Place de l'IRM cardiaque dans l'HFpEF

Dr. Théo Pezel

***Service de Cardiologie et Radiologie**, CHU Lariboisière (AP-HP), Paris, France*

***MIRACL.ai laboratory** (Multimodality Imaging for Research and Analysis Core Laboratory: Artificial Intelligence), Paris, France*

***INSERM U-942 MASCOT**, Paris, France*

Liens d'intérêt

- Consulting and lecture fees:
  - Astra Zeneca
  - Bayer
  - Bristol-Myers Squibb (BMS) – Pfizer
  - Vifor Pharma
  - Novartis
  - Boehringer Ingelheim
  - Amarin corporation
  - Siemens Healthineers (France, Global)
  - GE Healthcare (France)
  - MEDIS imaging
  - Hexacath

- Research grants:
  - Servier
  - Bayer

MIRACL.ai

Hôpital Lariboisière
Fernand-Widal
AP-HP

Part 1: Cardiac MRI in HFpEF

ESC European Society of Cardiology
European Heart Journal (2021) **00**, 1–128
doi:10.1093/eurheartj/ehab368

2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure

Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)

With the special contribution of the Heart Failure Association (HFA) of the ESC

Investigati… consider in selected patients		
CMR imaging is recommended to evaluate cardiac structure and function, to measure LVEF, and to characterize cardiac tissue, especially in subjects with inadequate echocardiographic images or where the echocardiographic findings are inconclusive or incomplete (but taking account of cautions/contraindications to CMR).	I	C
Coronary angiography is recom… …ible for coronary revascularization, to evaluate the coronary anatomy.	I	C
Myocardial perfusion/ischaemia imaging (echocardiography, CMR, SPECT, or PET) should be considered in patients thought to have CAD, and who are considered suitable for coronary revascularization, to determine whether there is reversible myocardial ischaemia and viable myocardium.	IIa	C

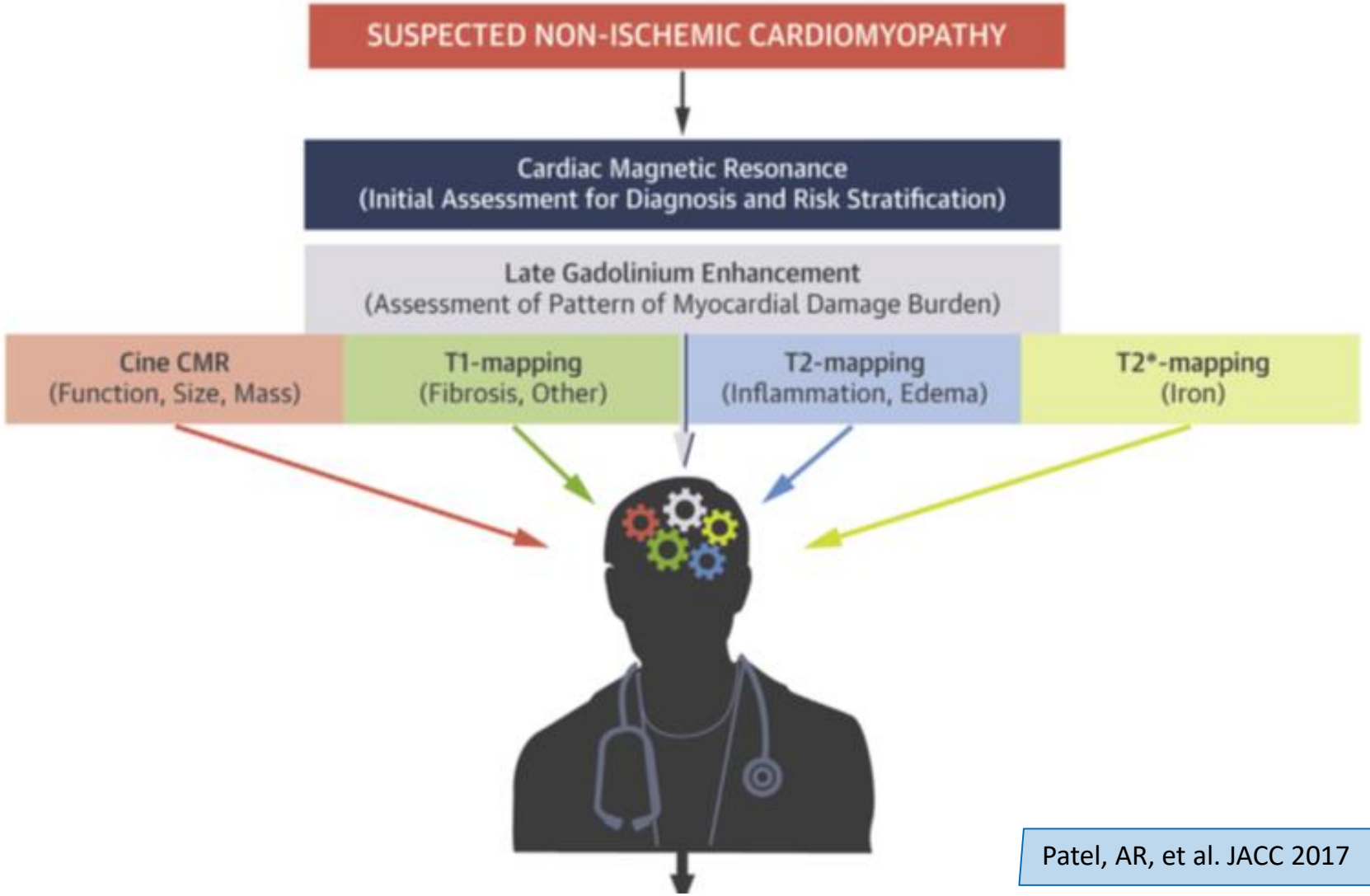
"… CMR is recommended to evaluate cardiac structure and function."

MIRACL.ai

Hôpital Lariboisière Fernand-Widal AP-HP

Role of CMR

Heart failure and cardiomyopathy



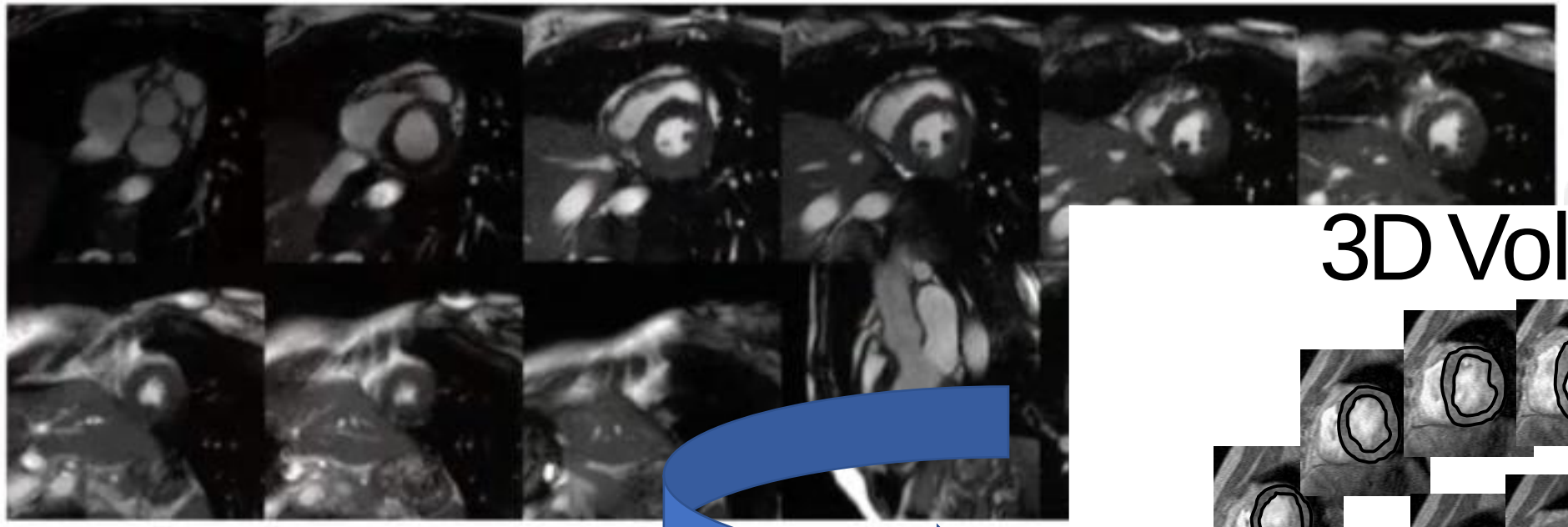
Patel, AR, et al. JACC 2017

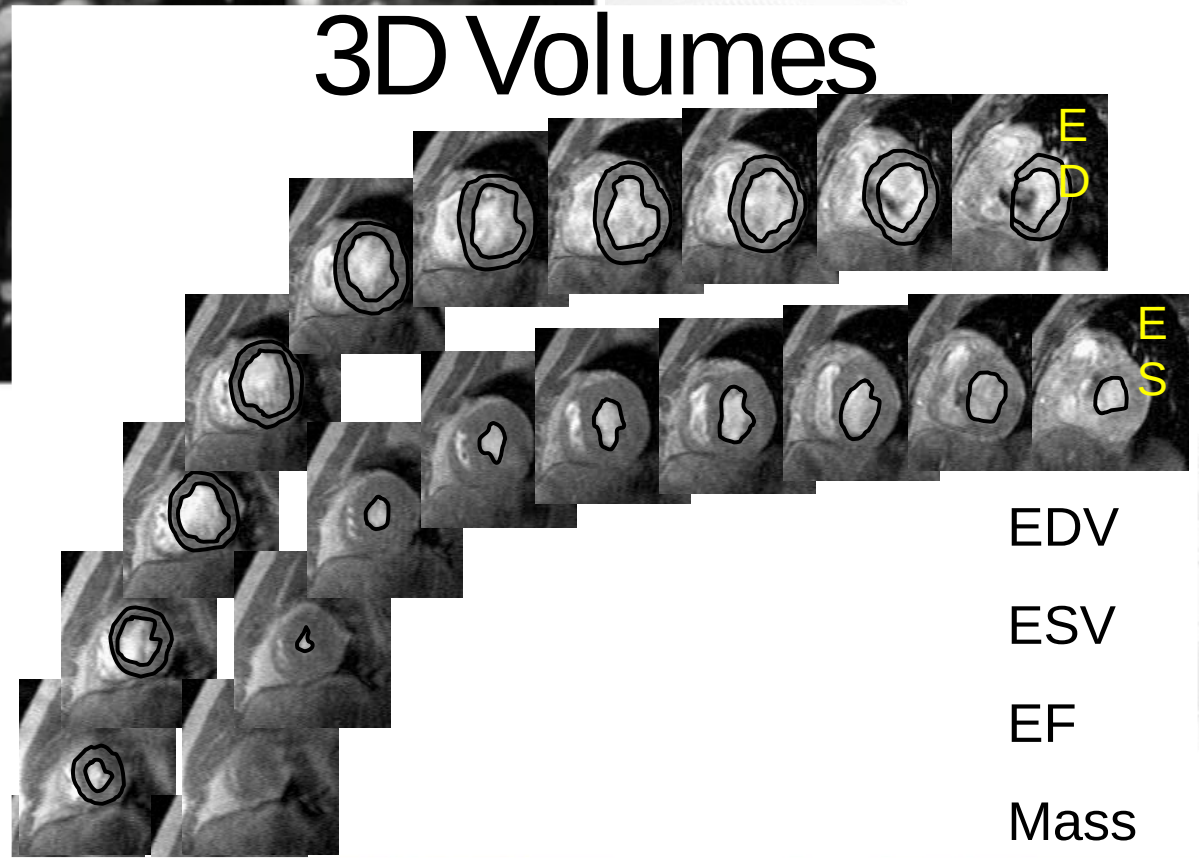
MIRACL.ai

Hôpital Lariboisière
Fernand-Widal
AP-HP

Cine-CMR

Left ventricle parameters



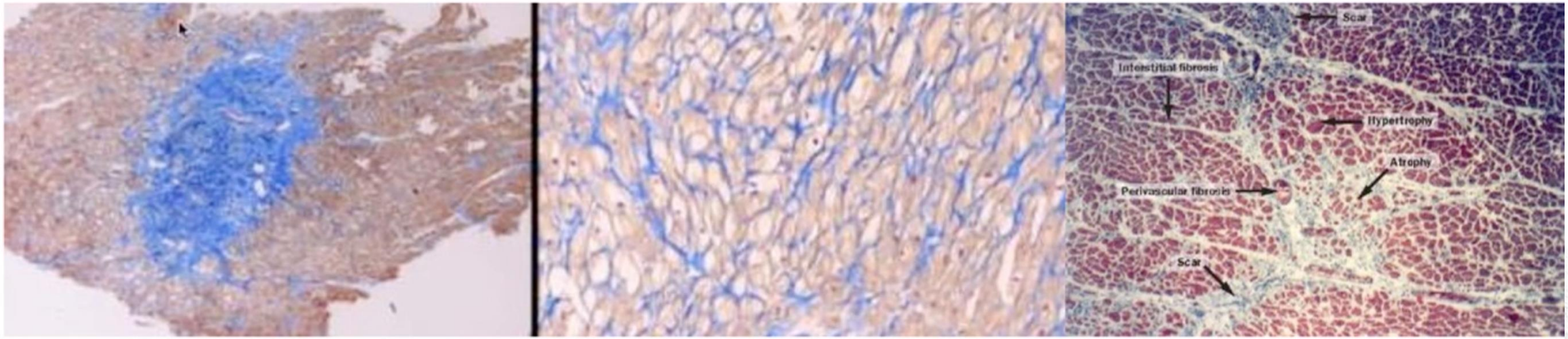


LV parameters

- **HFpEF → LVEF ≥ 50%**
- **LV ED volume** (LV dilation if **>100 ml/m²**)

Myocardial fibrosis

Two types of myocardial fibrosis



Replacement fibrosis | Interstitial fibrosis | Mixture

Braunwald's Heart Disease textbook, 11TH Edition. 2018

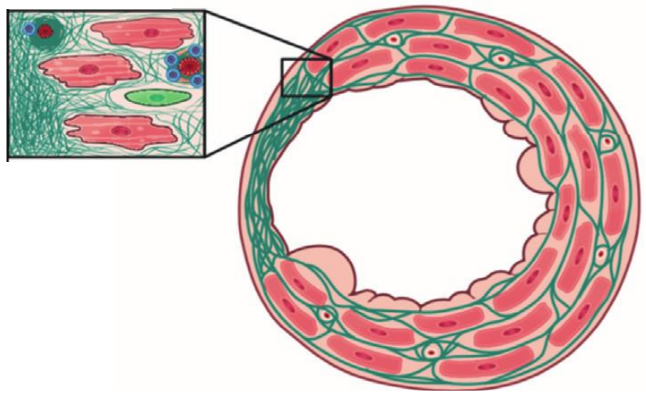
MIRACL.ai

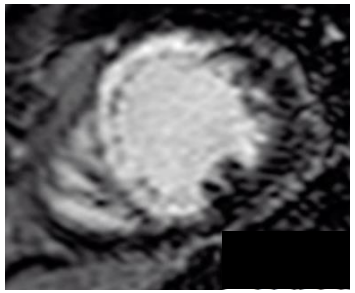
Hôpital Lariboisière Fernand-Widal AP-HP

Myocardial fibrosis

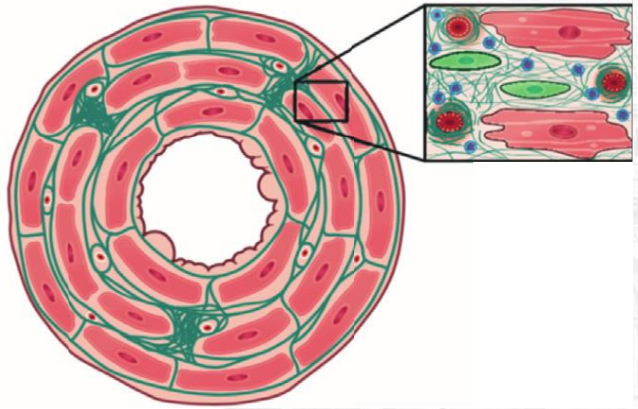
Two types of myocardial fibrosis

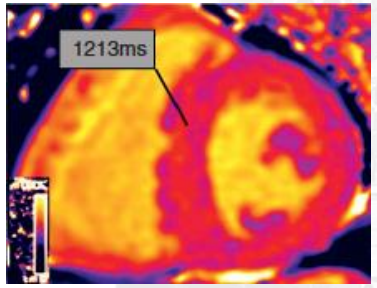
Replacement fibrosis
(focal myocardial scar)



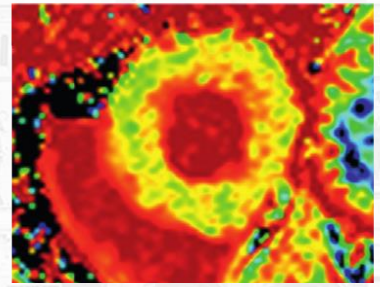


Diffuse interstitial fibrosis





Native T1 mapping



ECV mapping

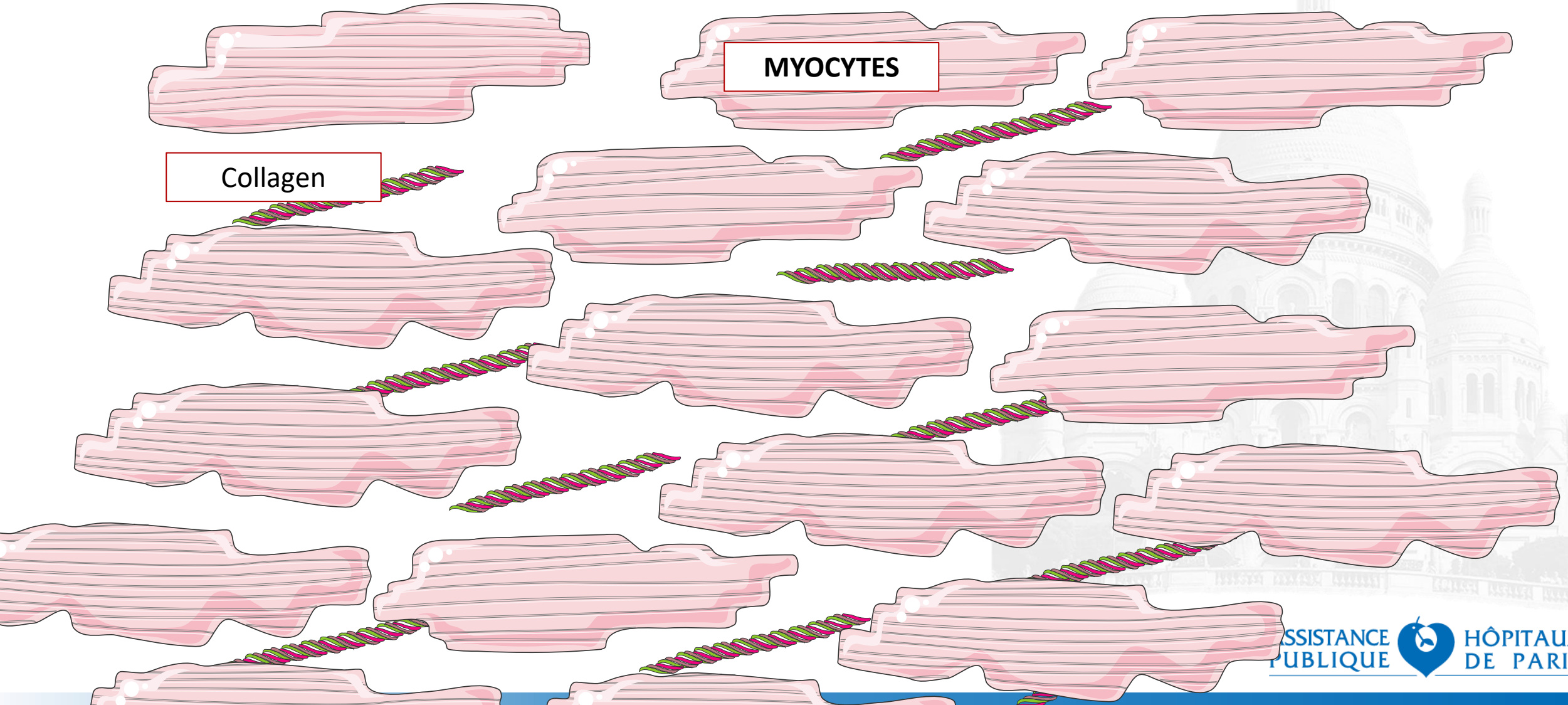
Adapted from Pezel T., et al. JACC Cardiovasc Imaging. 2021

MIRACL.ai

Hôpital Lariboisière
Fernand-Widal
AP-HP

Replacement fibrosis in CMR

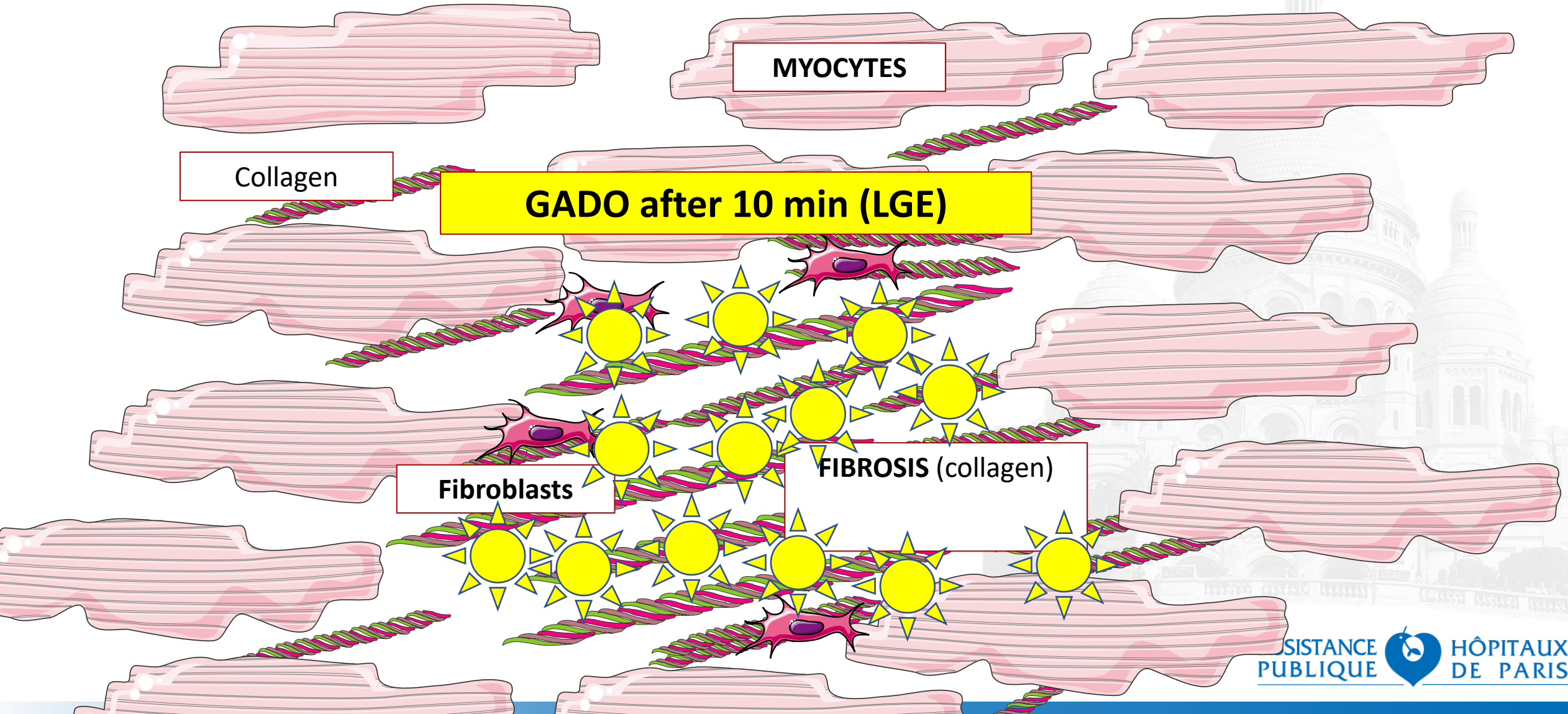
What is the Late gadolinium enhancement (LGE)?



ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Replacement fibrosis in CMR

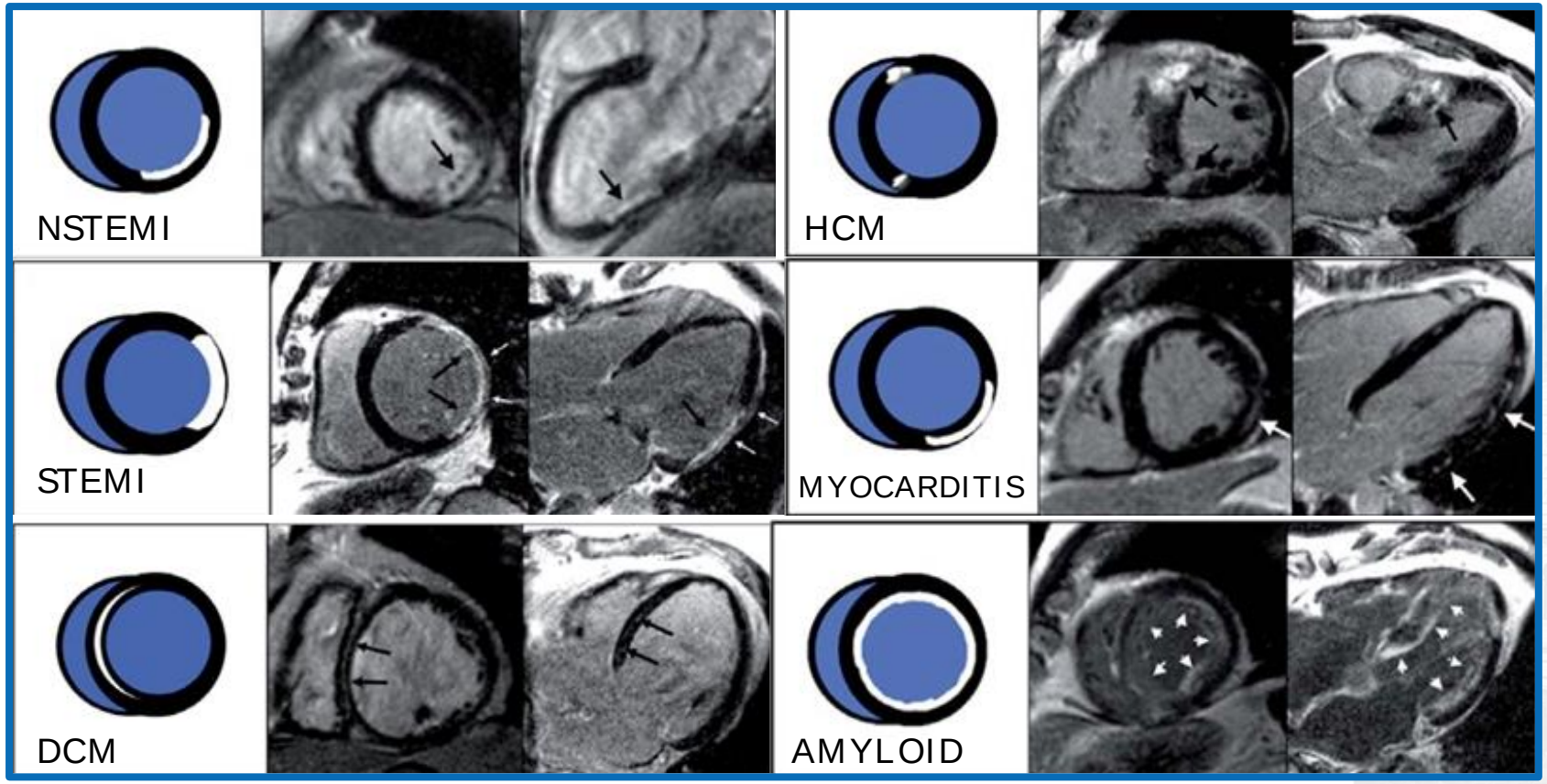
What is the Late gadolinium enhancement (LGE)?



ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Replacement fibrosis in CMR

What is the Late gadolinium enhancement (LGE)?



"LGE = focal increase of the extracellular volume"

i.e. myocardial necrosis, fibrosis, myocardial edema, amyloid deposits...

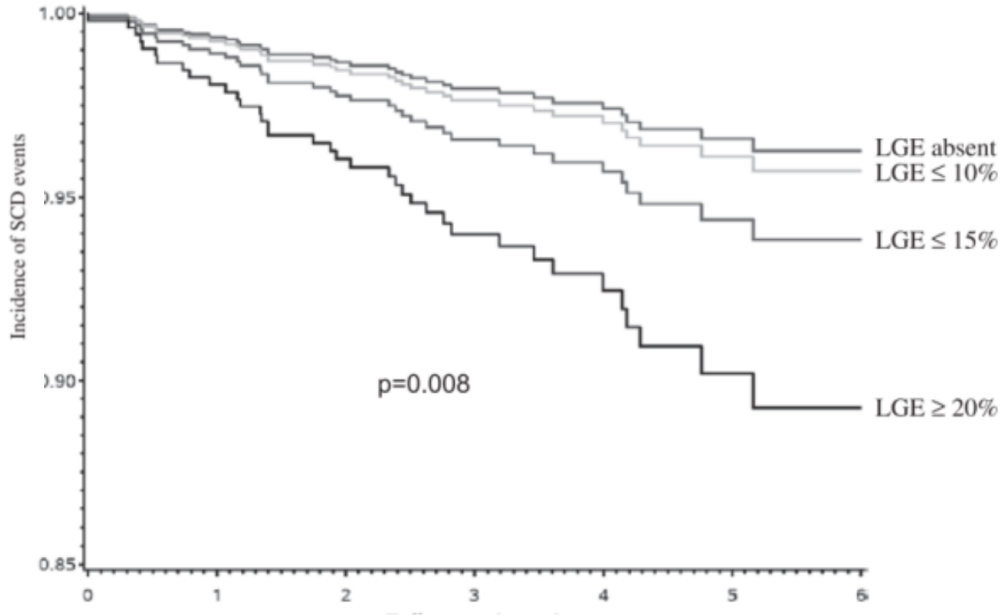
Mahrholdt H et al , EHJ 2005

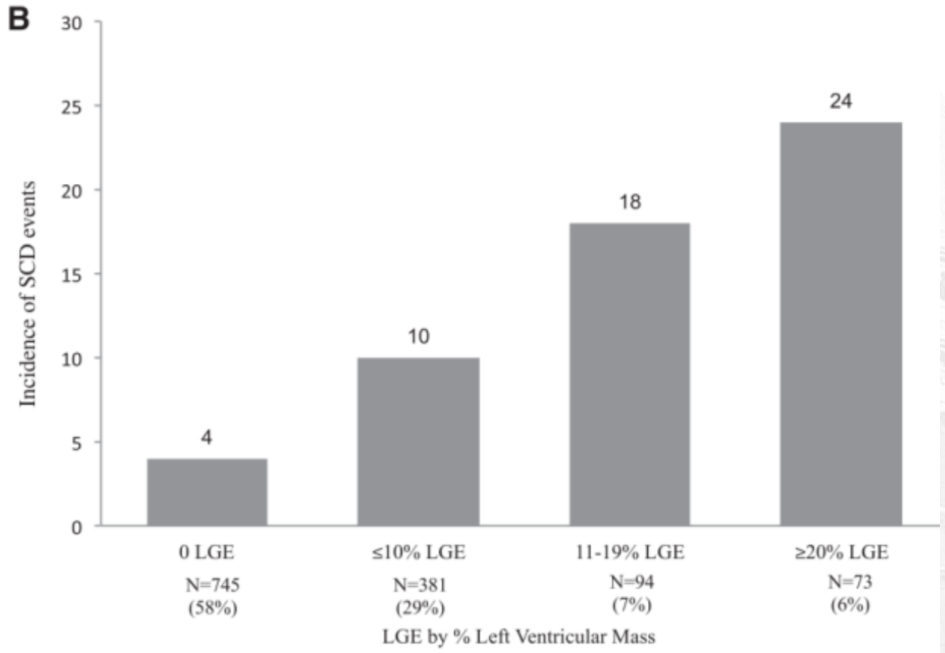
MIRACL.ai

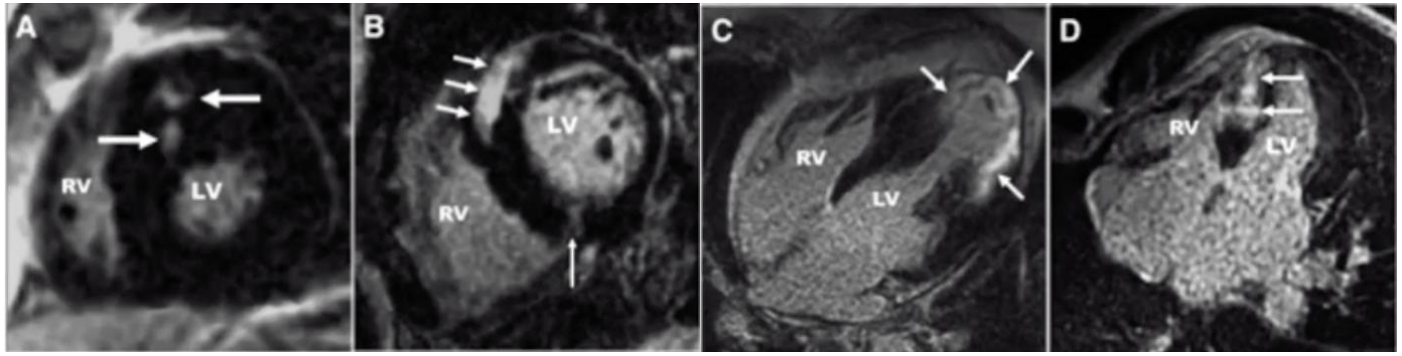
Hôpital Lariboisière Fernand-Widal AP-HP

Prognostic value of LGE

HFpEF patients with LV hypertrophy / HCM







Chan et al. Circulation 2014

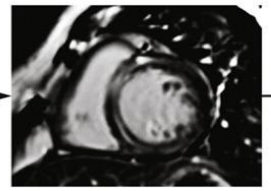
MIRACL.ai

Hôpital Lariboisière
Fernand-Widal
AP-HP

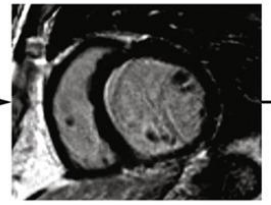
Prognostic value of diffuse interstitial fibrosis

T1/ECV mapping

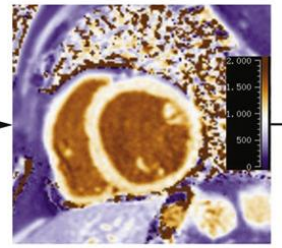
777 patients



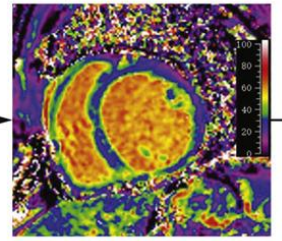
LGE positive



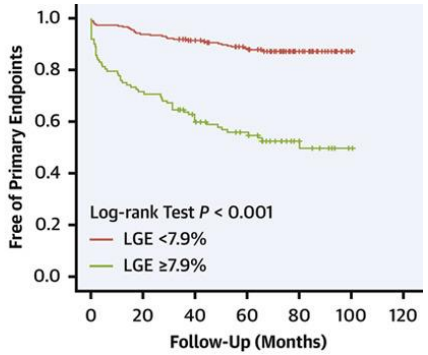
LGE negative

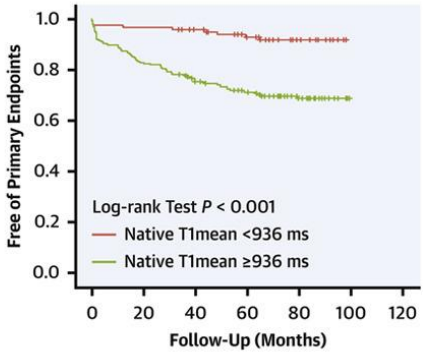


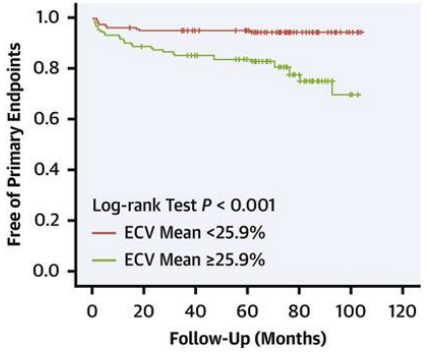
NativeT1



ECV





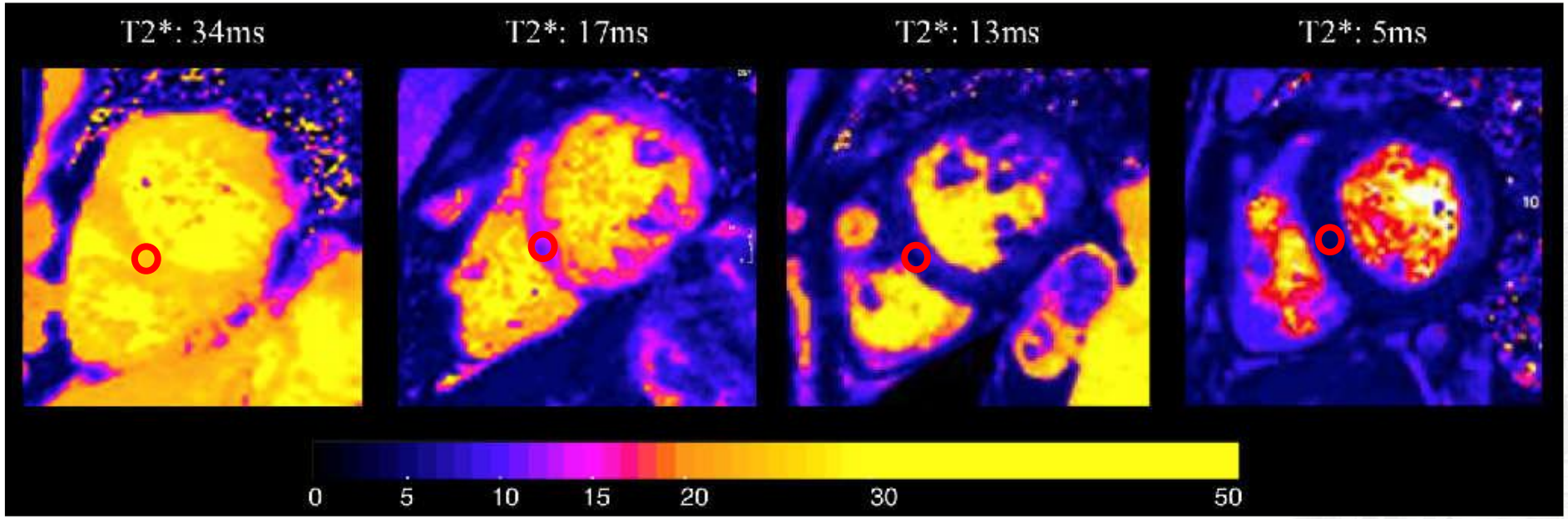


Shuang L, et al. JACC CV Imaging 2021

MIRACL.ai

Hôpital Lariboisière Fernand-Widal AP-HP

T2* mapping
Hemochromatosis



T2*mapping mid-septal (ROI) :

- norme **≥ 20 ms**
- Hemochromatosis **< 20 ms**

Torlasco et al. PLoS ONE 2018

MIRACL.ai

Hôpital Lariboisière Fernand-Widal AP-HP

Part 2: MIRACL.ai plateform

MIRACL.ai

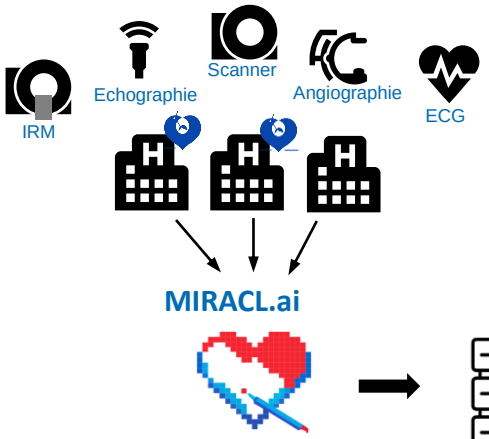
Multimodality Imaging Research for Analysis Core Laboratory and Artificial Intelligence

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

MIRACL. Core Lab

Multimodality Imaging Research for Analysis Core Laboratory and Artificial Intelligence

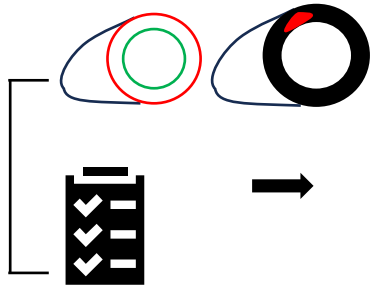
Pseudonymisation
et **Transfert sécurisé** des données



Stockage
sécurisé

Analyse
et post-traitement
par des experts

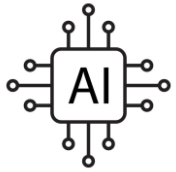
Annotations,
segmentations…

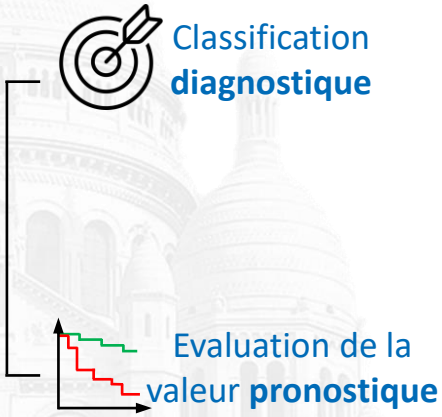


CR standardisé

Base de données
structurée
(nombreuses pathologies
avec plusieurs modalités
par patient)

Validation et
développement
d'algorithmes
avec ou sans IA





Classification
diagnostique

Evaluation de la
valeur **pronostique**

Publications

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

MIRACL.ai

Plateforme de recherche académique « multi-centres d'expertise CHU »

CHU LILLE

CHU AMIENS PICARDIE

Hôpital Lariboisière Fernand-Widal AP-HP

CHRU NANCY

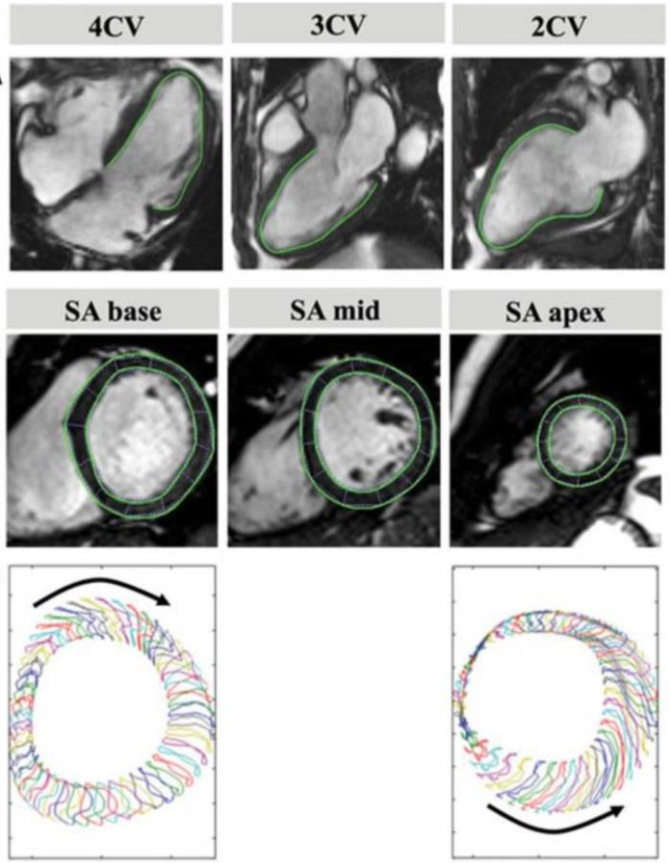
INSTITUT CARDIOVASCULAIRE PARIS SUD

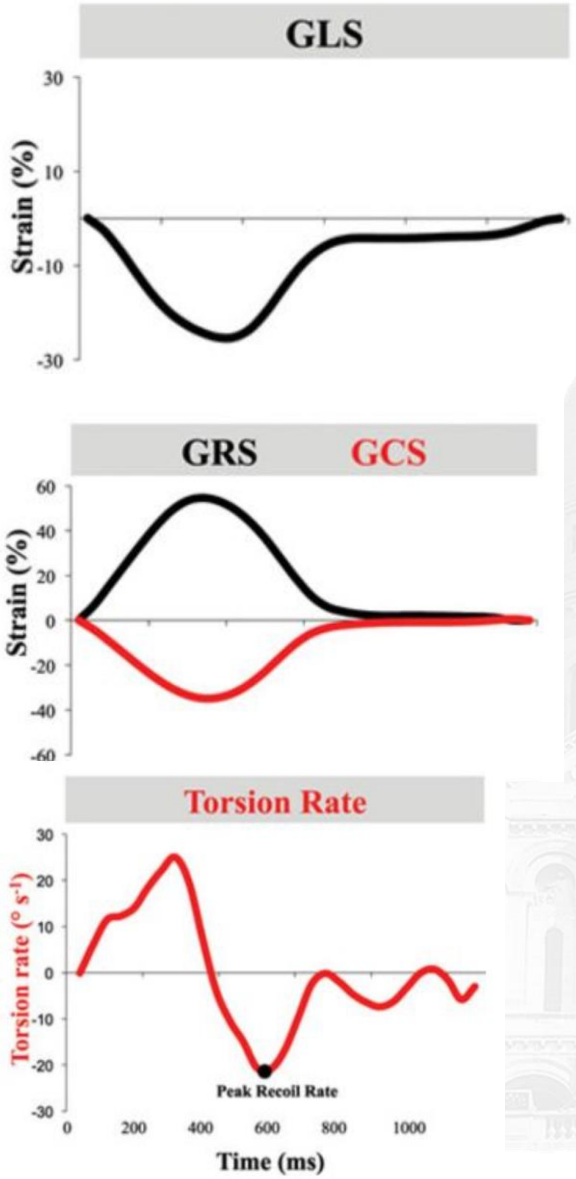
CHU ROUEN NORMANDIE

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Imaging Biomarkers in HF

LV Strain





Strain longitudinal

Strain radiaire
Strain circonférentiel

Torsion

Schuster A et al. Circ CVI 2016

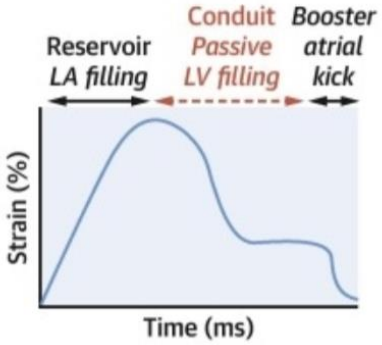
MIRACL.ai

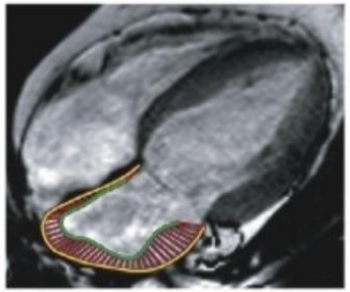
Hôpital Lariboisière
Fernand-Widal
AP-HP

Imaging Biomarkers in HF

LA Strain

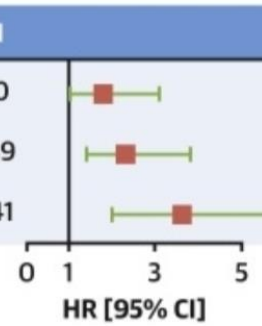
CMR-Feature Tracking LA Strain in Dilated Cardiomyopathy



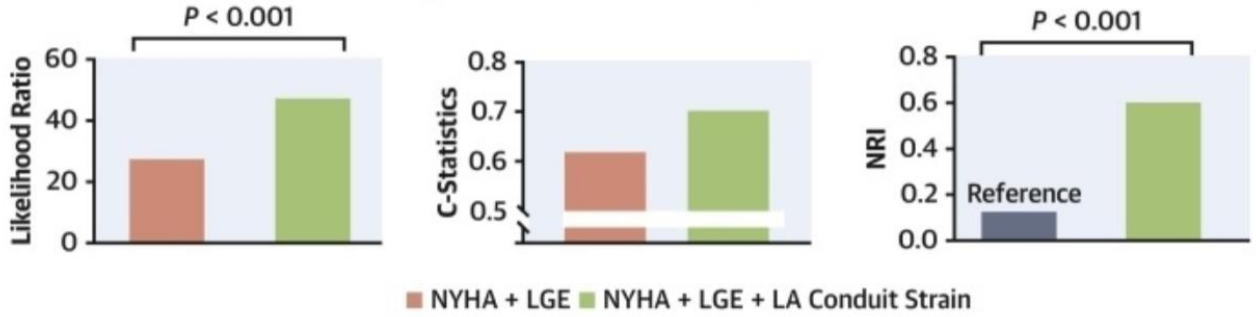


Multivariable Adjusted Analysis
Outcome: sudden/cardiac death, HF hospitalization and life-threatening arrhythmias

	N	HR [95% CI]	*P* Value
NYHA functional class >II	70	1.81 [1.05-3.12]	0.033
LGE presence	189	2.33 [1.42-3.85]	< 0.001
LA-strain (conduit) <12%	241	3.65 [2.01-6.64]	< 0.001



LA Conduit Strain is a Strong Independent Prognostic Predictor, **Superior** to **Left Ventricular Strain, LVEF and LA Volume Index,** and **Incremental** to **LGE**



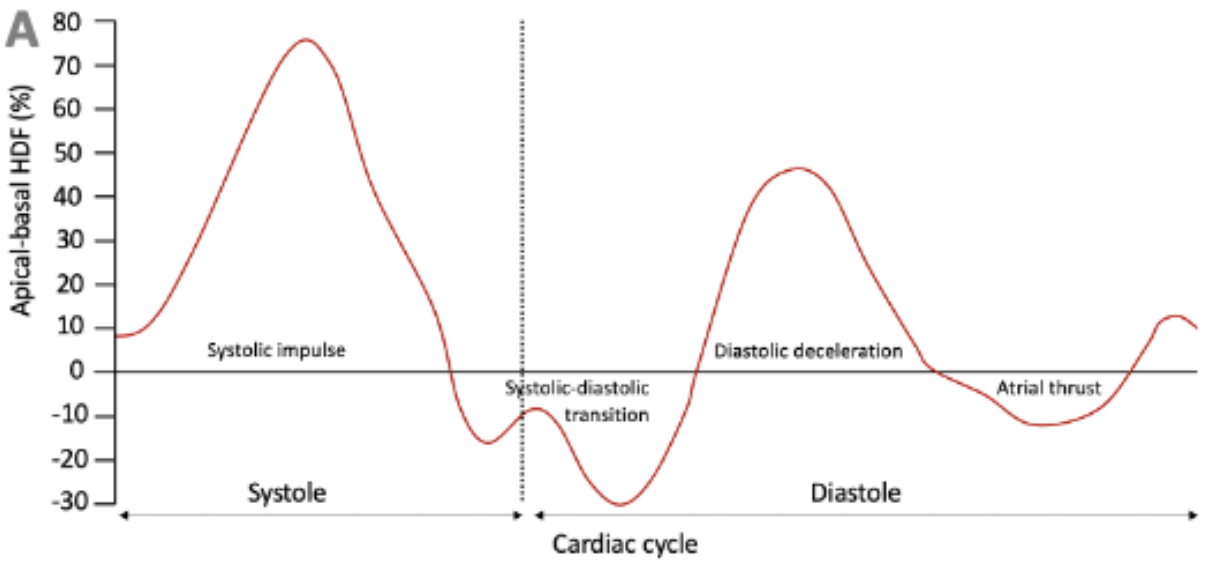
Raafs AL, et al. JACC Cardiovascular Imaging. 2022;15(6):1015-1026

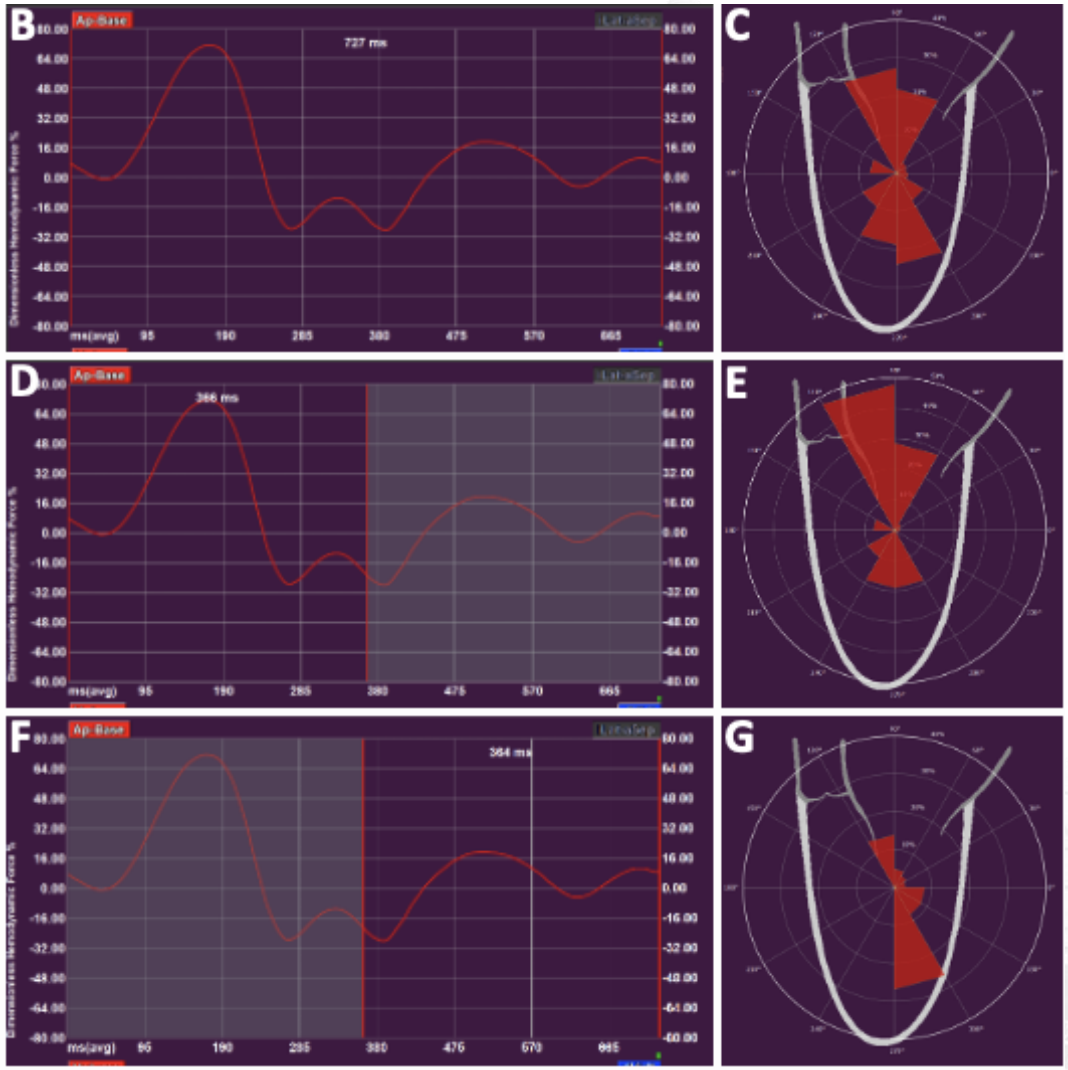
MIRACL.ai

Hôpital Lariboisière Fernand-Widal AP-HP

Imaging Biomarkers in HF

Hemodynamic forces (Medis imaging)

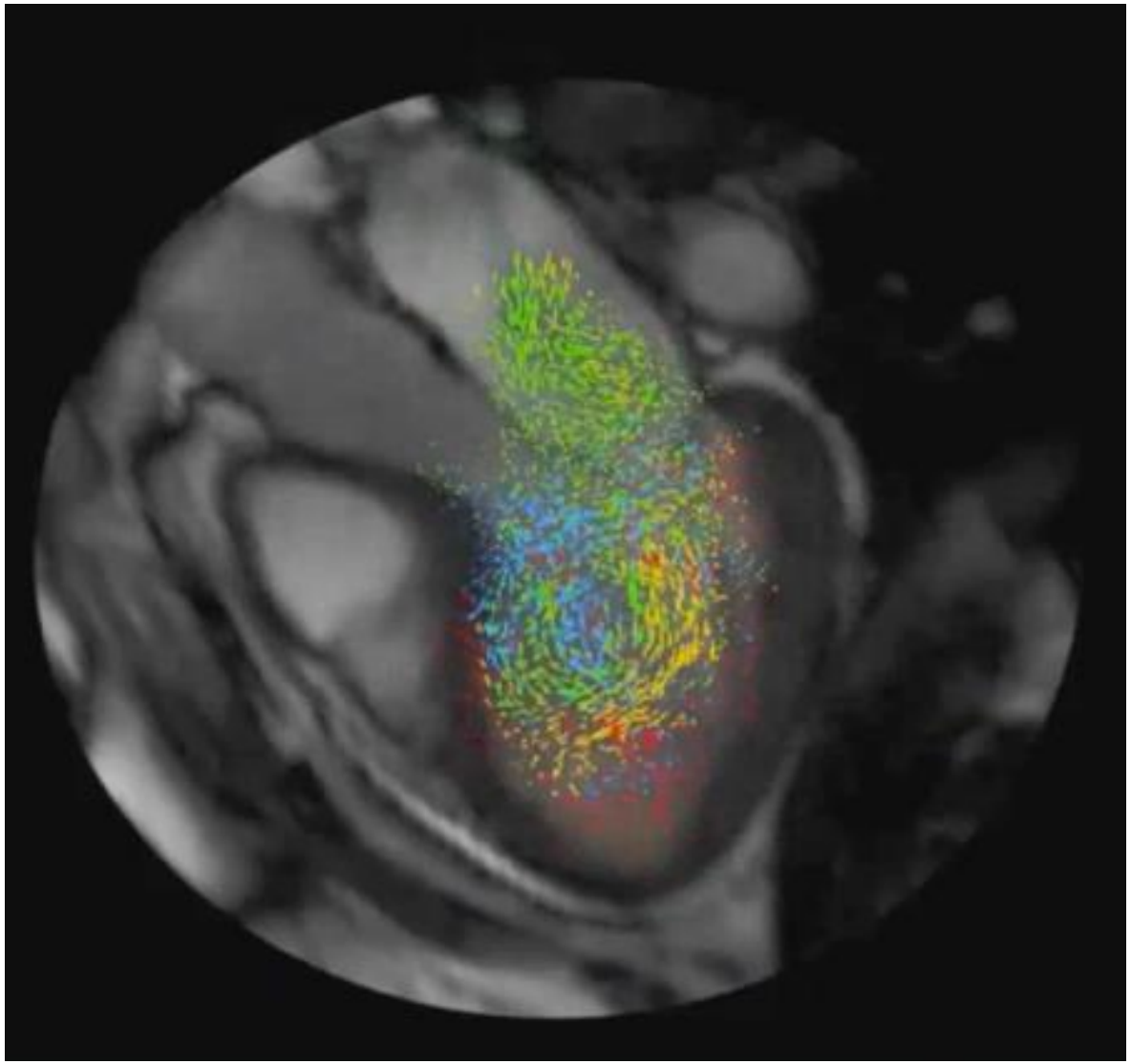




Andreea A et al. LV hemodynamic forces in Systemic Sclerosis patients, in preparation

Imaging Biomarkers in HF

4D Flow Components and Kinetic Energy

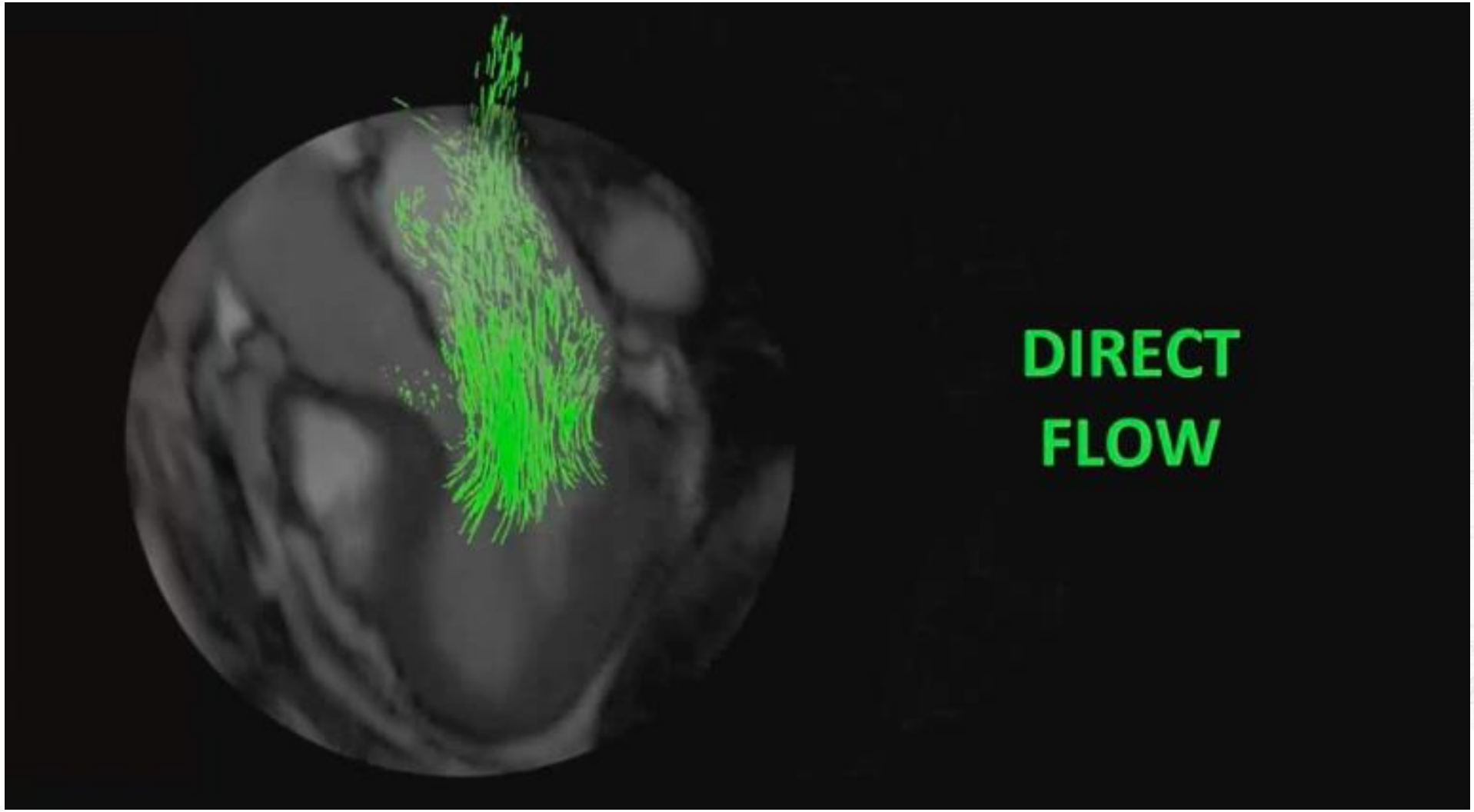


MIRACL.ai

Hôpital Lariboisière
Fernand-Widal
AP-HP

Imaging Biomarkers in HF

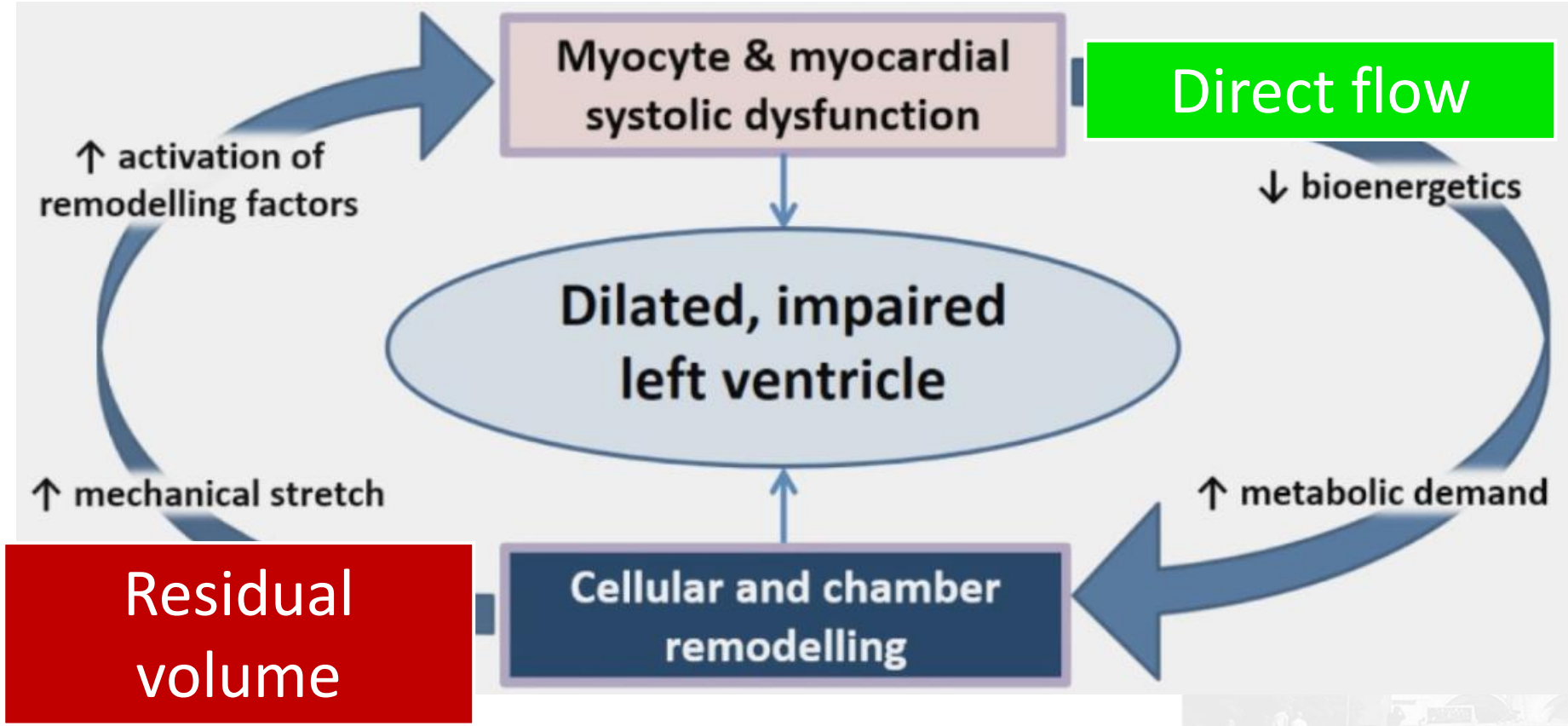
4D Flow Components and Kinetic Energy



ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Imaging Biomarkers in HF

4D Flow Components and Kinetic Energy

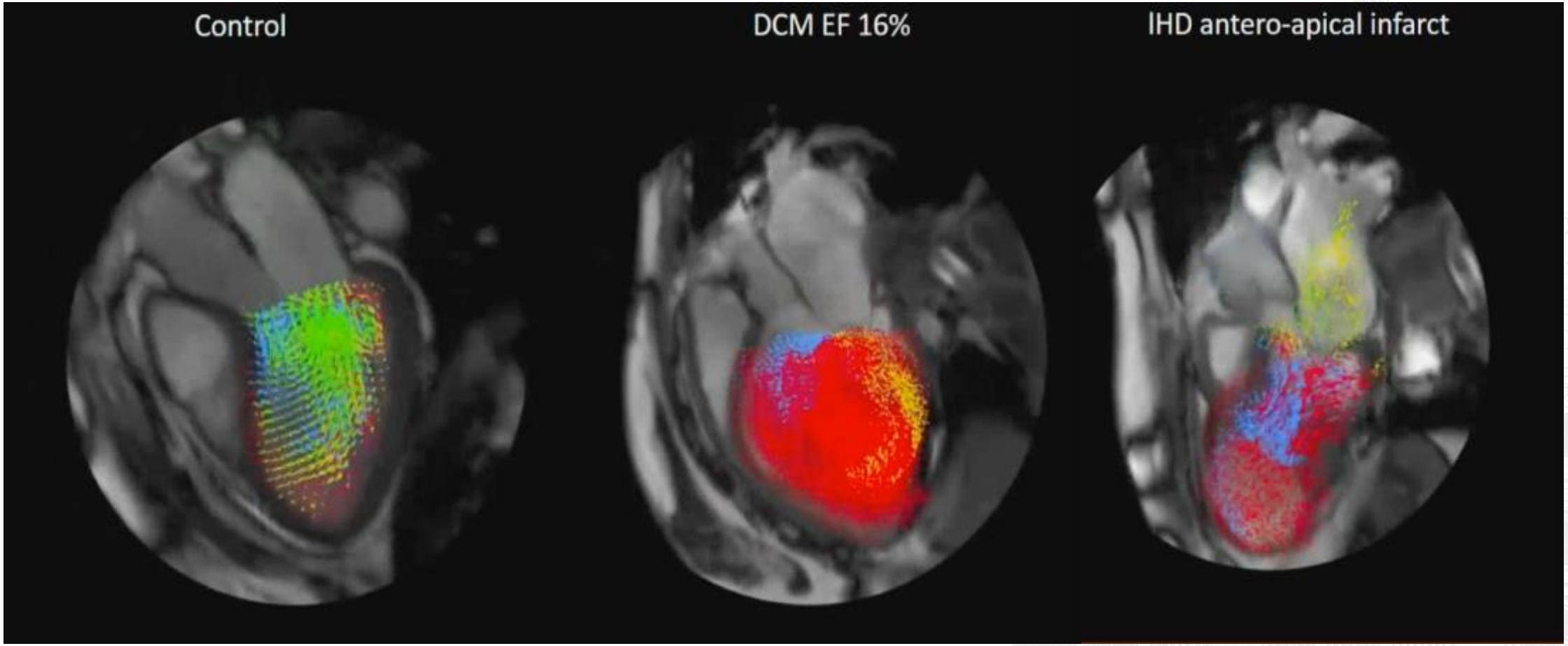


Stoll V et al. European Heart Journal, 2017

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Imaging Biomarkers in HF

4D Flow Components and Kinetic Energy



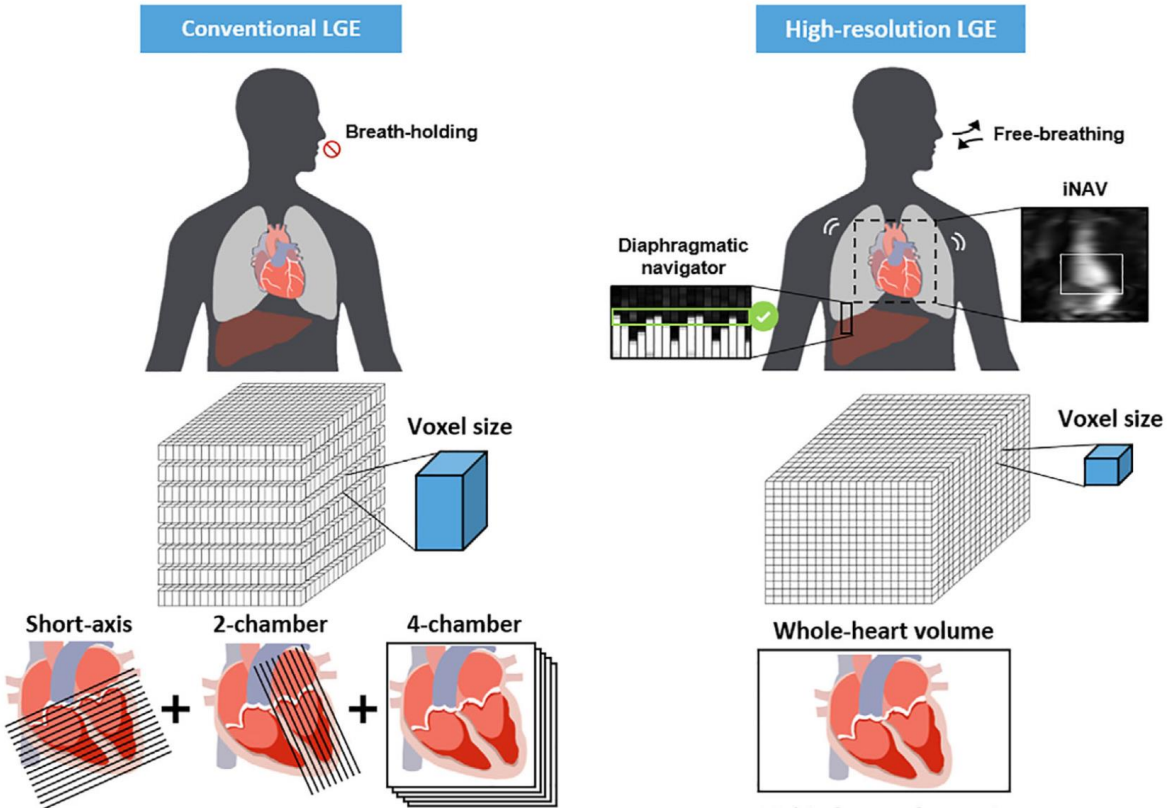
Study in progress for HFpEF…

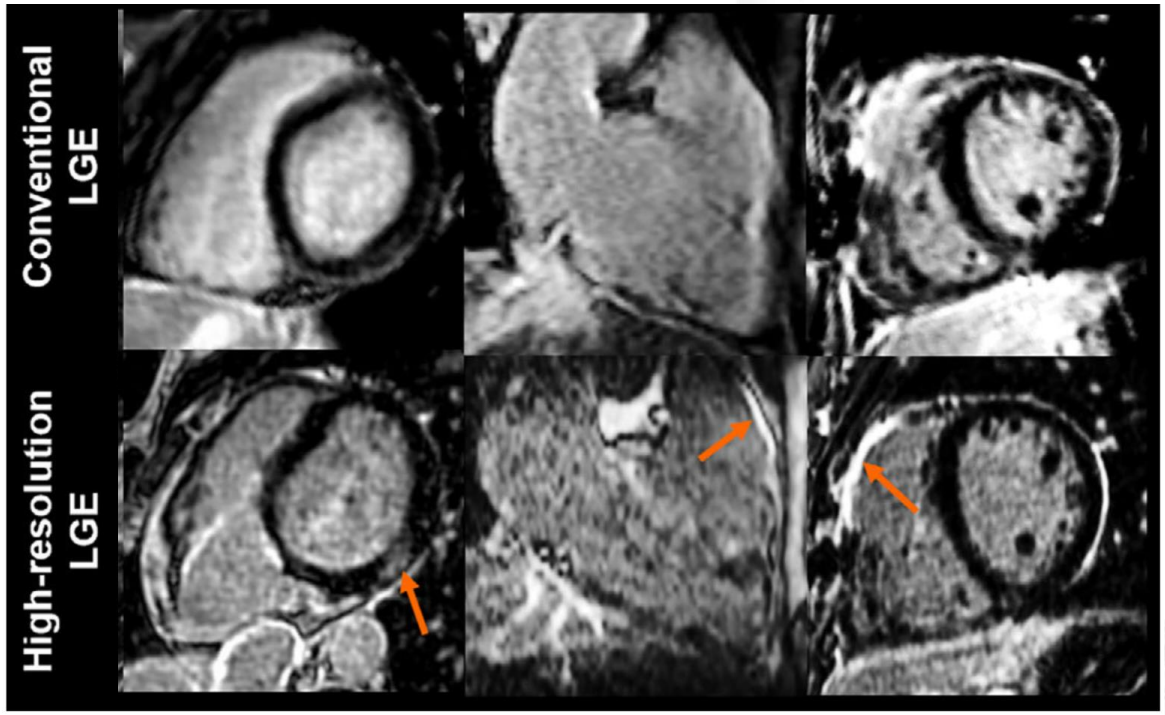
MIRACL.ai

Hôpital Lariboisière
Fernand-Widal
AP-HP

Innovations in CMR

3D High-Resolution LGE sequence





3D-HR LGE: voxel size 1.25 × 1.25 × 2.5 mm

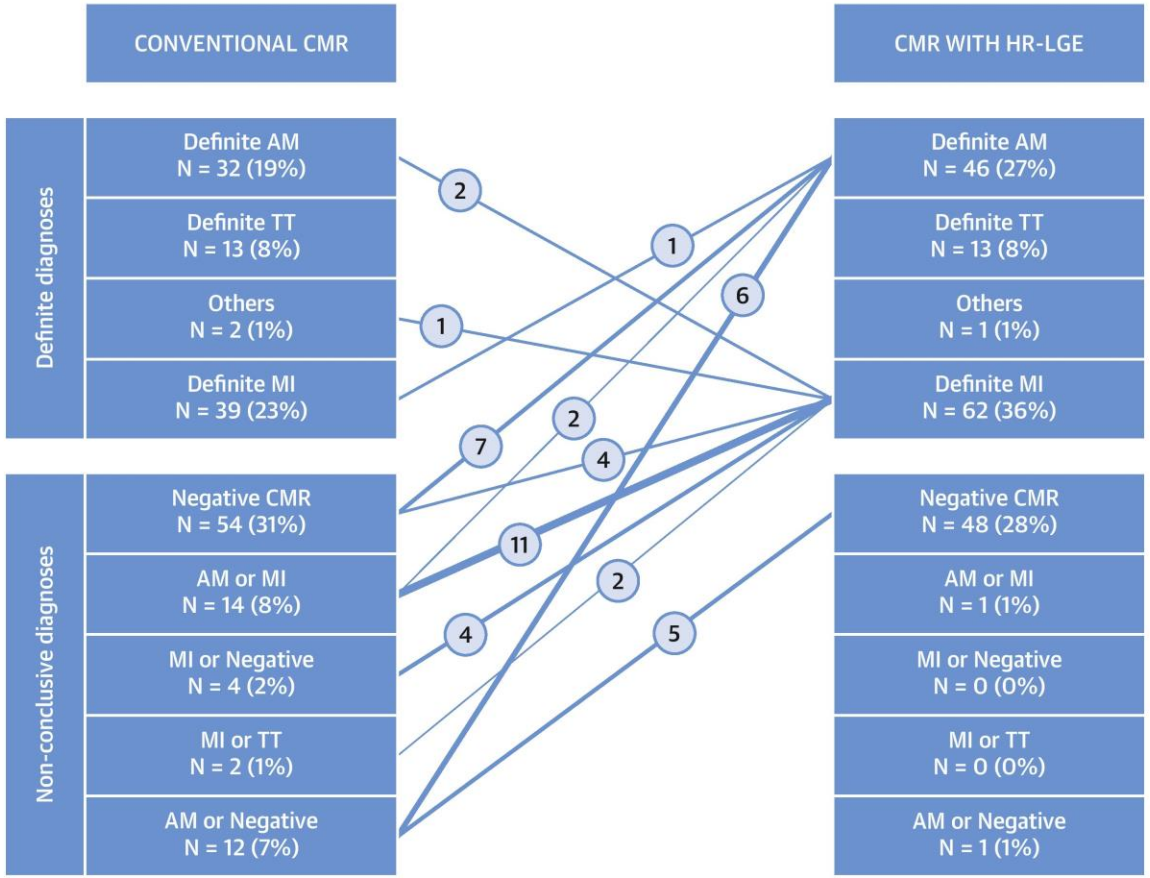
Toupin S, Pezel T, Bustin A, Cochet H. JMRI. 2021

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Innovations in CMR

3D High-Resolution LGE sequence

CENTRAL ILLUSTRATION: Diagnostic Changes Introduced by HR LGE Imaging (172 Patients With Both Conventional CMR and HR LGE Imaging)



Lintingre, P.-F. et al. J Am Coll Cardiol Img. 2020;13(5):1135-48.

- 172 patients with MINOCA
- and negative or inconclusive conventional LGE

Changes in final diagnosis for 26% of patients with MINOCA!

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

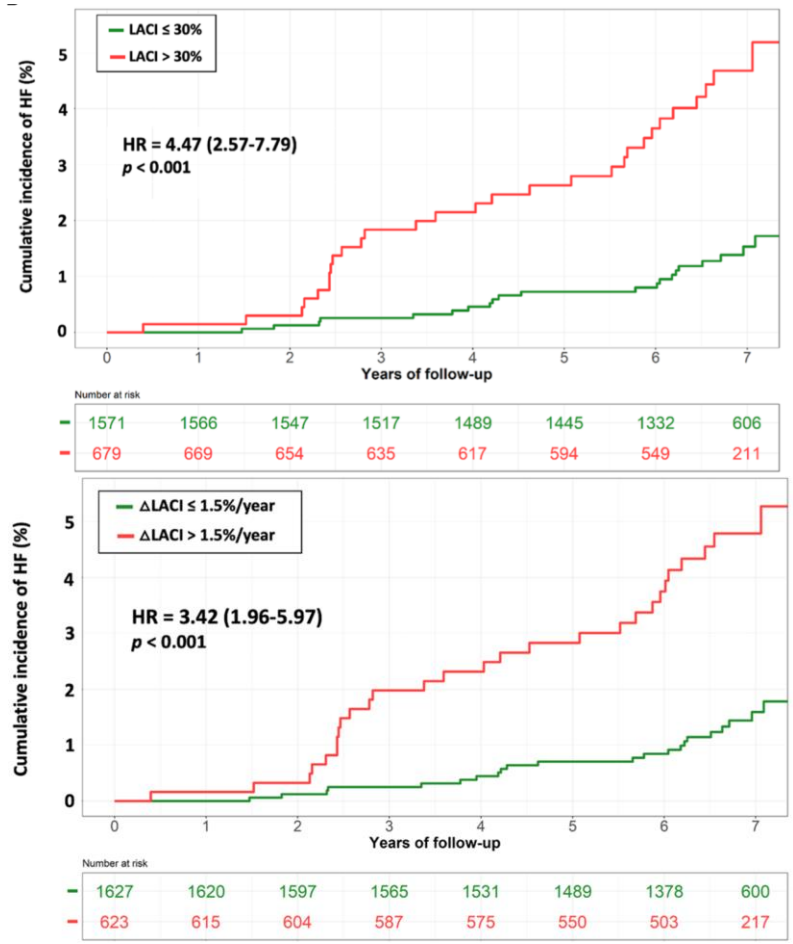
Nouvel index de couplage OG/VG

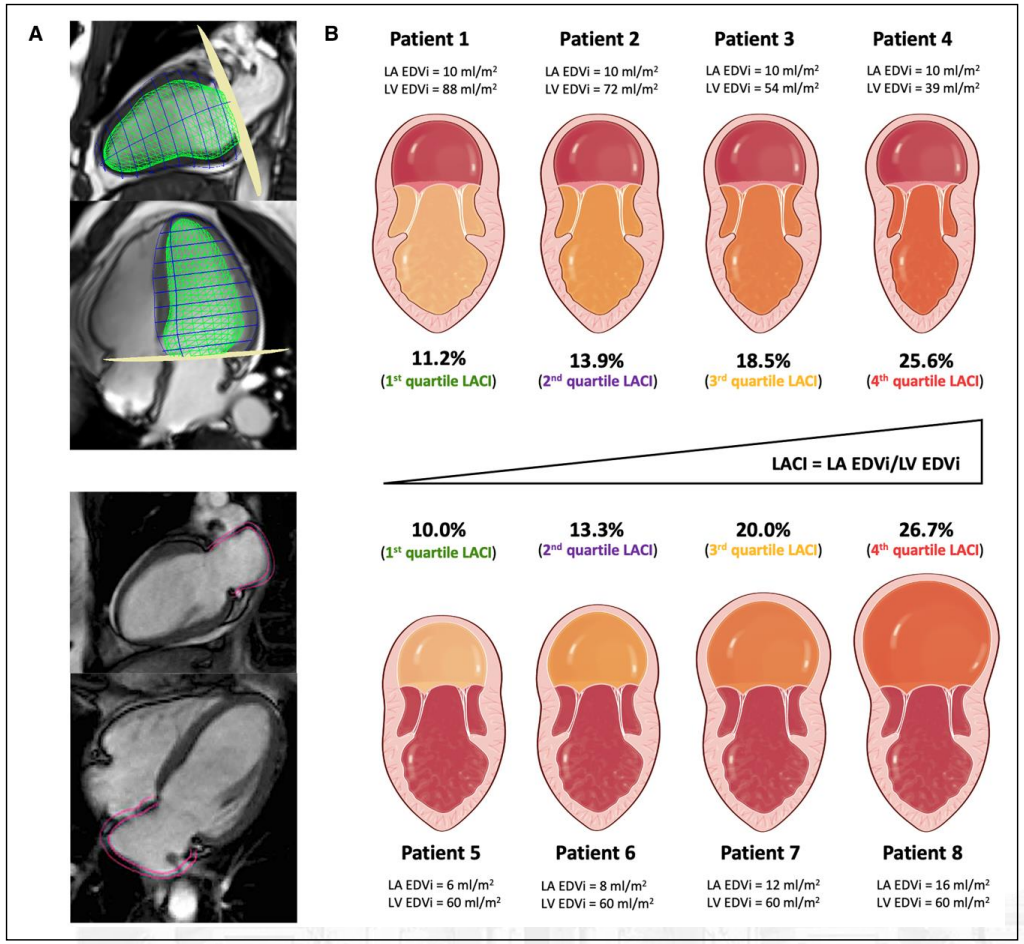
Left atrioventricular coupling index (LACI)

$$\text{LACI} = \frac{\text{Volume TD OG (ml)}}{\text{Volume TD VG (ml)}}$$

Most **powerful prognostic imaging biomarker** to predict the risk of HFpEF

LACI > any LA or LV imaging biomarkers





Pezel T, et al. Hypertension. 2021;78(3):661-671.
Pezel T, et al. Front Cardiovasc Med. 2021;8:704611.
Pezel T, et al. Radiology. 2022;303(2):317–26.
Pezel T, et al. Arch Cardiovasc Dis. 2022;115(8–9):414–25.
Pezel T, et al. Front Cardiovasc Med. 2022 21;9:1066849.
Pezel T, et al. JACC Cardiovasc Imaging. 2023; S1936-878X(23)00112-2.
Pezel T, et al. Diagn Interv Imaging. 2023:S2211-5684(23)00146-8
Pezel T, et al. EHJ CV imaging, 2024, accepted

Hôpital Lariboisière
Fernand-Widal
AP-HP

Inserm

Université
Paris Cité

ASSISTANCE
PUBLIQUE
HÔPITAUX
DE PARIS

MIRACL.ai

Merci pour votre attention !