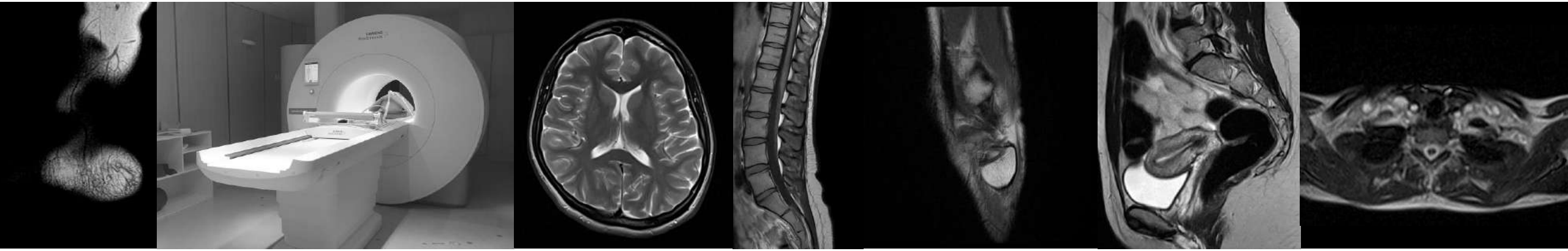
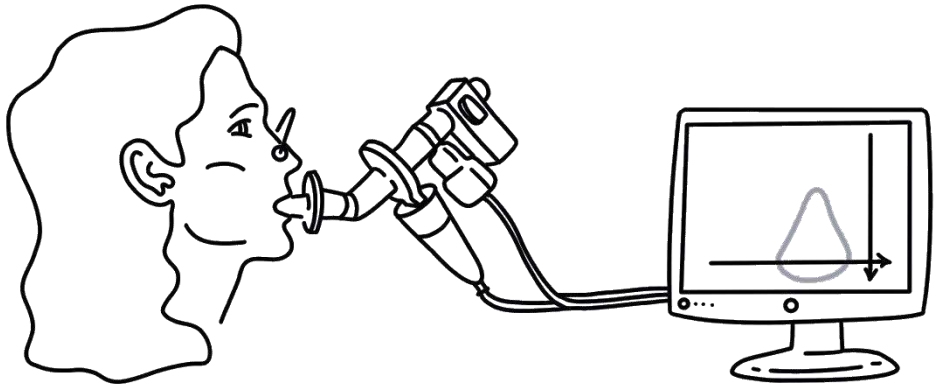
Respirer à plus bas champs

Xavier Maître

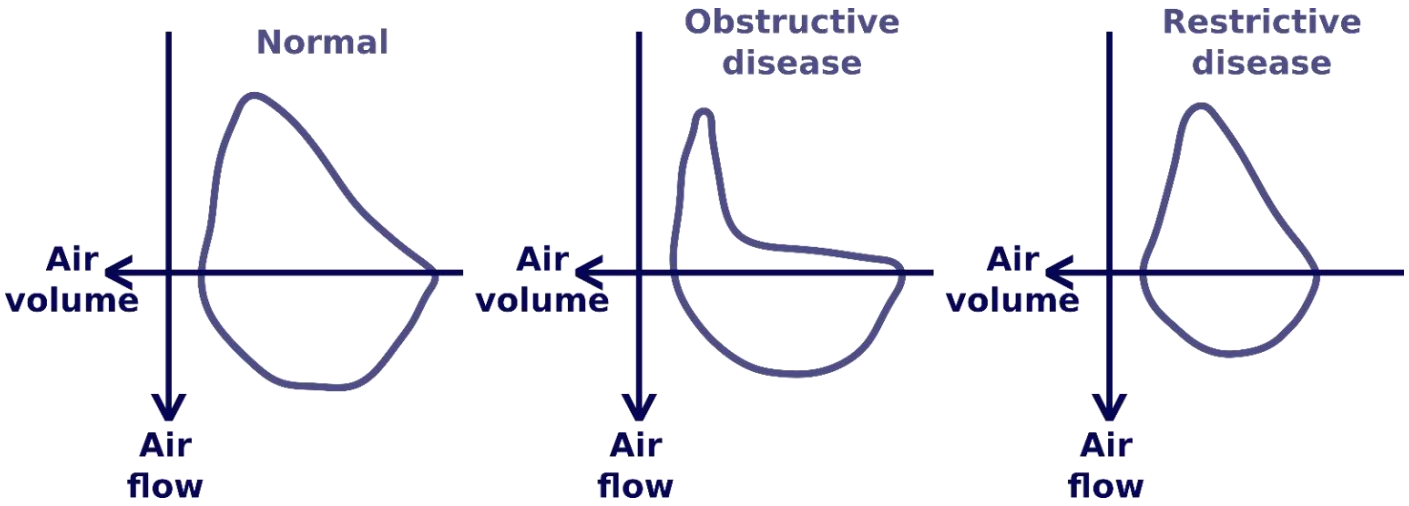


Pulmonary function tests



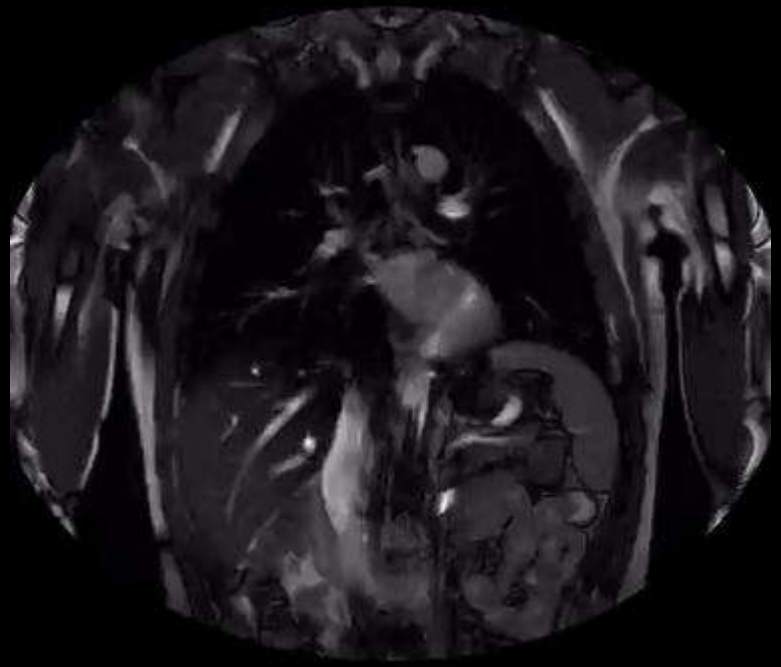
- Forced respiration

→ **Flow-volume curves**
→ **FVC (Force Volume Capacity)**
→ **FEV_1 (Forced Expiratory Volume in 1 s)**

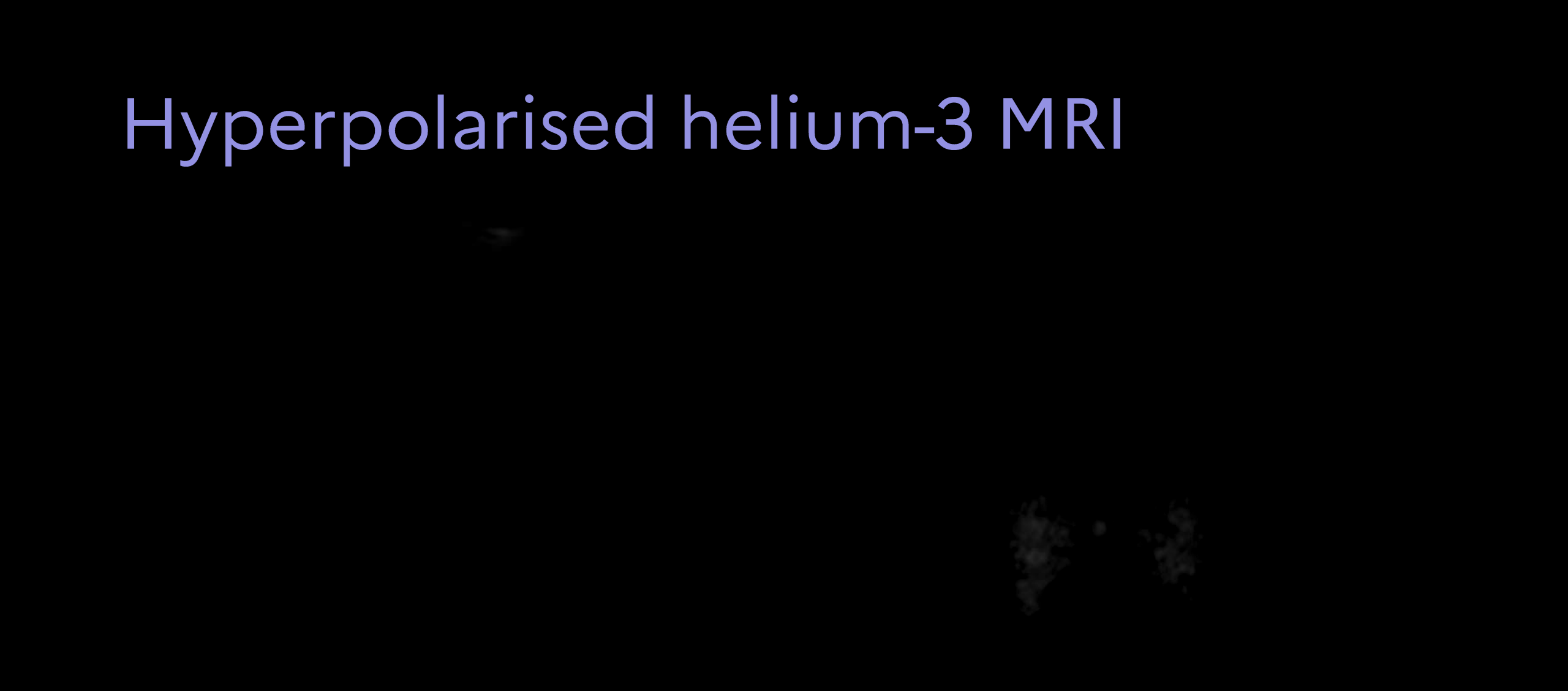


- non-invasive and simple, widely available, robust, repeatable and reproducible
  - Forced respiration
  - Global measurement

Where it all starts



Hyperpolarised helium-3 MRI

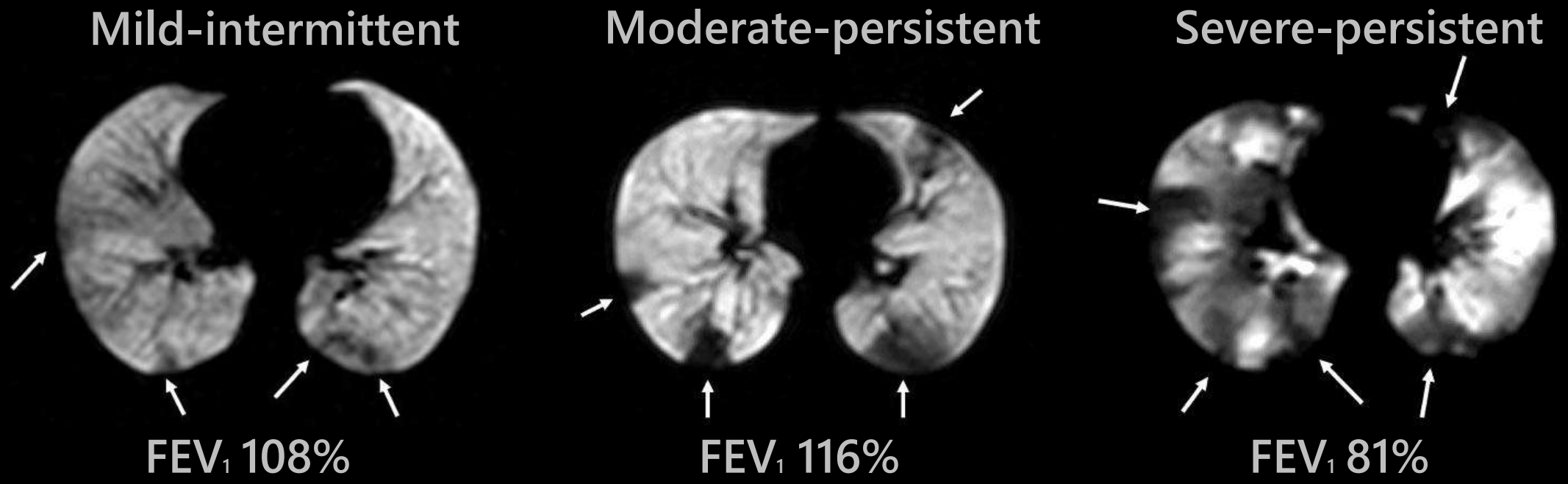


2D dynamic MRI

3D static MRI

Pulmonary disease localization

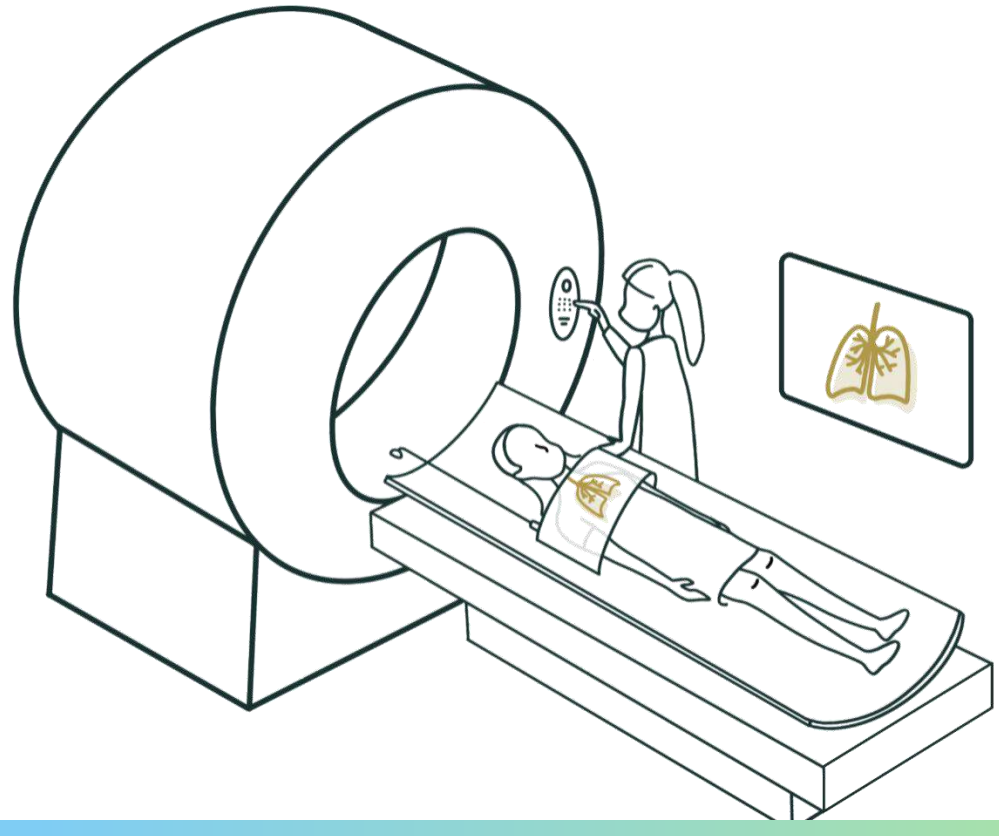
^{3}He MRI in asthma



Lung Function Test

with FEV_1: Forced Expiratory Volume in 1 s

Dynamic lung MRI acquisition



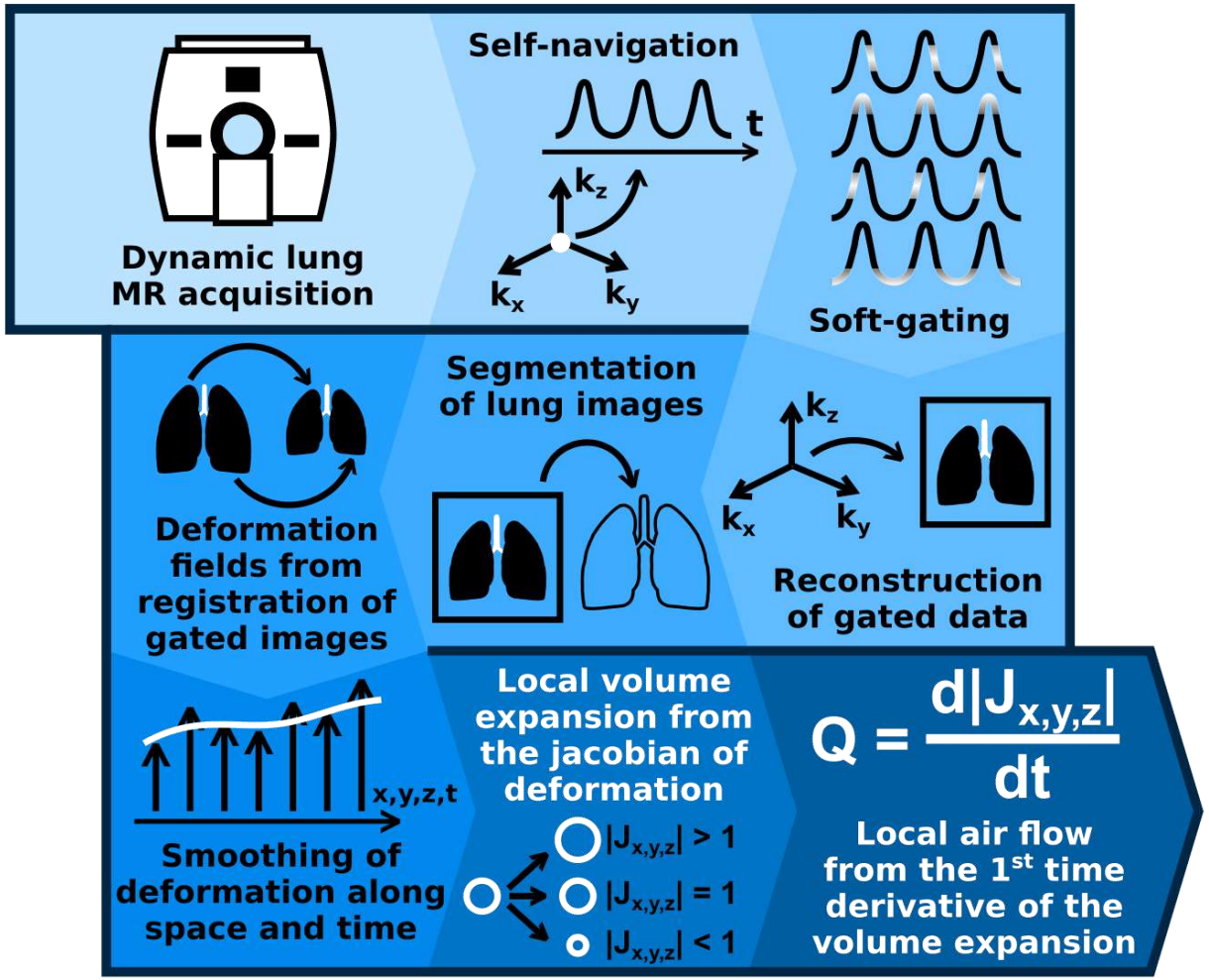
A 10 min MRI acquisition with a 3D UTE pulse sequence

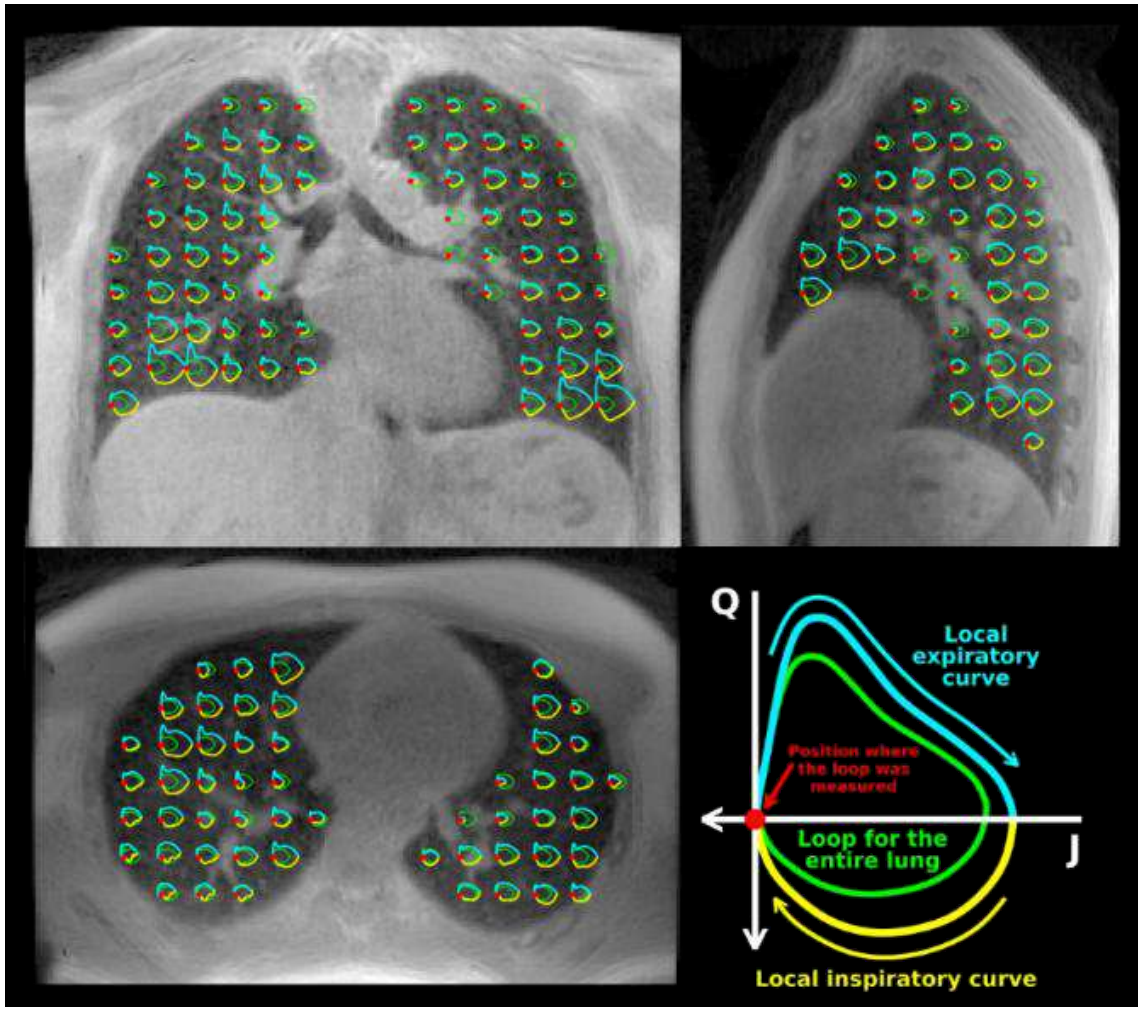
- GE PET-MRI 3 T
- 30-channel thoracic coil
- TE = 12 µs
- TR = 2 ms
- FA = 3°
- Voxel size = 1.5 mm isotropic
- Matrix size = (212 × 212 × 142) voxels
- BW = 100 kHz
- RF spoiling, no gradient spoiling
- AZTEK trajectory
- 320 000 spokes

Dynamic lung MRI

3 cm MIP (maximum intensity projection)

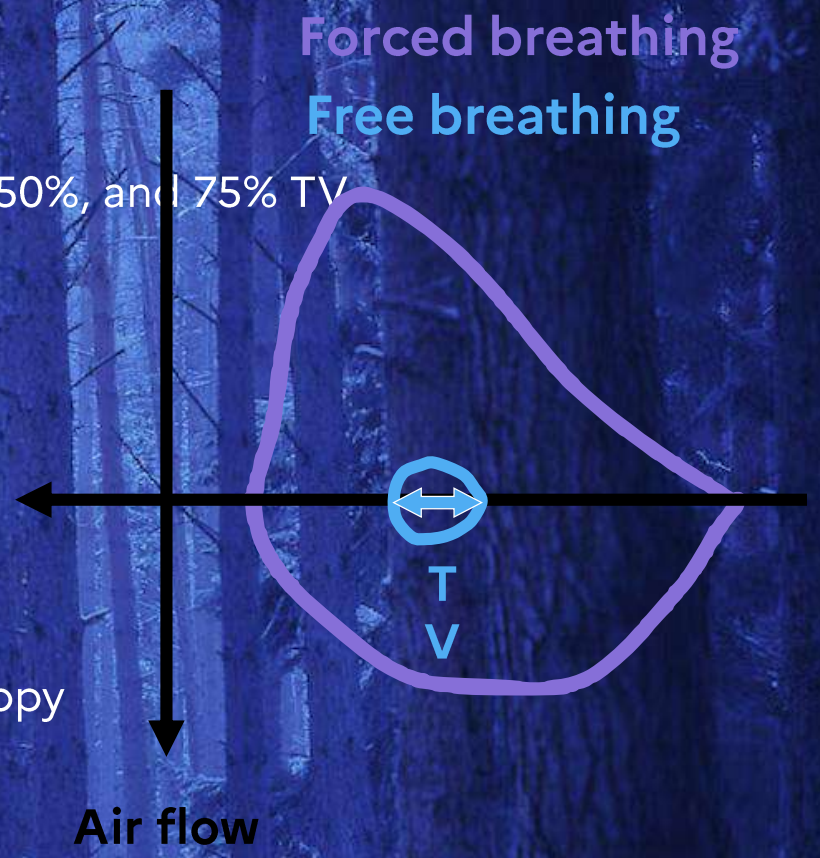
3D MR Spirometry





3D MR Spirometry outcomes

- Functional parameters
  - TV, tidal volume
  - SPEF, spontaneous peak expiratory flow
  - VSPEF, volume at SPEF
  - SEF25, SEF50, SEF75 spontaneous expiratory flow at 25%, 50%, and 75% TV
  - LV_{FRC}, lung volume at functional residual capacity
- Mechanical parameters
  - J, static (TV) and dynamic volume expansions
  - ε_{SI}, ε_{AP}, ε_{LR}, static and dynamic normal strains
  - υ, Poisson ratio
  - $\varepsilon_{SI\text{-}AP}$, $\varepsilon_{AP\text{-}LR}$, $\varepsilon_{LR\text{-}SI}$, static and dynamic shear strains
  - ADI, anisotropic deformation index, FA, fractional anisotropy
- Anatomical trajectories
  - Lengths, areas, ellipticities



- A million measurements within 0.1-1.5 µL

A first clinical research protocol

g-Spiro3D

- Promotion: CEA
- Principal investigator: Vincent Lebon
- Financial support: PE
- 25 healthy volunteers

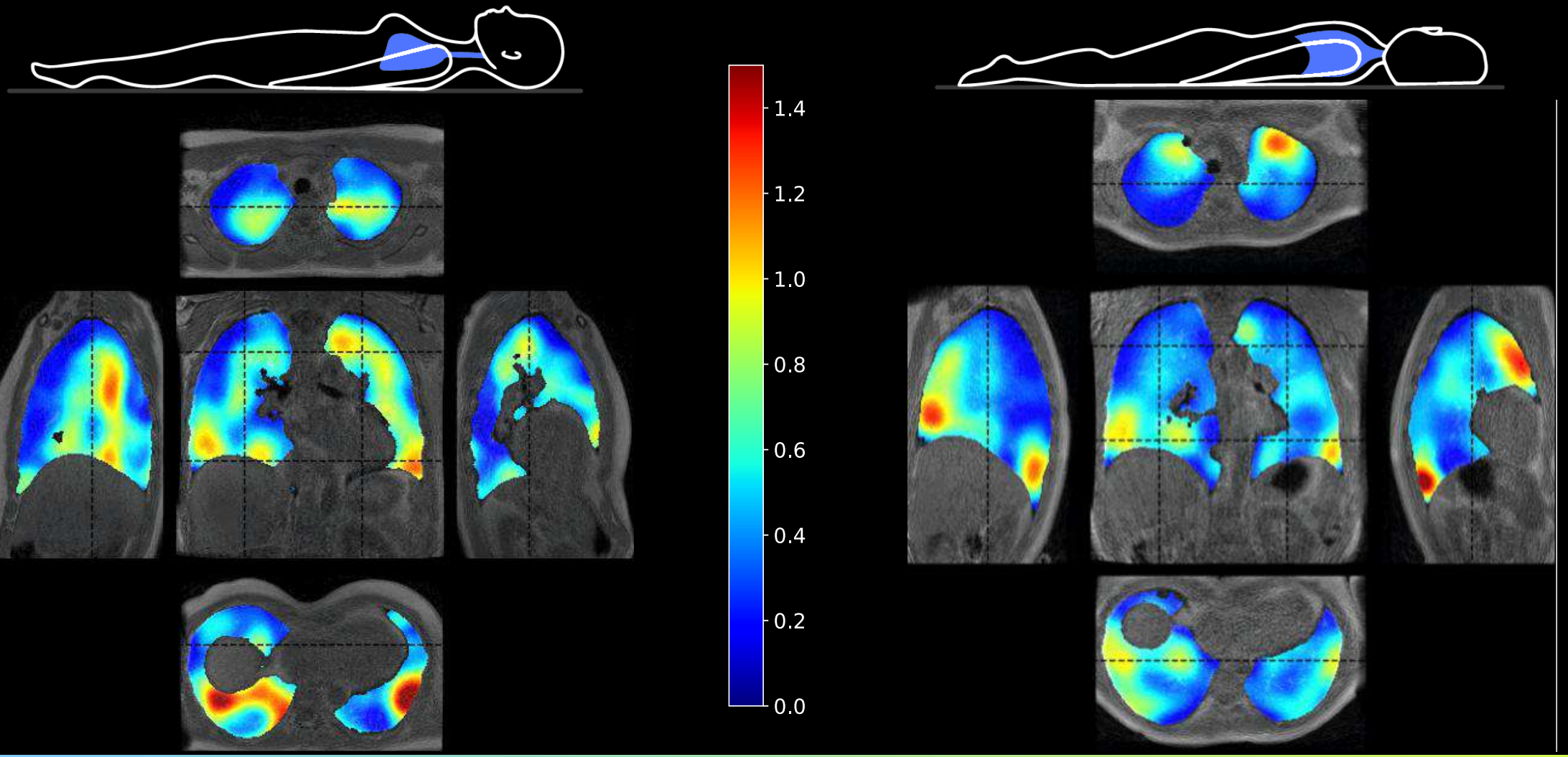
10 Females/15 Males, (45±17) y.o (24±2,9) kg·m^{-2}

MRI acquisition protocol

- 2 × 3D MR spirometry in supine
- 2 × 3D MR spirometry in prone

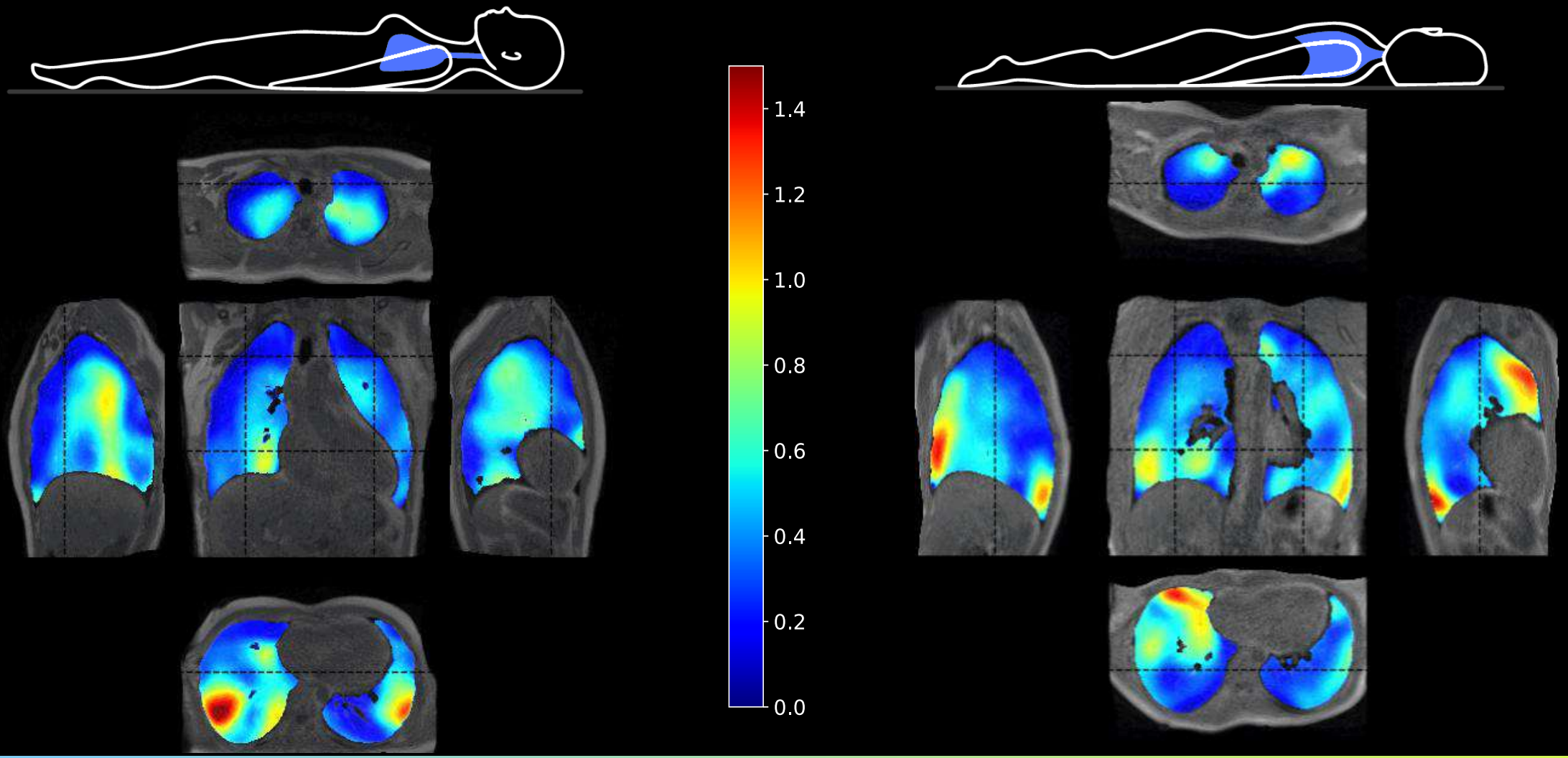
→ Repeatability and sensitivity

Challenging repeatibility



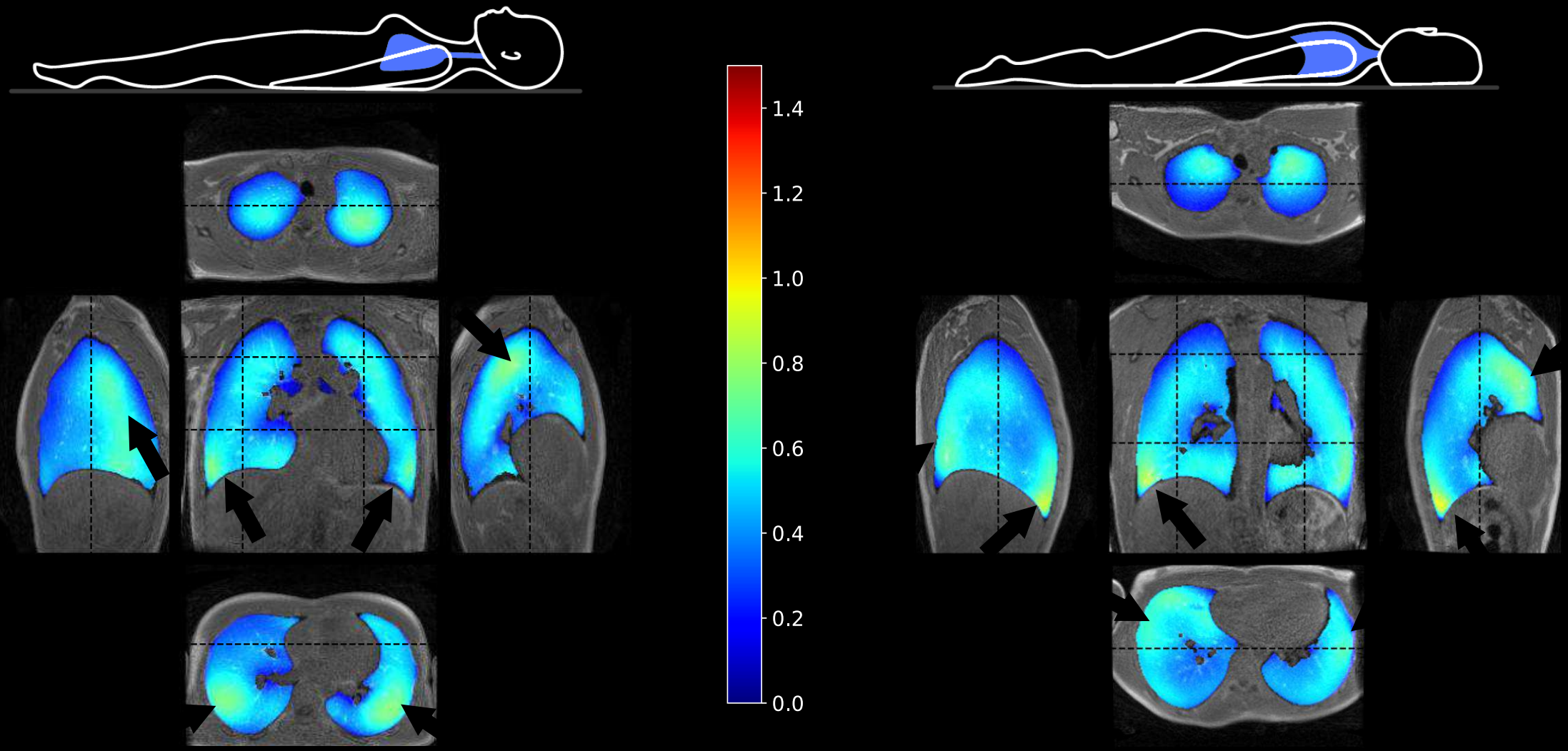
Barrau, N. *et al*. Functional patterns of healthy human respiratory dynamics by 3D MR spirometry. *Eur Radiol* https://doi.org/10.1007/s00330-025-11838-0 (2025)

Nominal functional patterns



Barrau, N. *et al*. Functional patterns of healthy human respiratory dynamics by 3D MR spirometry. *Eur Radiol* https://doi.org/10.1007/s00330-025-11838-0 (2025)

Nominal functional patterns

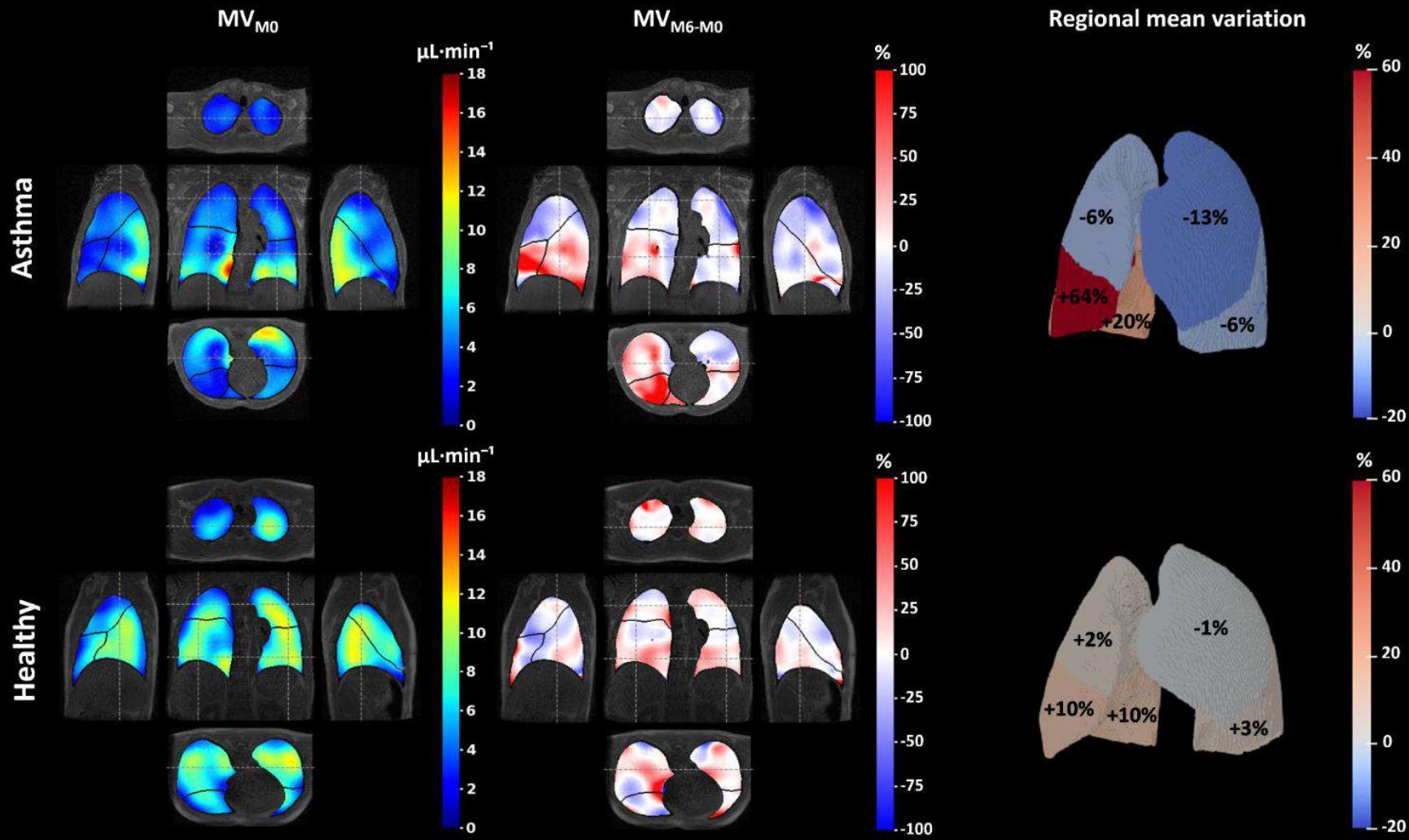


Barrau, N. *et al*. Functional patterns of healthy human respiratory dynamics by 3D MR spirometry. *Eur Radiol* https://doi.org/10.1007/s00330-025-11838-0 (2025)

Severe asthma before and after biotherapy

FEV_1 M0=76%
FEV_1 M6=79%

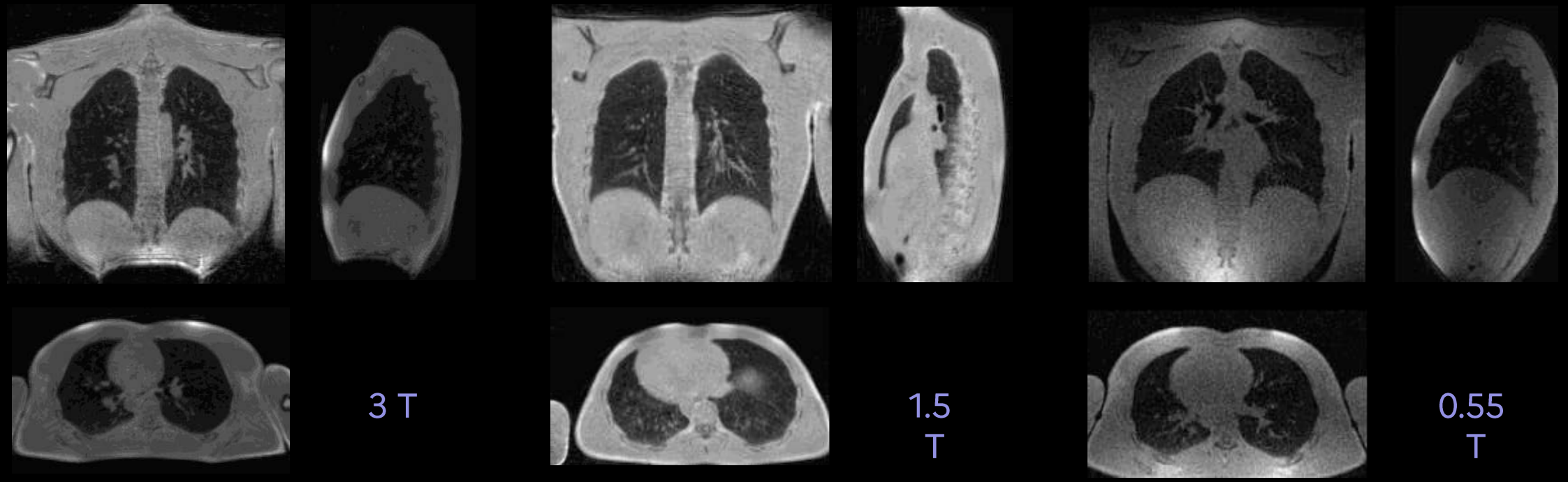
FEV_1 M0=132%
FEV_1 M6=126%



Very|Low-field 3D MR Spirometry

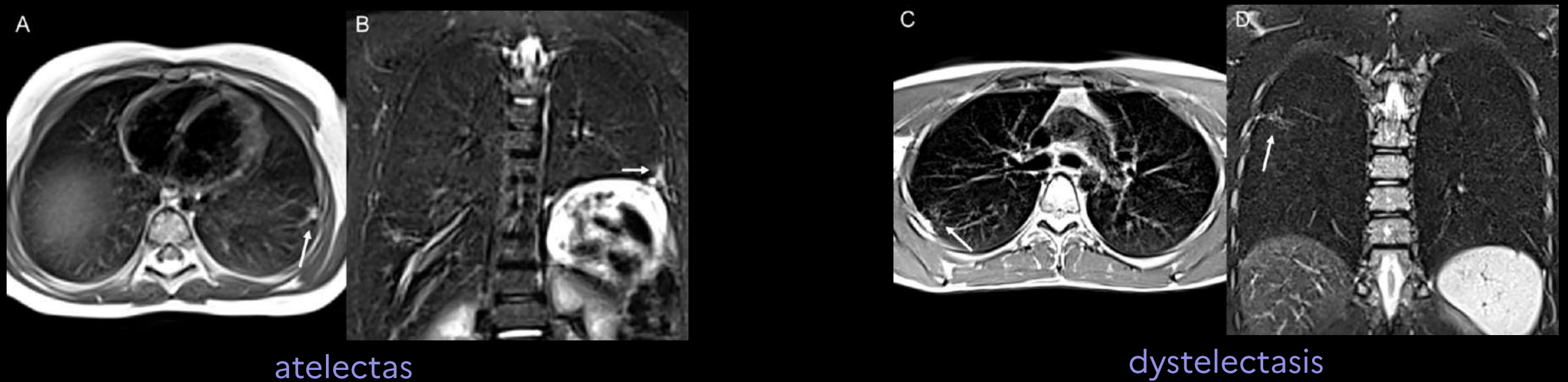
V | LF Spiro3D

3D MR spirometry towards 0.55 T



TE = 50 µs | TR = 3.4 ms | Voxel = (2×2×2) mm^3 | Matrix = (160×160×150) | T_{acq}=11 min

Proton density and T2-weighted at 0.55 T



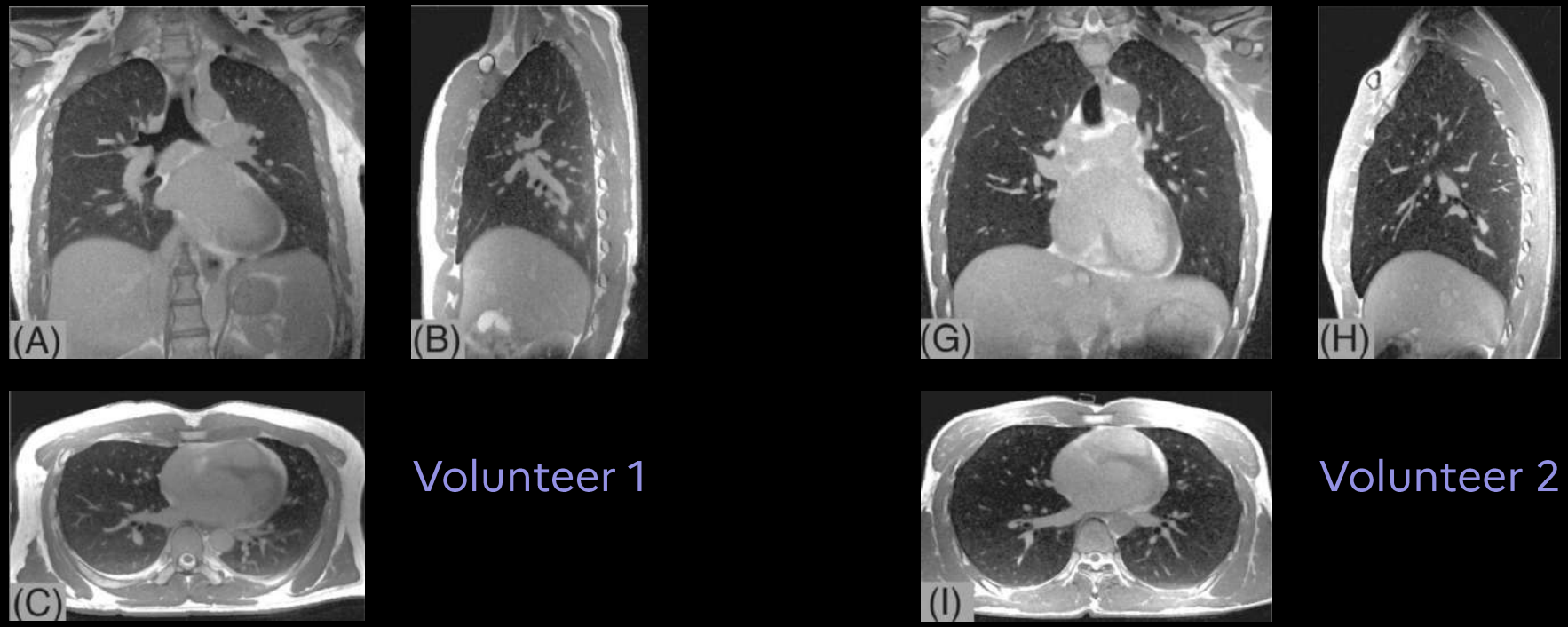
atelectasis

dystelectasis

PROPELLER

TE = 35-80 ms | TR = 2 000 ms | Voxel = (1.3×1.3) mm^3 | Matrix = (304×272) | Slice = 6 mm

Balanced steady-state free precession (bSTAR) at 0.55 T

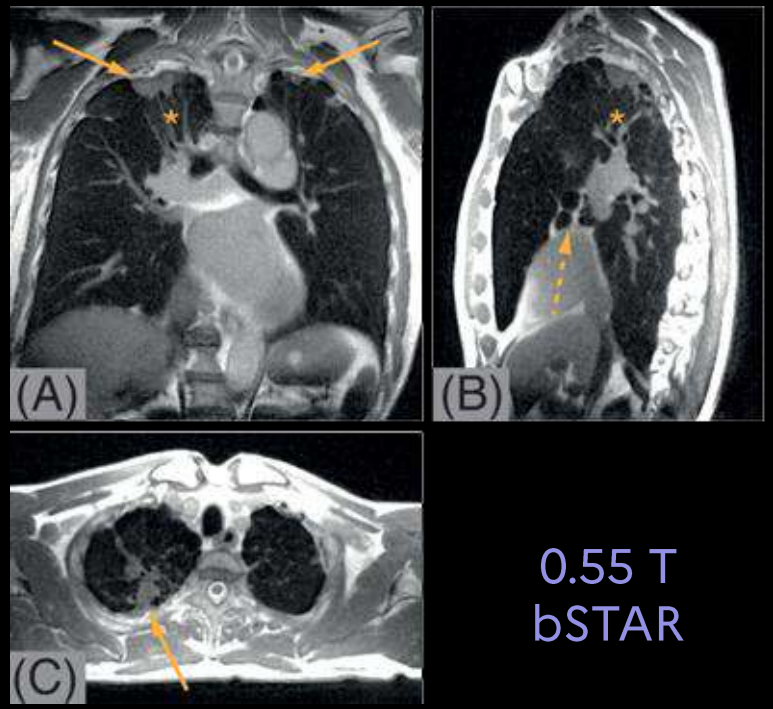


Volunteer 1

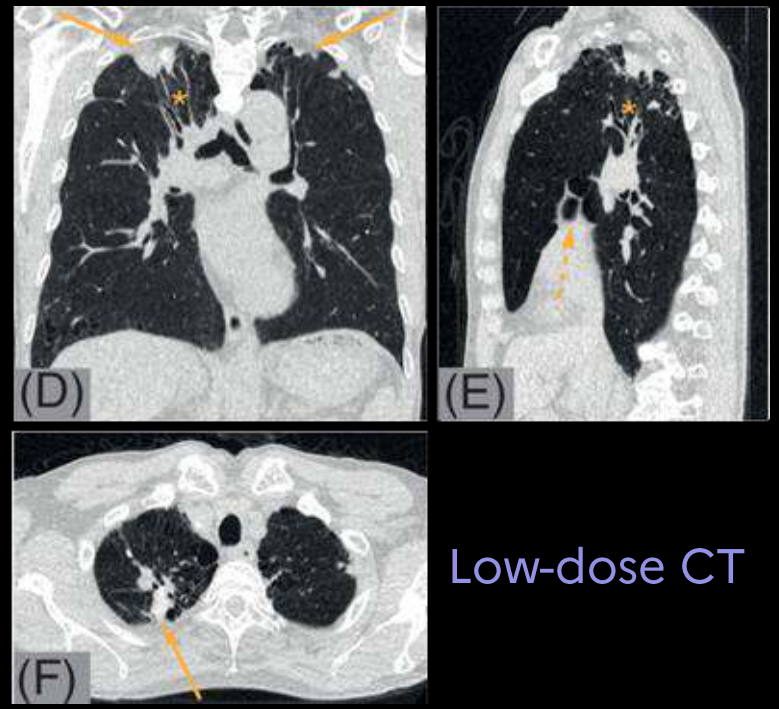
Volunteer 2

TE = 0.13-1.93 ms | TR = 2.14 ms | Voxel = (0.9×0.9×0.9) mm^3 | Matrix = (512×512×512) | Tacq=12 min 50

Low-field bSTAR vs low-dose CT



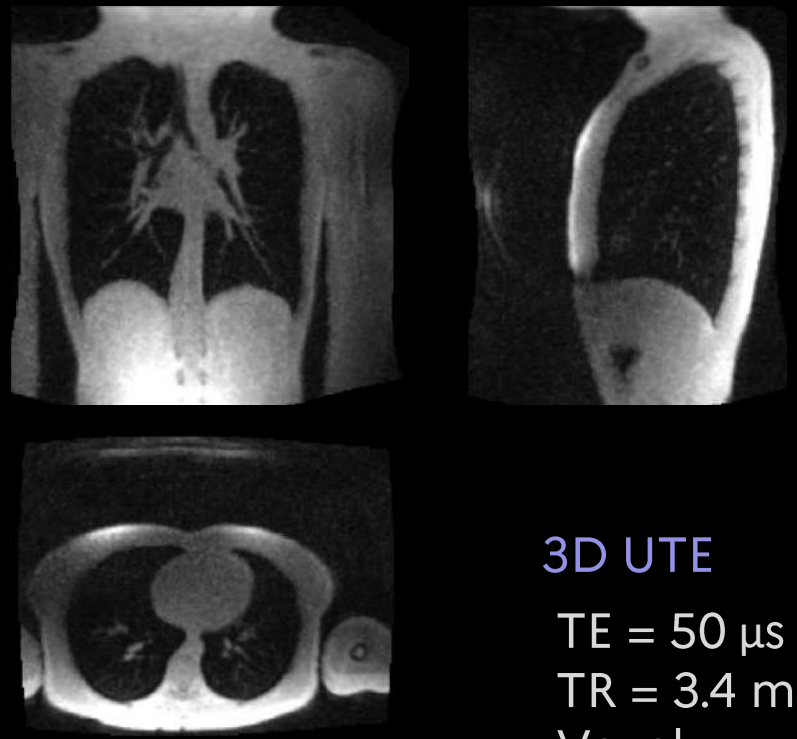
0.55 T
bSTAR



Low-dose CT

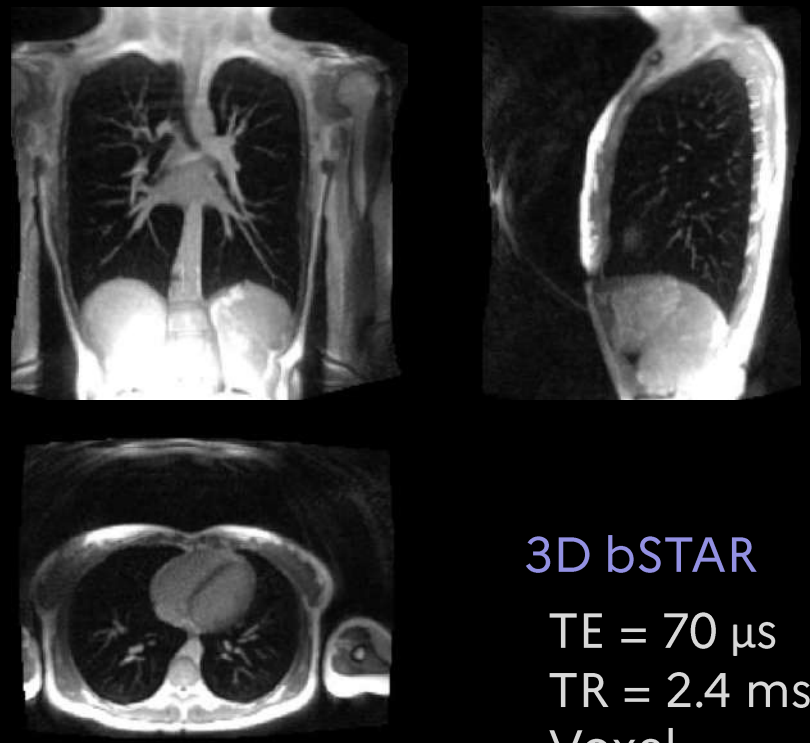
Bauman *et al*. Submillimeter lung MRI at 0.55 T using bSSFP with half-radial dual-echo readout (bSTAR). *Magnetic Resonance in Medicine* **90**, 1949–1957 (2023).

From 3DUTE to 3D bSTAR at 0.55 T



3D UTE

TE = 50 µs
TR = 3.4 ms
Voxel =
(2×2×2) mm^3
T_{acq}=40 s



3D bSTAR

TE = 70 µs
TR = 2.4 ms
Voxel =
(2×2×2) mm^3
T_{acq}=40 s

Lower-field breathing

BioMaps
LABORATOIRE D'IMAGERIE BIOMÉDICALE

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Tolga Emre (Msc)
Ithar Gharmaoui (PhD)
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Antoine Loquet (Msc)
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Angéline Nemeth
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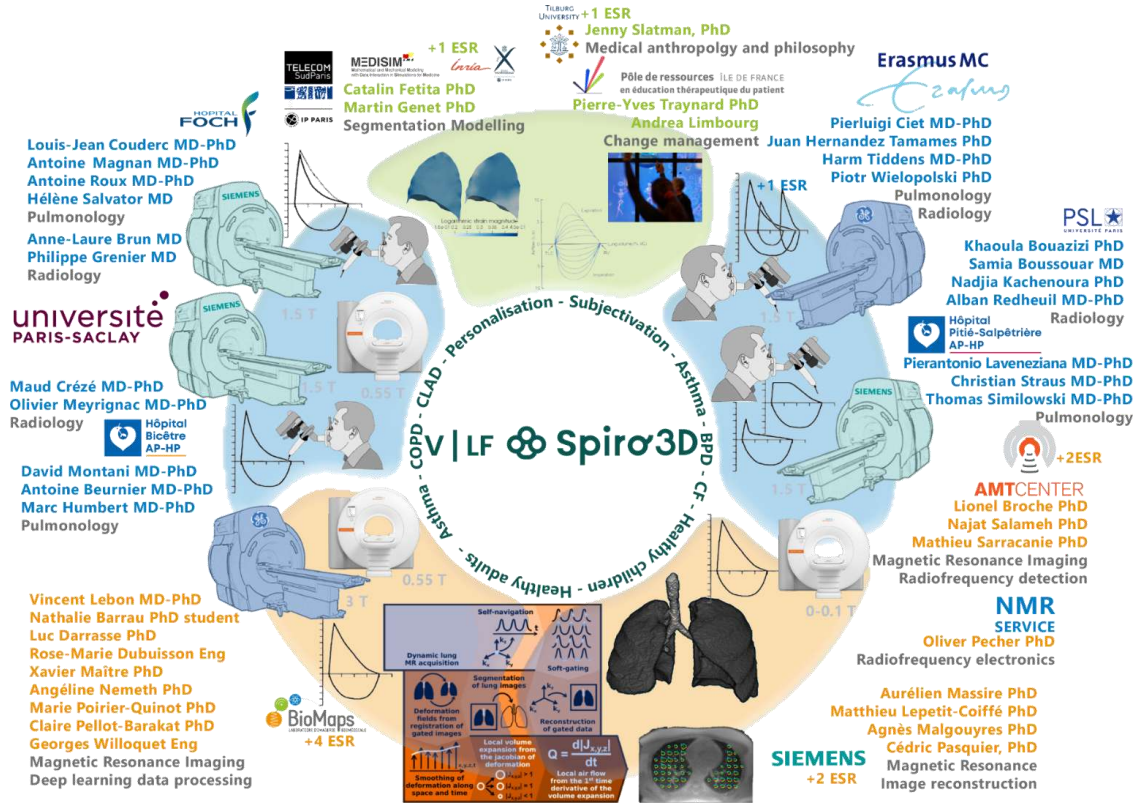
Anna Reitmann (Msc)
Dima Rodriguez
Killian Sambourg (Msc)
Georges Willoquet



TE = 2 ms| TR = 15 ms | Voxel = (3.8×3.8×3.8) mm^3 | T_{acq}=15-30 min

PASREL