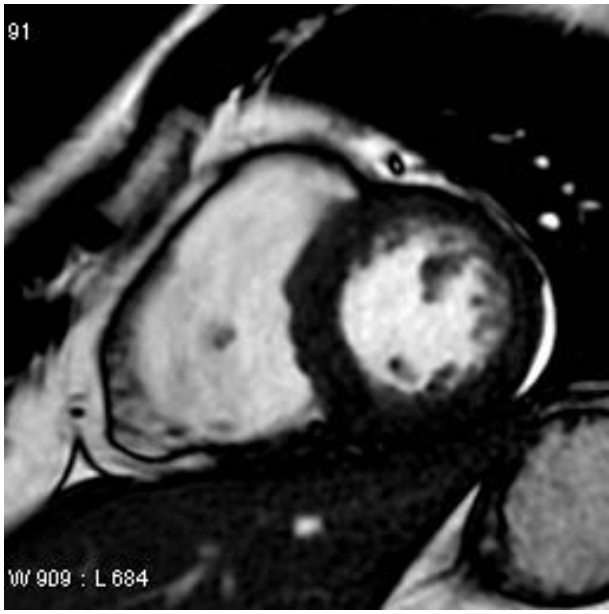
W 1044 : L 598


91
W 909 : L 684

# Rétention tardive / Fibrose

- Principes :
  - Imagerie de contraste entre zones saines et pathologiques par accroissement du VDi du produit de contraste
  - EG pondérée T1
  - 10-15min après l'injection

- Chélates de gadolinium « cliniques »
  - Petite taille 5nm
  - Diffusion libre vers le secteur interstitiel (jusqu'à 50% de la dose injectée dès le 1$^{er}$ passage)
  - Pas d'entrée dans les cellules
  - Élimination rénale rapide

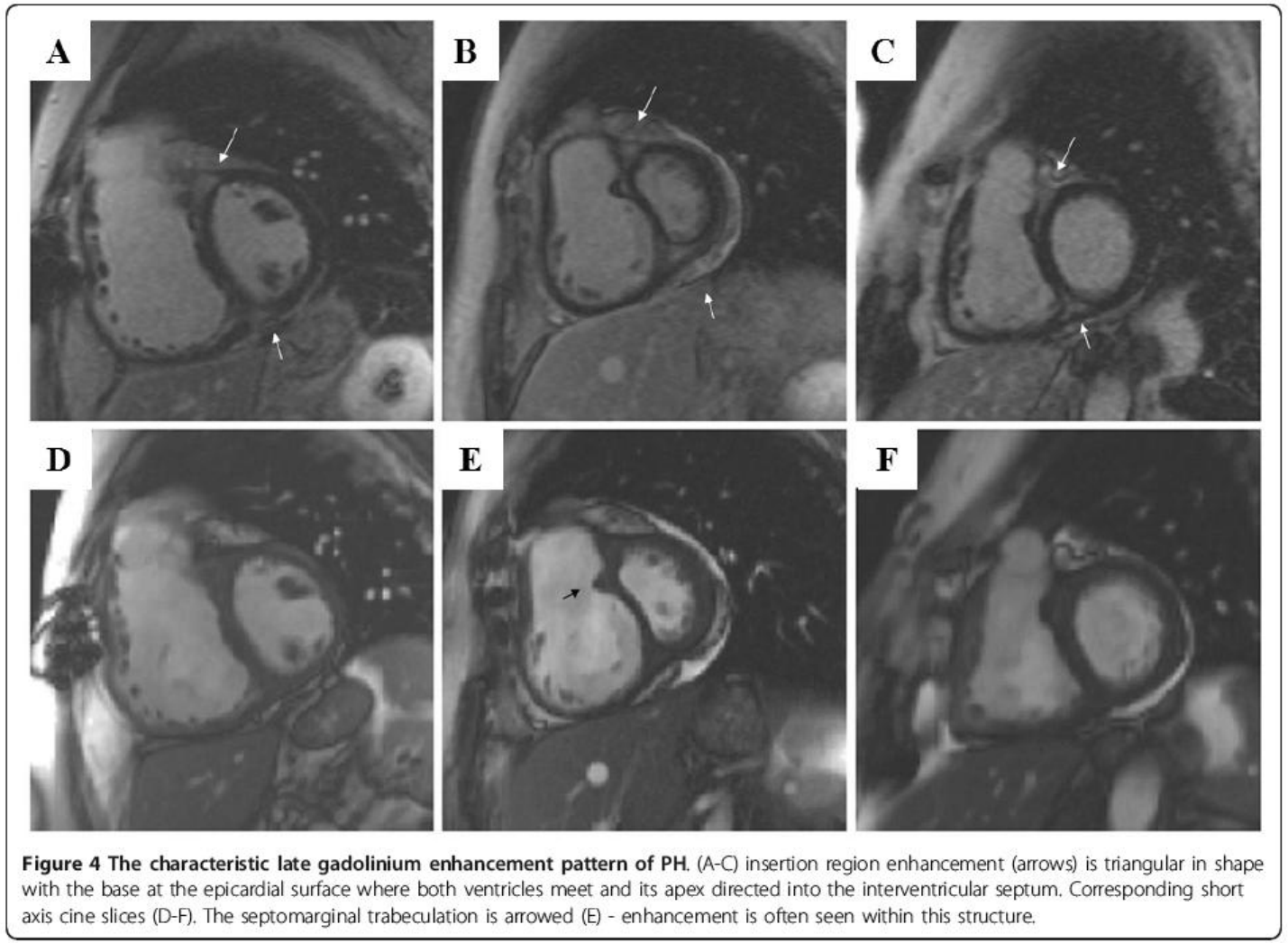
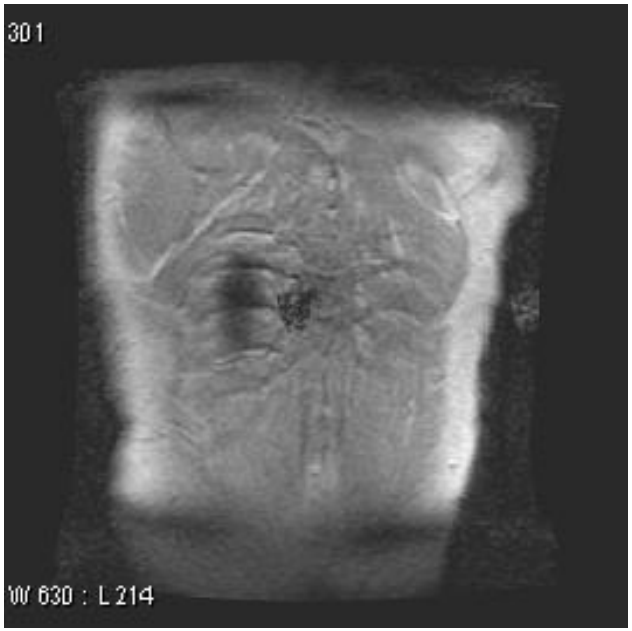


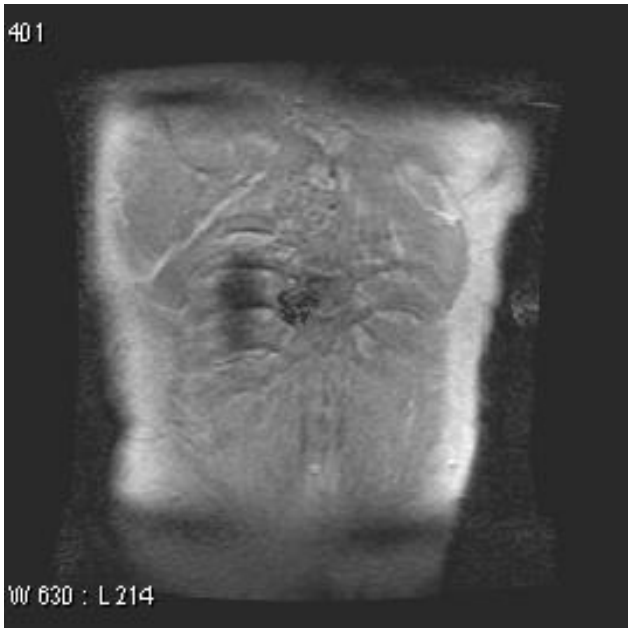

**Figure 4 The characteristic late gadolinium enhancement pattern of PH.** (A-C) insertion region enhancement (arrows) is triangular in shape with the base at the epicardial surface where both ventricles meet and its apex directed into the interventricular septum. Corresponding short axis cine slices (D-F). The septomarginal trabeculation is arrowed (E) - enhancement is often seen within this structure.

1. Bradlow WM, Gibbs JSR, Mohiaddin RH. Cardiovascular magnetic resonance in pulmonary hypertension. J Cardiovasc Magn Reson. 2012;14:6.

# Perfusion pulmonaire

- Imagerie T1 de perfusion au 1$^{er}$ passage après injection
- ≠ scintigraphie (embolisation de macroaggrégats)


301
W 630 : L 214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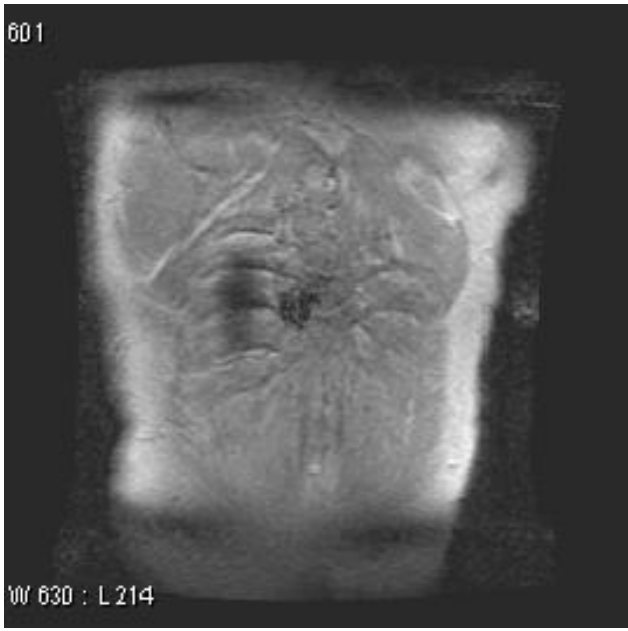
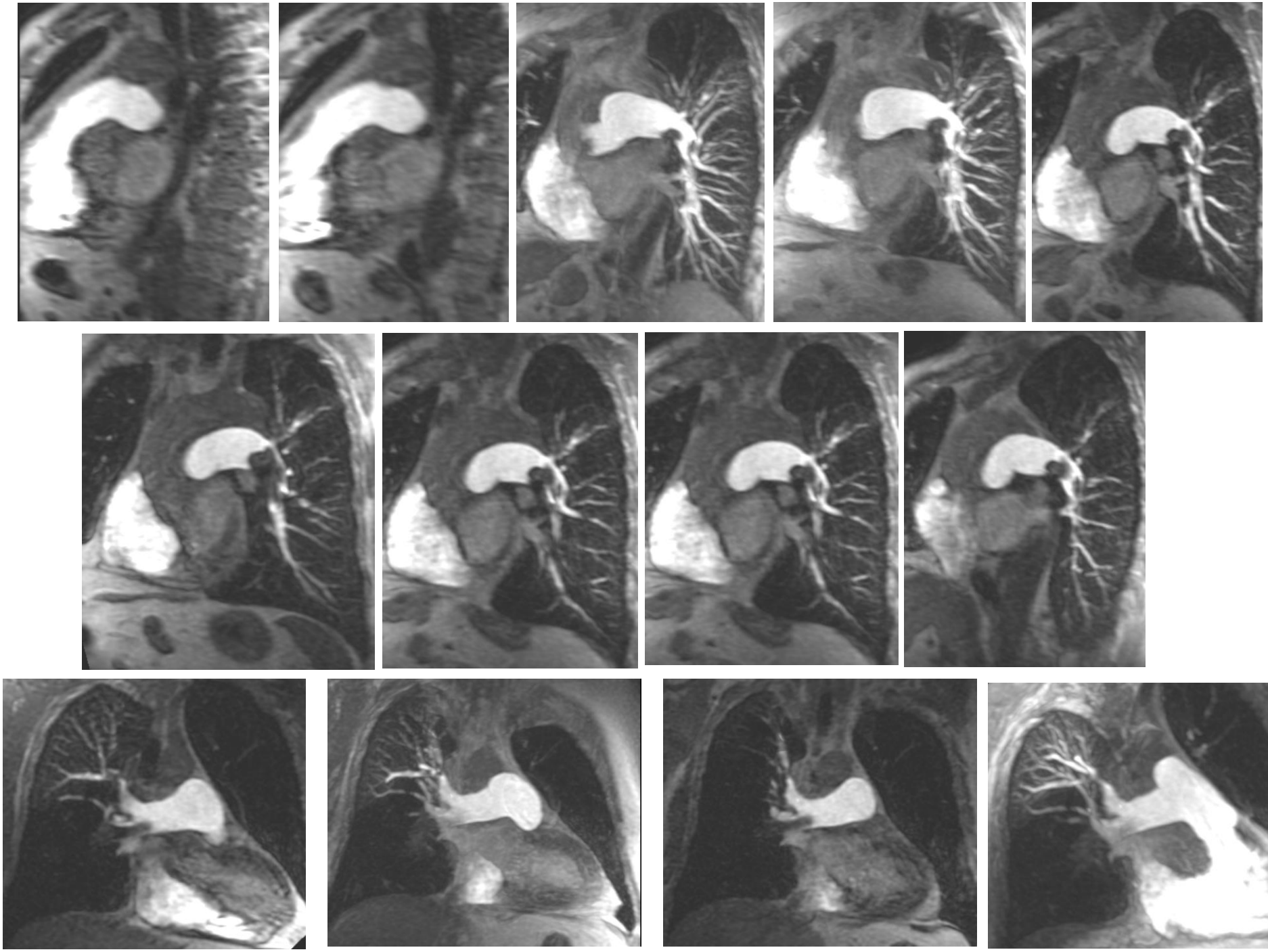
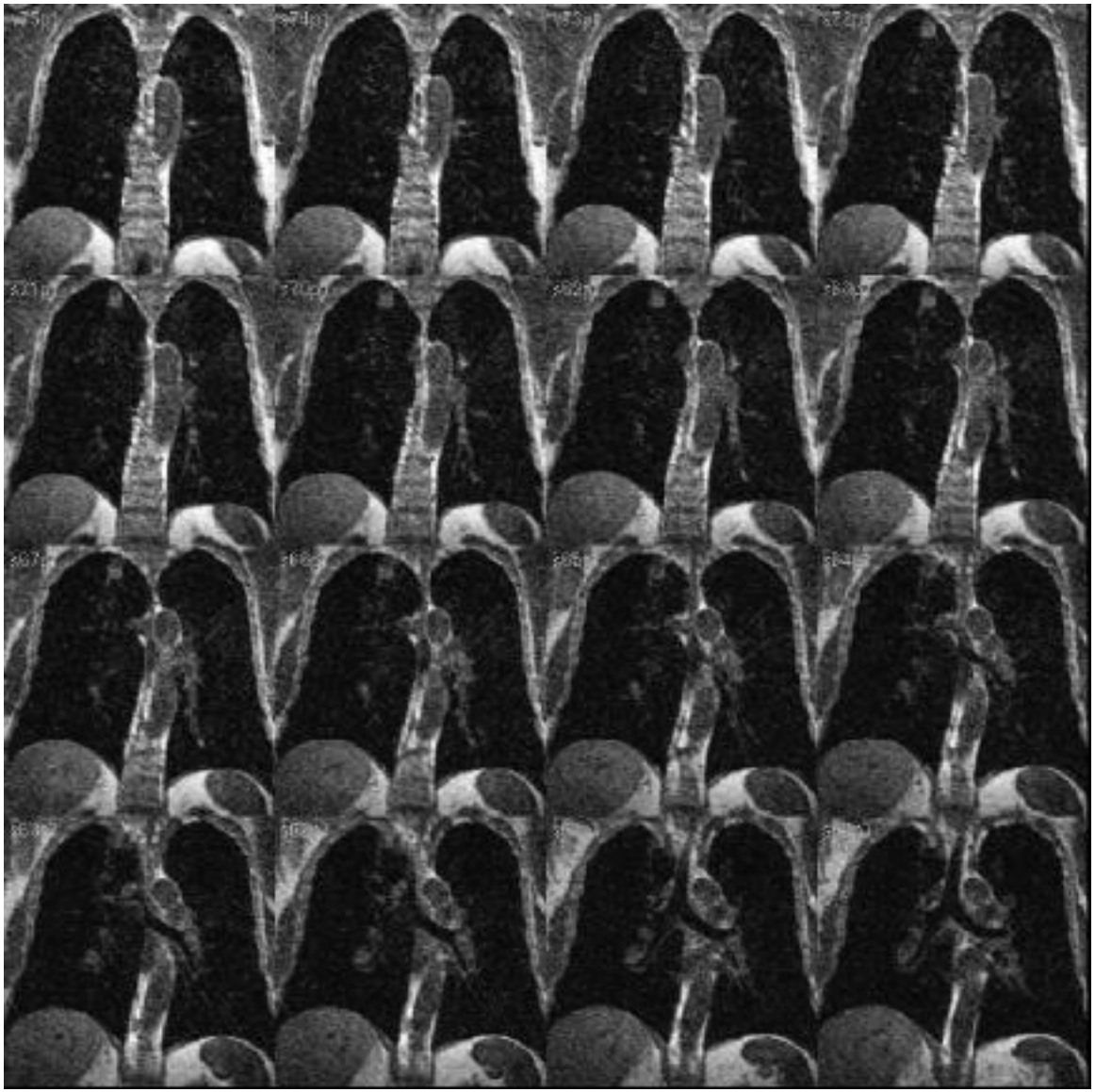
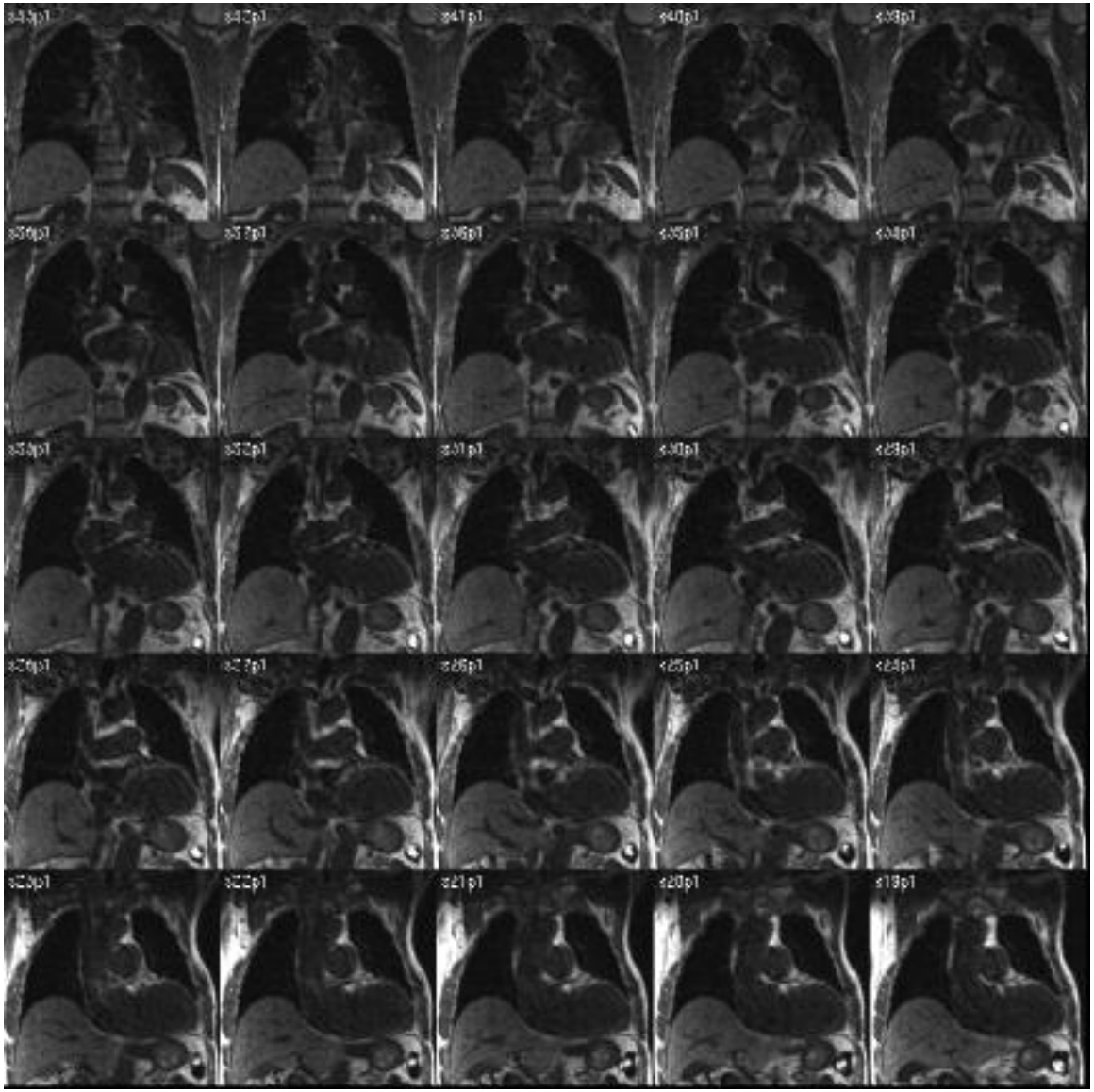
W 630 : L 214


601
W 630 : L 214



# Analyse visuelle





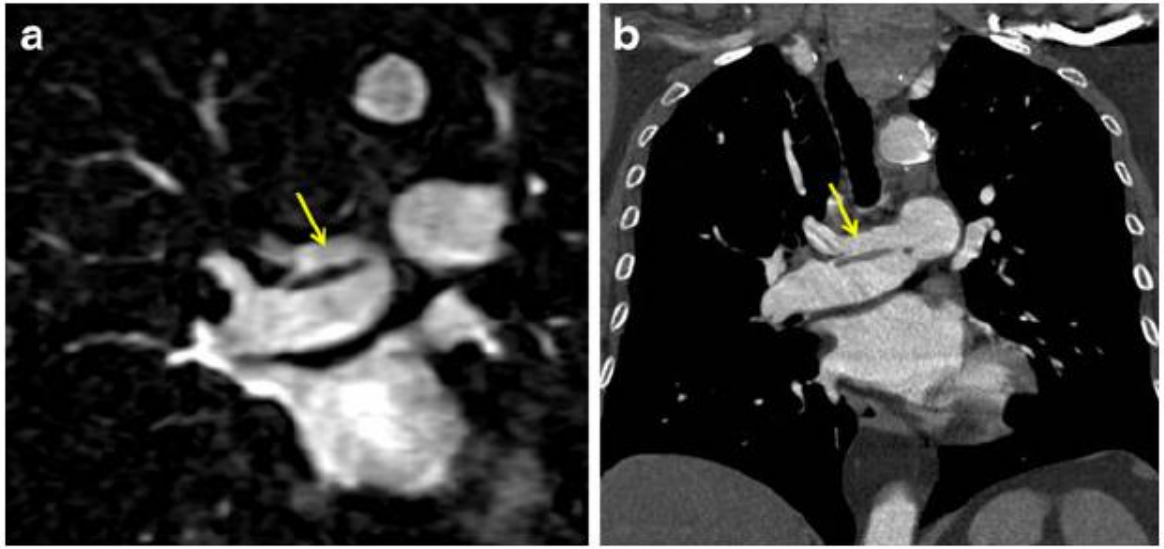
# Diagnostic accuracy of contrast-enhanced MR angiography and unenhanced proton MR imaging compared with CT pulmonary angiography in chronic thromboembolic pulmonary hypertension

Eur Radiol (2012) 22:310–317
DOI 10.1007/s00330-011-2252-x

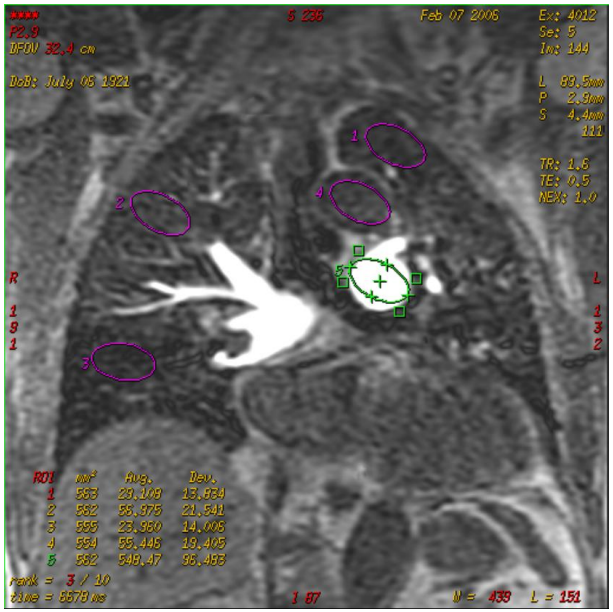
**Table 2** Sensitivity of CE-MRA and the added benefit of unenhanced MRA in the diagnosis of CTEPH as a function of site of disease (CE-MRA: contrast-enhanced MR angiography)

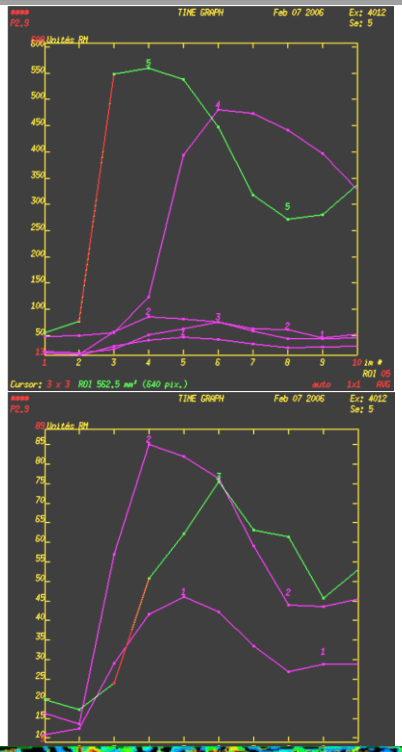
| | CE-MRA/CTPA | Sensitivity [%] | Kappa | CE-MRA + unenhanced-MRA/CTPA | Sensitivity [%] | Kappa |
|---|---|---|---|---|---|---|
| Central | 4/8 | 50 | 0.95 | 7/8 | 87.9 | 0.86 |
| Lobar | 20/27 | 74.07 | 0.90 | 23/27 | 85.2 | 0.79 |
| Segmental | 34/42 | 80.95 | 0.81 | 34/42 | 80.95 | – |
| Sub-segmental | 3/29 | 10.34 | 0.74 | 3/29 | 10.34 | – |

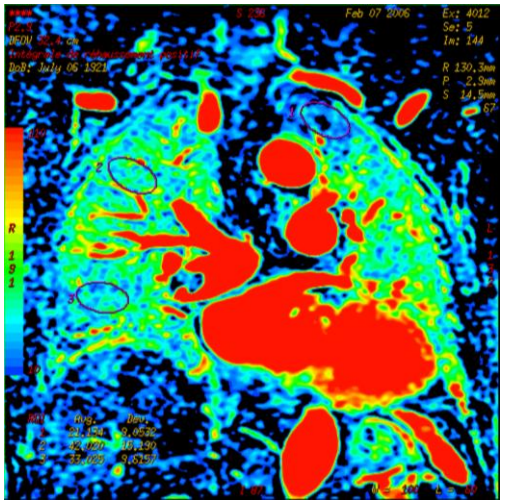
*Inter-observer agreement (Kappa) between the two readers for CE-MRA and CE-MRA + unenhanced-MRA



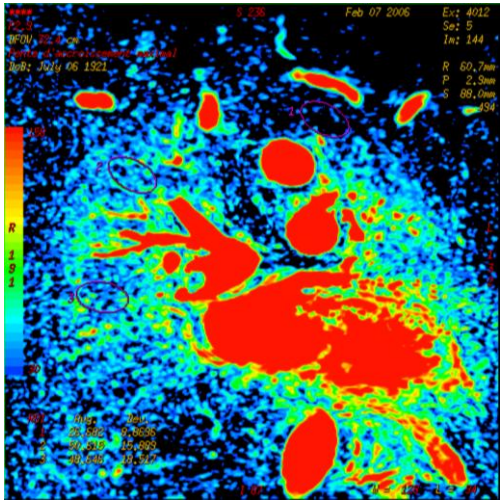
# Analyse semi-quantitative



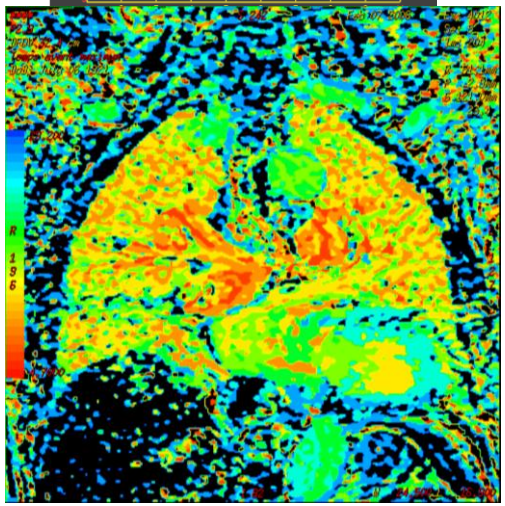




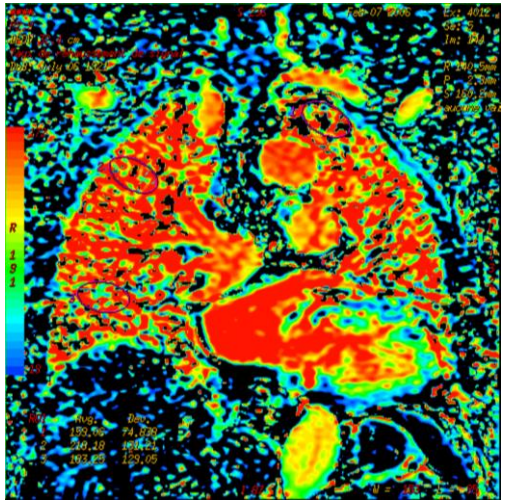
Intégrale de rehaussement



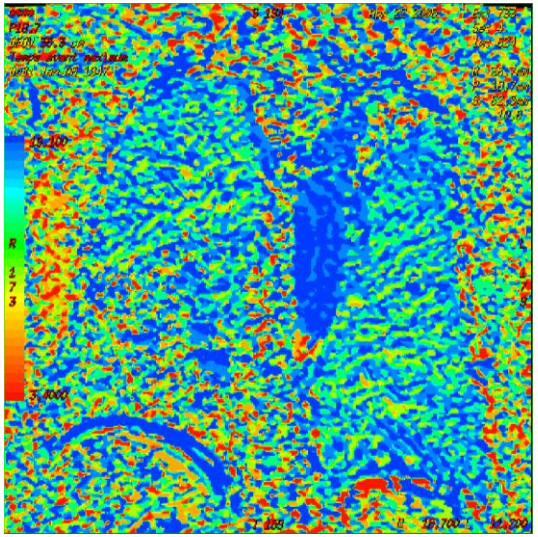
Pente maximale



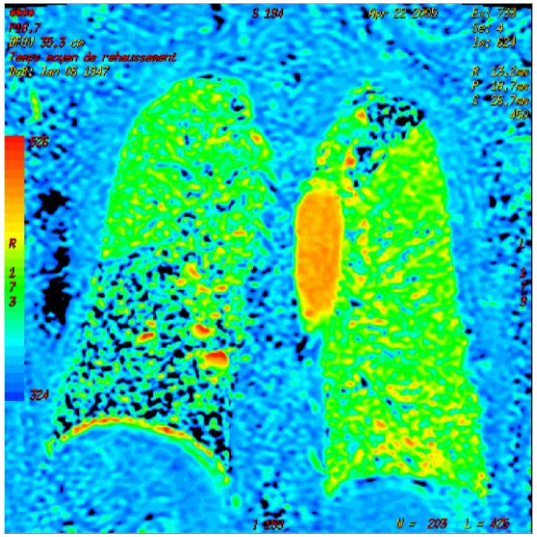
Temps au maximum



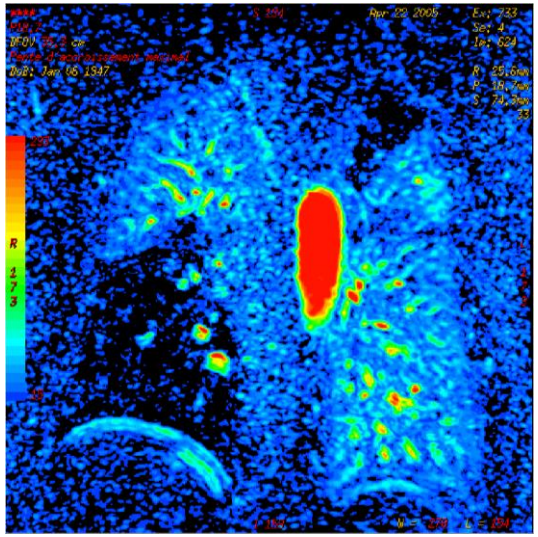
Rehaussement



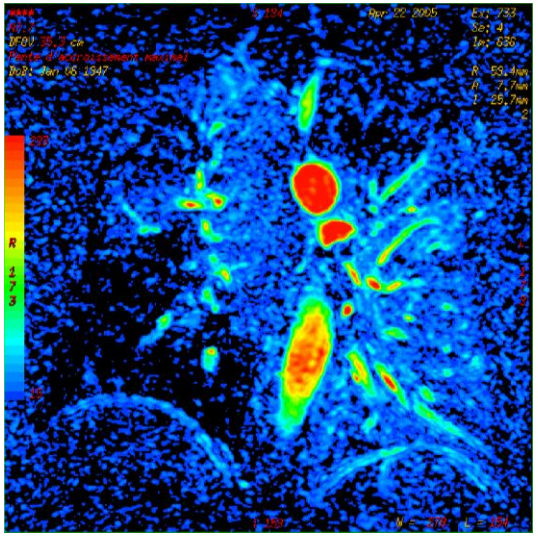
TTP



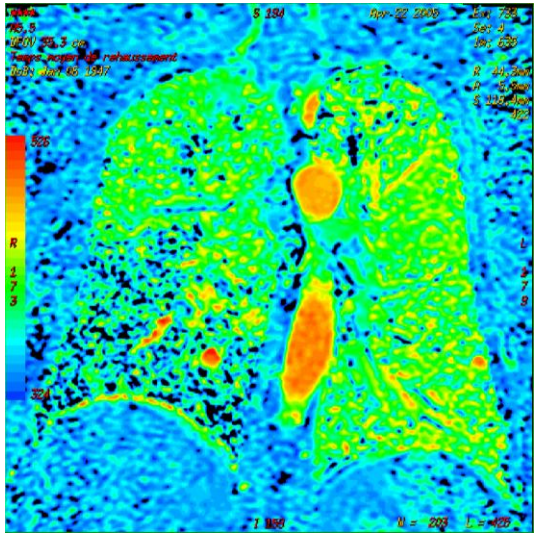
Temps moyen rehaussement



Pente maximale



Pente maximale



Temps moyen rehaussement

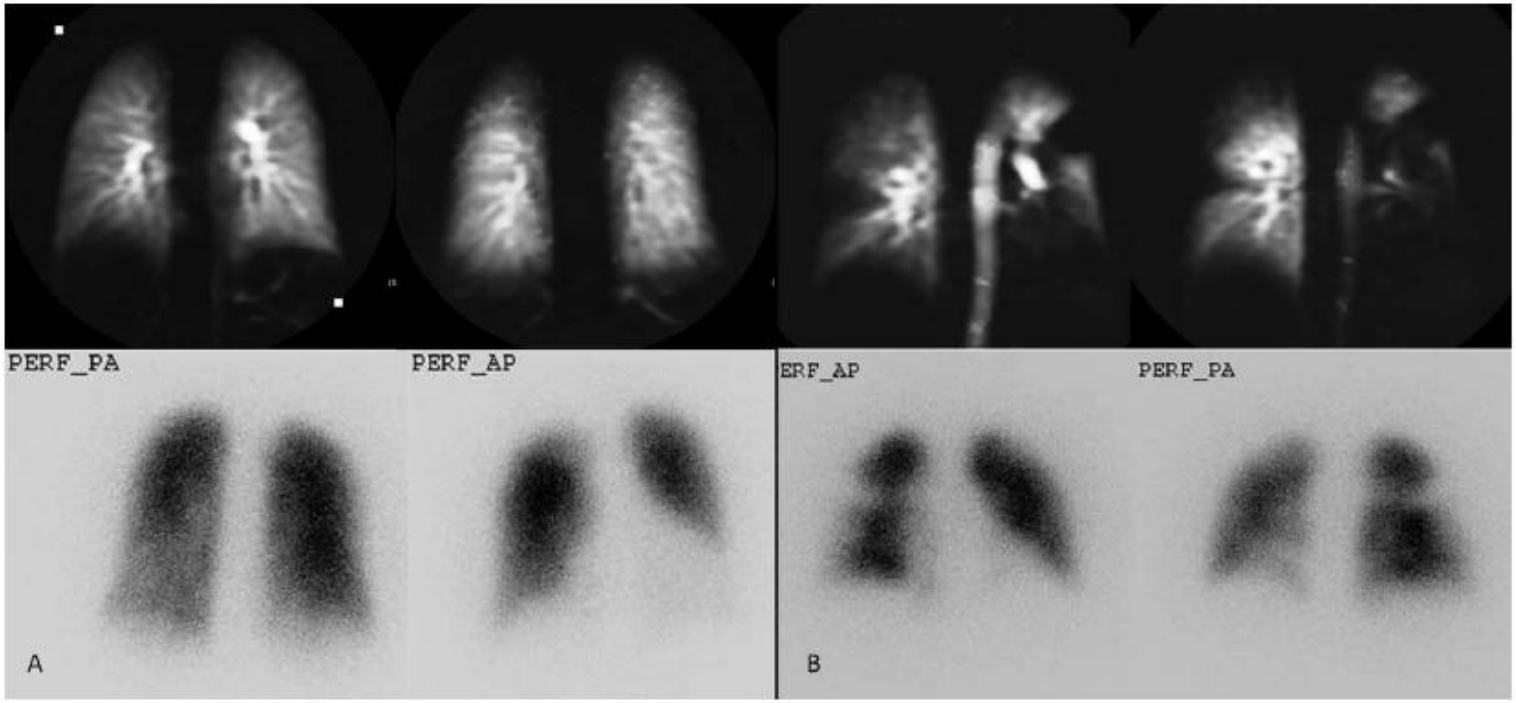



**Table 1** Summary of diagnostic performance of perfusion scintigraphy, MR perfusion and CTPA in the diagnosis of CTEPH

| | Q scan | MR perfusion* | CTPA |
|---|---|---|---|
| Sensitivity (%) | 96 (95% CI 0.89% to 0.99%) | 97 (95% CI 0.91% to 0.99%) | 94 (95% CI 0.85% to 0.98%) |
| Specificity (%) | 90 (95% CI 0.77% to 0.97%) | 92 (95% CI 0.80% to 0.97%) | 98 (95% CI 0.88% to 0.99%) |
| Positive predictive value (%) | 94 (95% CI 0.86% to 0.98%) | 95 (95% CI 0.88% to 0.99%) | 99 (95% CI 0.92% to 0.99%) |
| Negative predictive value (%) | 93 (95% CI 0.82% to 0.99%) | 96 (95% CI 0.85% to 0.99%) | 90 (95% CI 0.78% to 0.96%) |
| Accuracy (%) | 94 | 95 | 95 |

*Inter-observer agreement, $\kappa$ of 0.83.
CTEPH, chronic thromboembolic pulmonary hypertension; CTPA, CT pulmonary angiography.

1. Rajaram S, Swift AJ, Telfer A, Hurdman J, Marshall H, Lorenz E, et al. 3D contrast-enhanced lung perfusion MRI is an effective screening tool for chronic thromboembolic pulmonary hypertension: results from the ASPIRE Registry. Thorax. 2013 Jan 24.

# Points clés

- IRM
  - Évaluation fonctionnelle AP + VG/VD
    - Sans limite de fenêtre acoustique
    - Mais limite de la résolution temporelle
  - Recherche de shunt
  - Imagerie indirecte de la fibrose (facteur pronostique de la réponse au traitement ?)

- CT
  - Analyse morphologique ++
    - EP aiguë / chronique
  - Double voire multi énergie -> « perfusion »