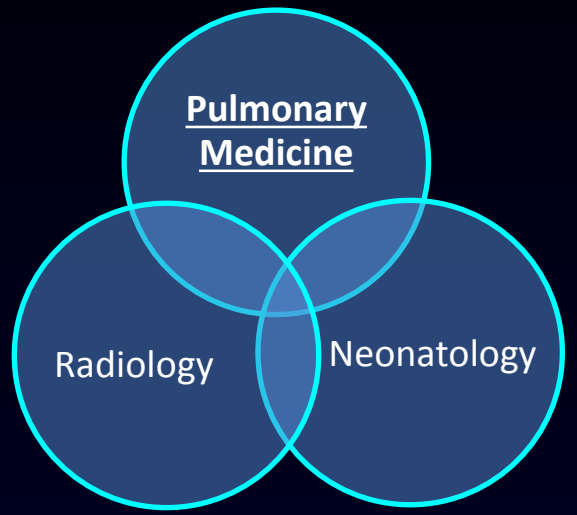
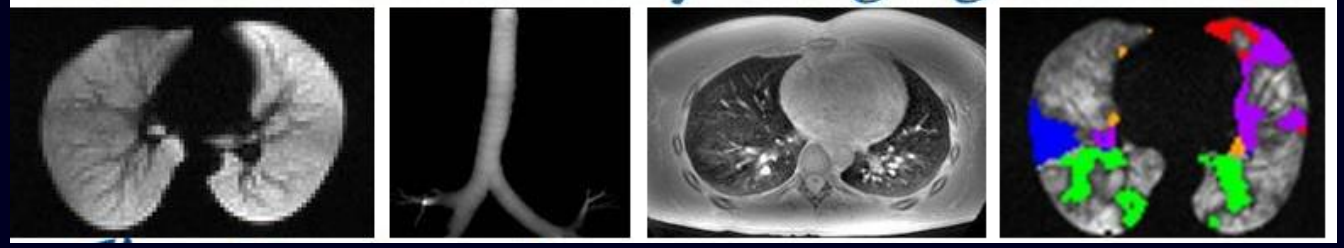
Advanced MR Imaging for Lung Diseases

Jason C. Woods



Cincinnati Children's™
changing the outcome together

Center for Pulmonary Imaging Research



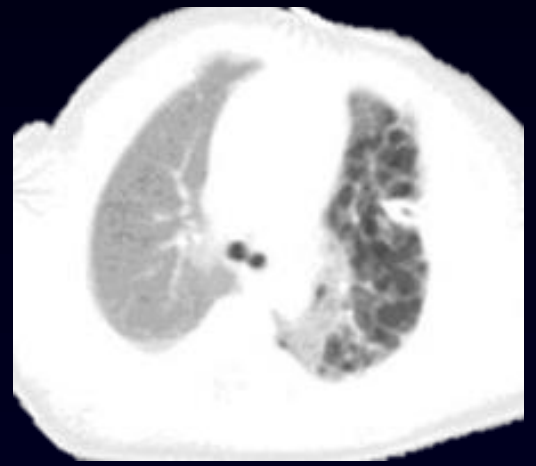
CPIR

Lung is most challenging solid organ to image

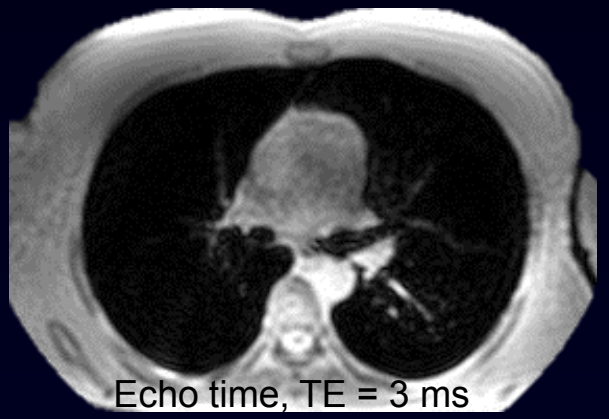
1. Large and moves with respiration (motion artifacts)
2. Low density (ρ = 0.2 g/cm^3 at TLC)
3. Multiple air-tissue interfaces (alveoli) cause fast MRI decay of signal

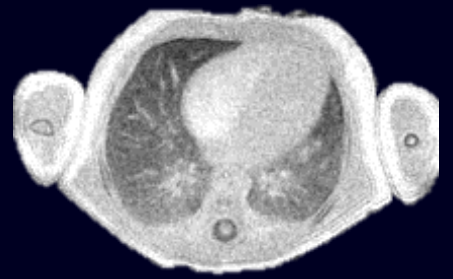
X-ray (not tomographic)

X-ray CT (fairly high ionizing radiation)



MRI (no radiation, but historically bad for parenchyma)





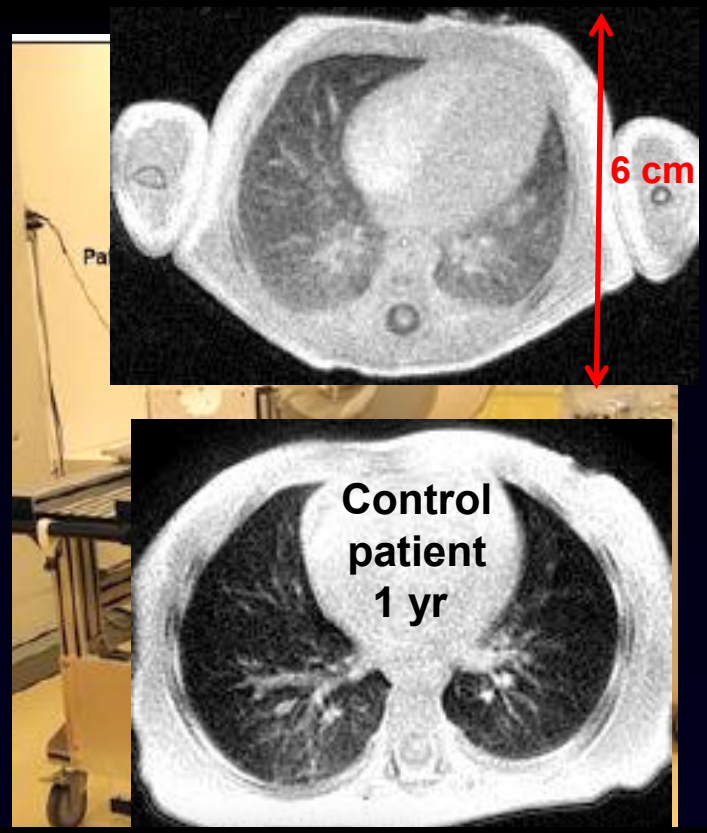
neonate

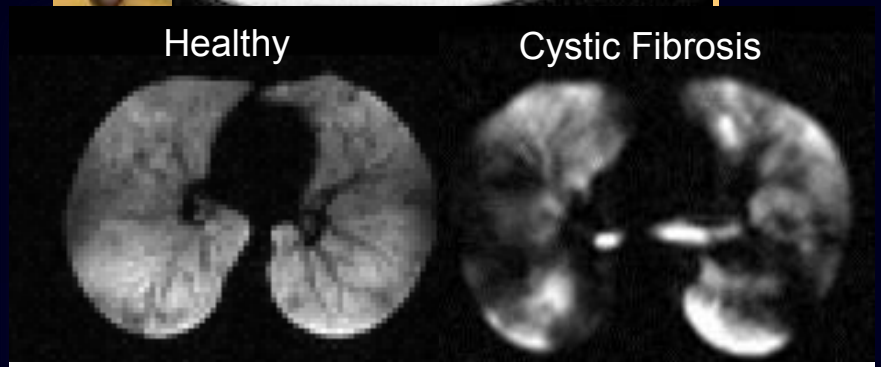
Challenges have caused innovation

1. UTE MRI sequences (echo time < 0.2 ms)
   - Early CF Lung disease
   - Neonates in NICU (with “self”-respiratory gating)

2. A scaled-down, neonatal MRI scanner
   - 1.5T ONI / GE hybrid

3. Hyperpolarized-gas MRI (^{3}He or ^{129}Xe)
   - Realtime ventilation (breath hold for 10-15 s)
   - Measure of alveolar-airspace size
   - Measures of gas exchange





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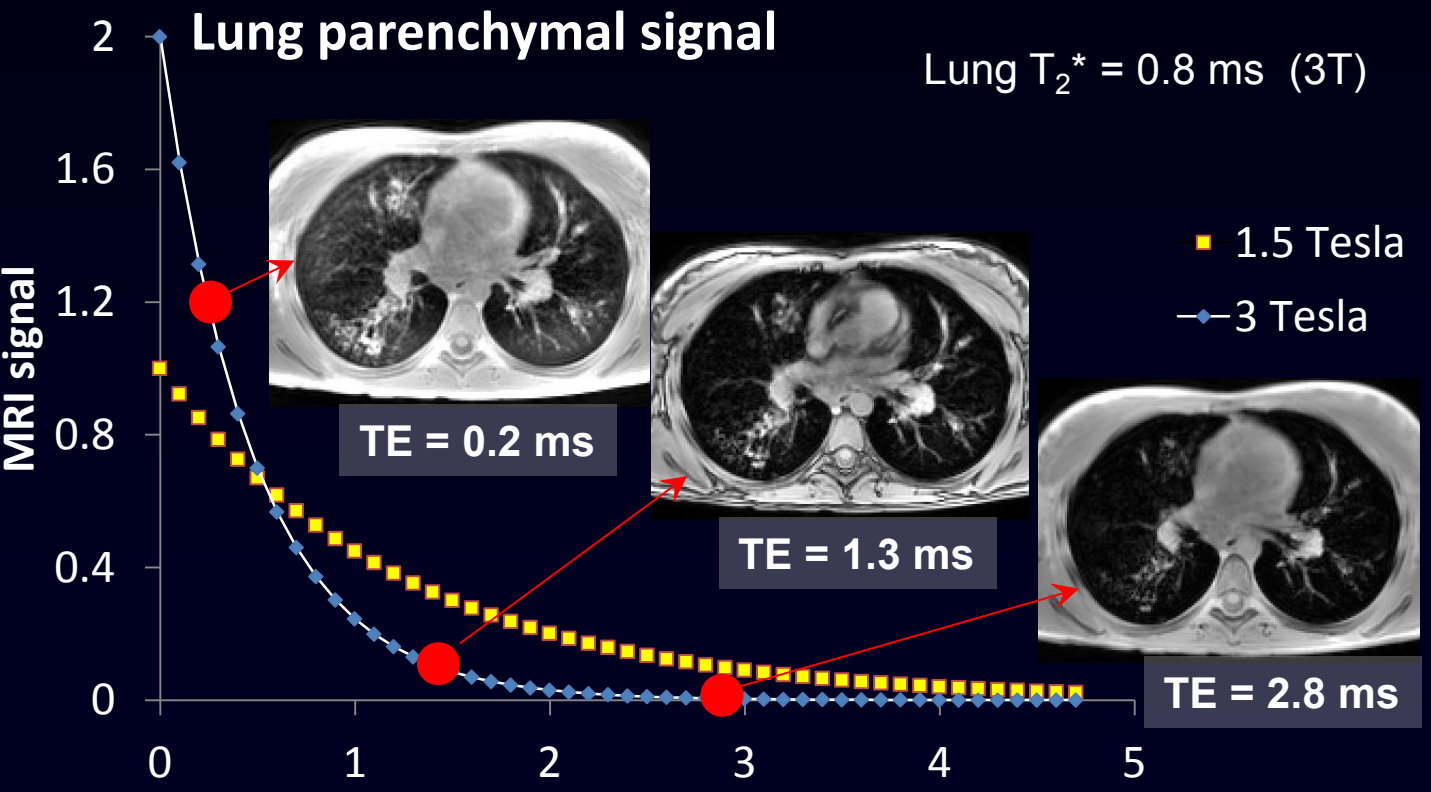
UTE and Hyperpolarized-gas MRI:

Sensitive, regional measures of structure & function

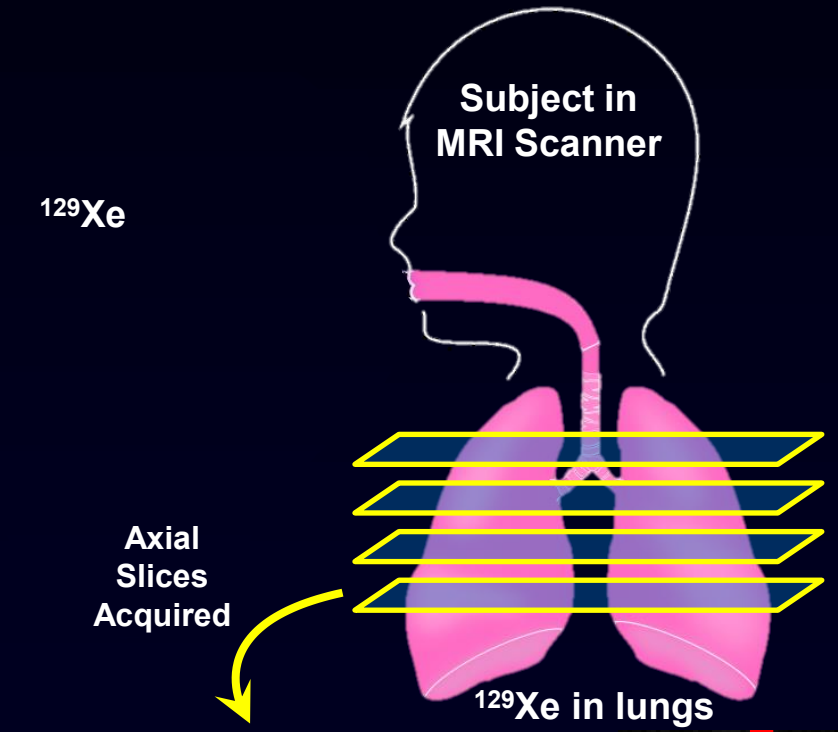
Structure via UTE MRI

Lung parenchymal signal decays quickly with time:



Function (ventilation): ^{129}Xe MRI

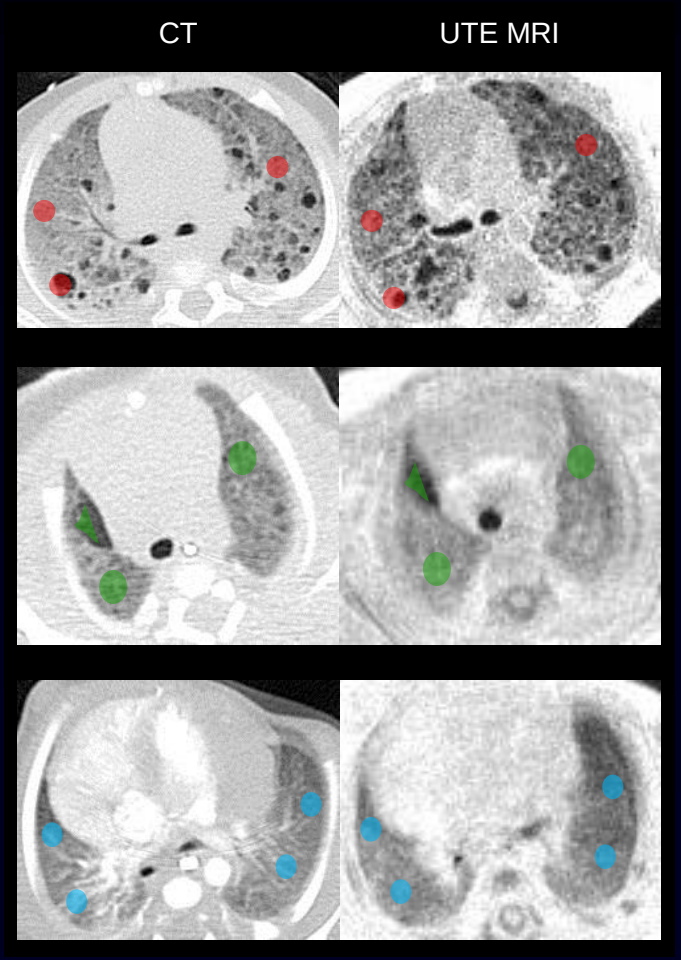
Gas with strong magnetic signal

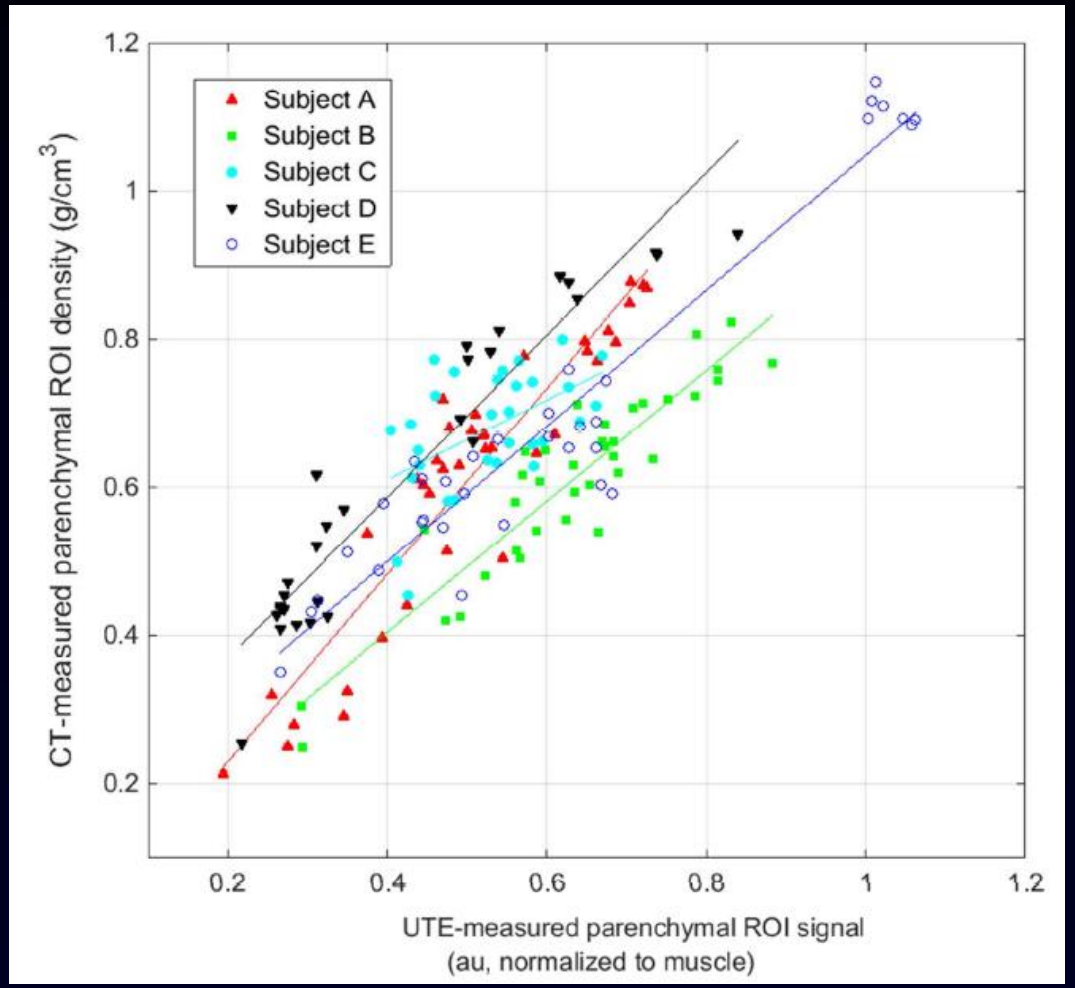


1. Thomen *et al. J Cyst Fibros.* 2016
2. Walkup *et al. Pediatr Radiol.* 2016

Density quantification via MRI is now possible

(validation by CT)





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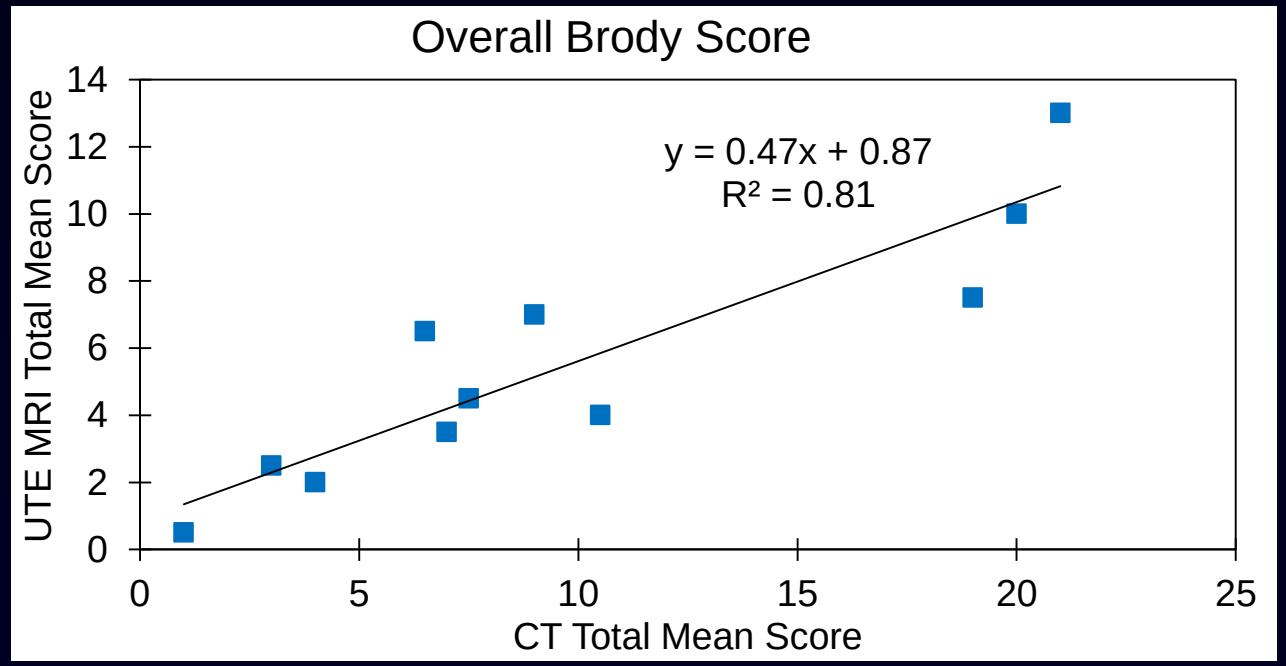
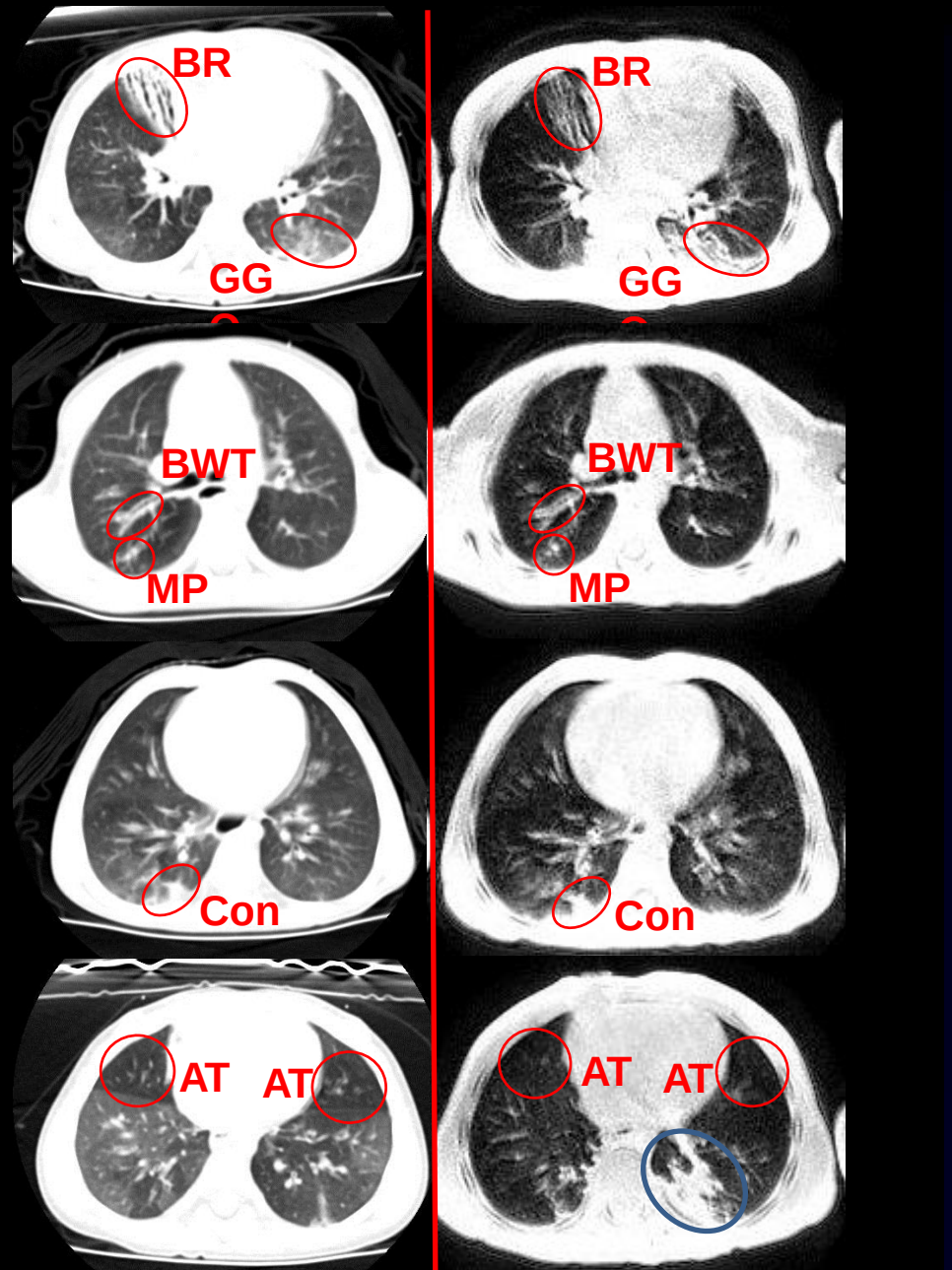
NS Higano, et al., *J Magn Reson Imag* 2017 (in press) doi 10.1002/jmri.25643

JM Stein, et al., *Pediatric Radiology* 2016; 46: 1804

Can UTE MRI quantify abnormalities like CT?: 1-3 y.o.

- Score both MRI and CT via Brody Score
- Lung Abnormalities
  - Bronchiectasis (**BR**)
  - Ground glass opacity (**GGO**)
  - Bronchial wall thickening (**BWT**)
  - Mucus Plugging (**MP**)
  - Consolidation (**Con**)
  - Air trapping (**AT**)

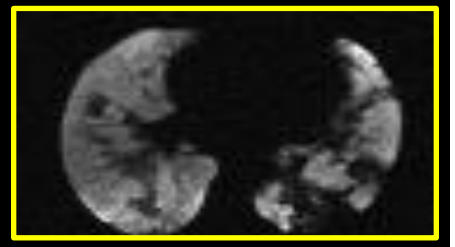


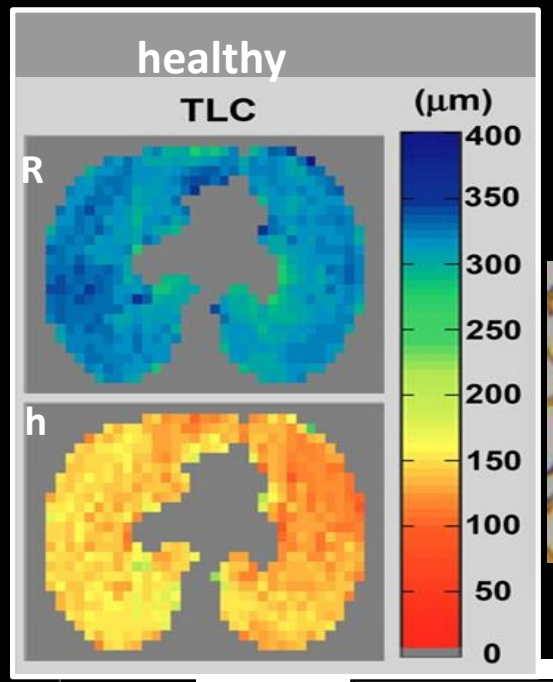


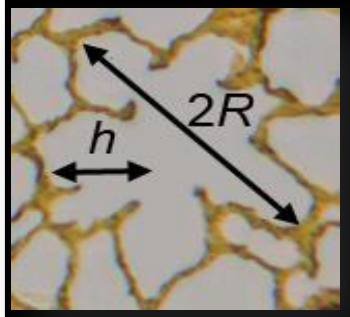
Techniques with hyperpolarized ^{129}Xe

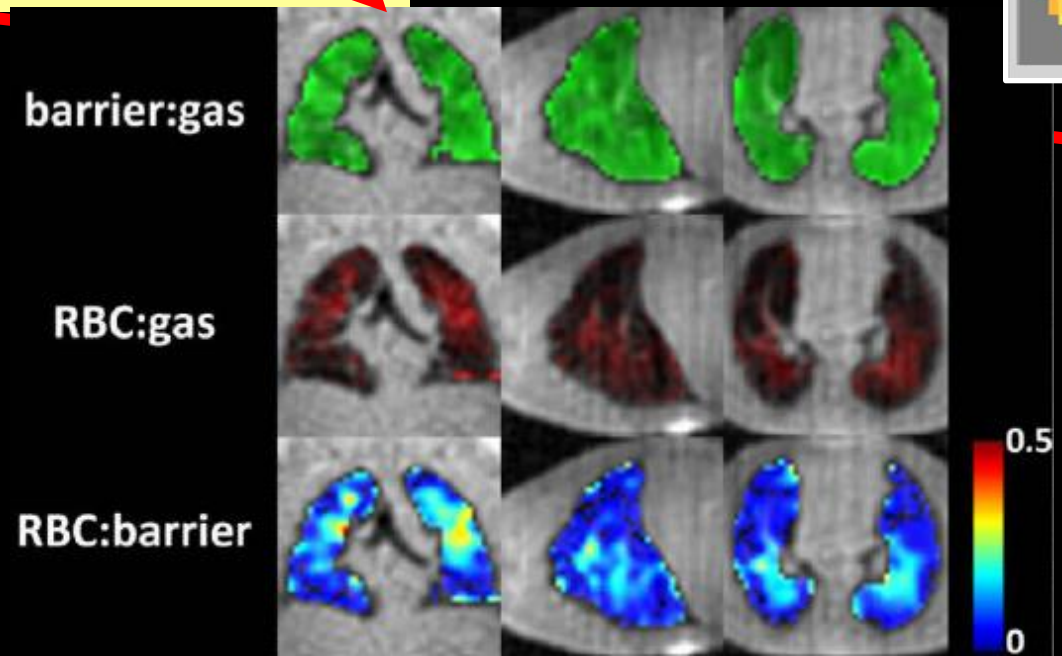
Hyperpolarized ^{129}Xe

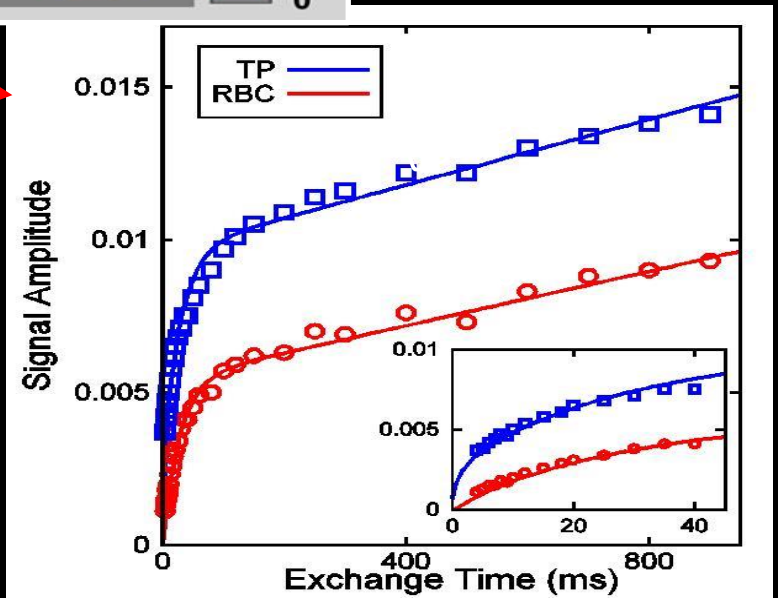
- Ventilation (spin density of ^{129}Xe)
- Restricted diffusion for acinar microstructure
- ^{129}Xe dissolved-phase time dynamics & images





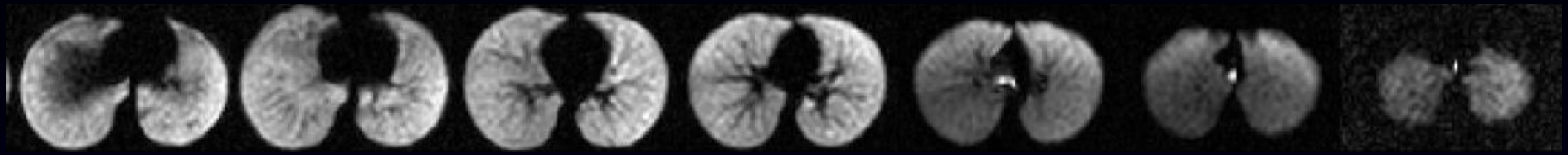






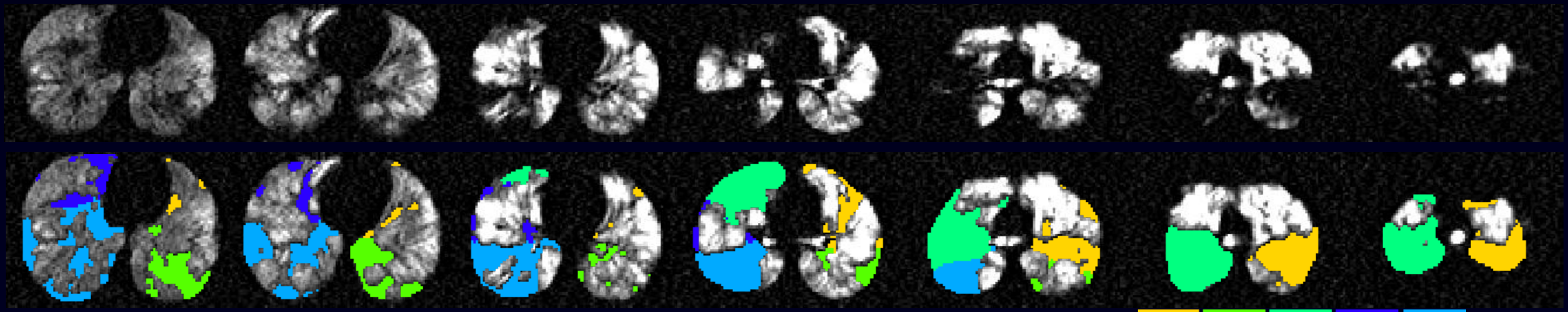
^{129}Xe ventilation MRI: Detection of early obstruction

14 y.o. male control subject, FEV_1 = 103% (normal lung function)

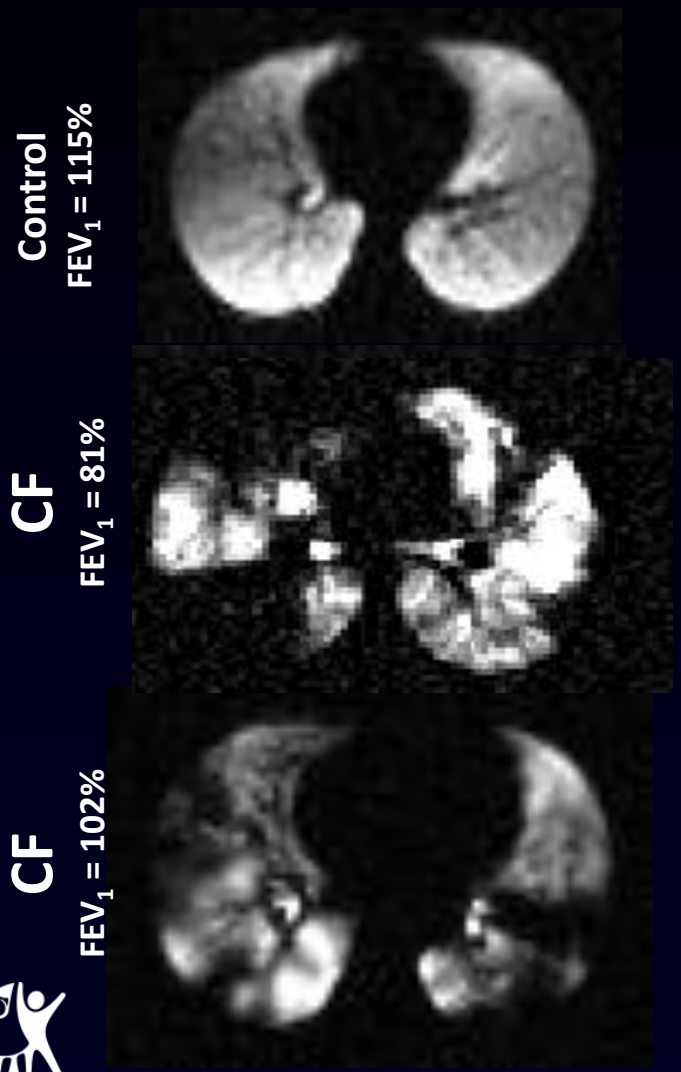


All control subjects: uniform ^{129}Xe ventilation and low ^{129}Xe ventilation defect percentage (VDP)

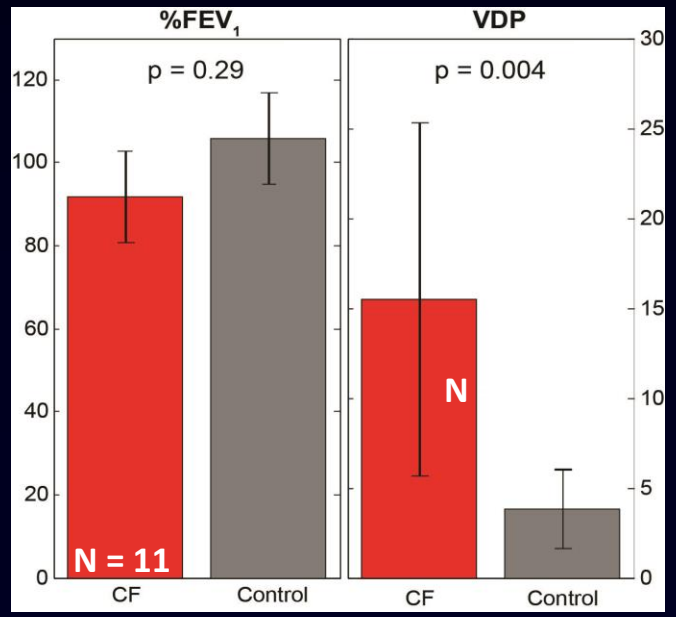
15 y.o. female CF subject, FEV_1 = 73%

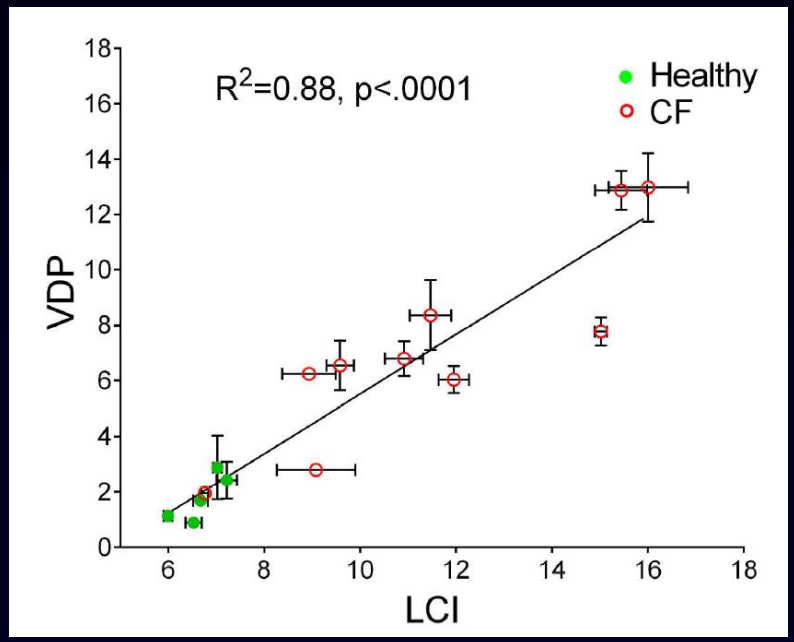


CF: ^{129}Xe Ventilation Defect Percentage (VDP) in CF



Much more sensitive than FEV1
Provides spatial heterogentiy complementary to time-heterogeneity with LCI



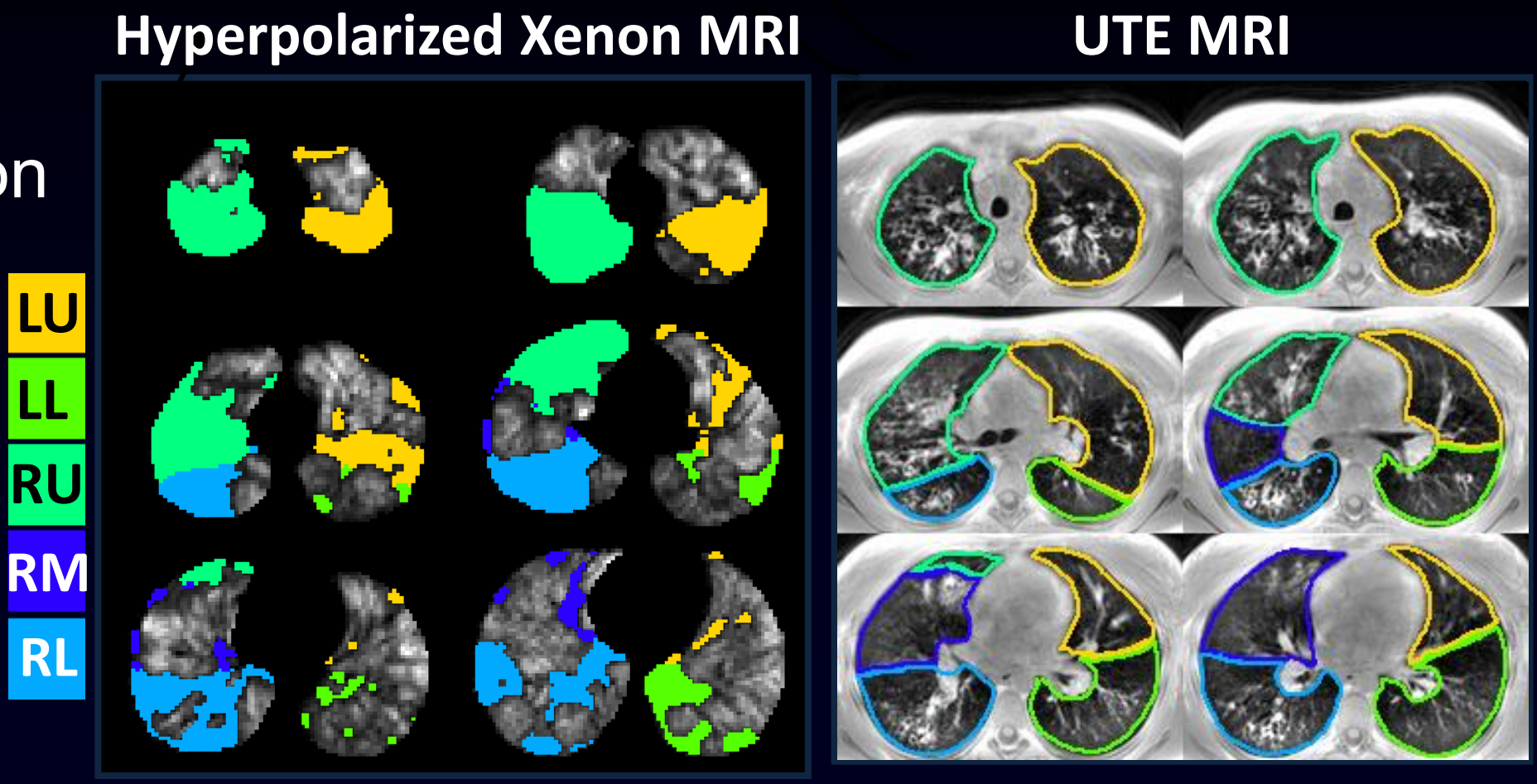


RL Thomen et al, *J Cyst Fibrosis* 2016 Jul 28. Kanhere *et al., Am J Respir Crit Care Med* 2017, 28 Feb

Combining structure and function

function

structure

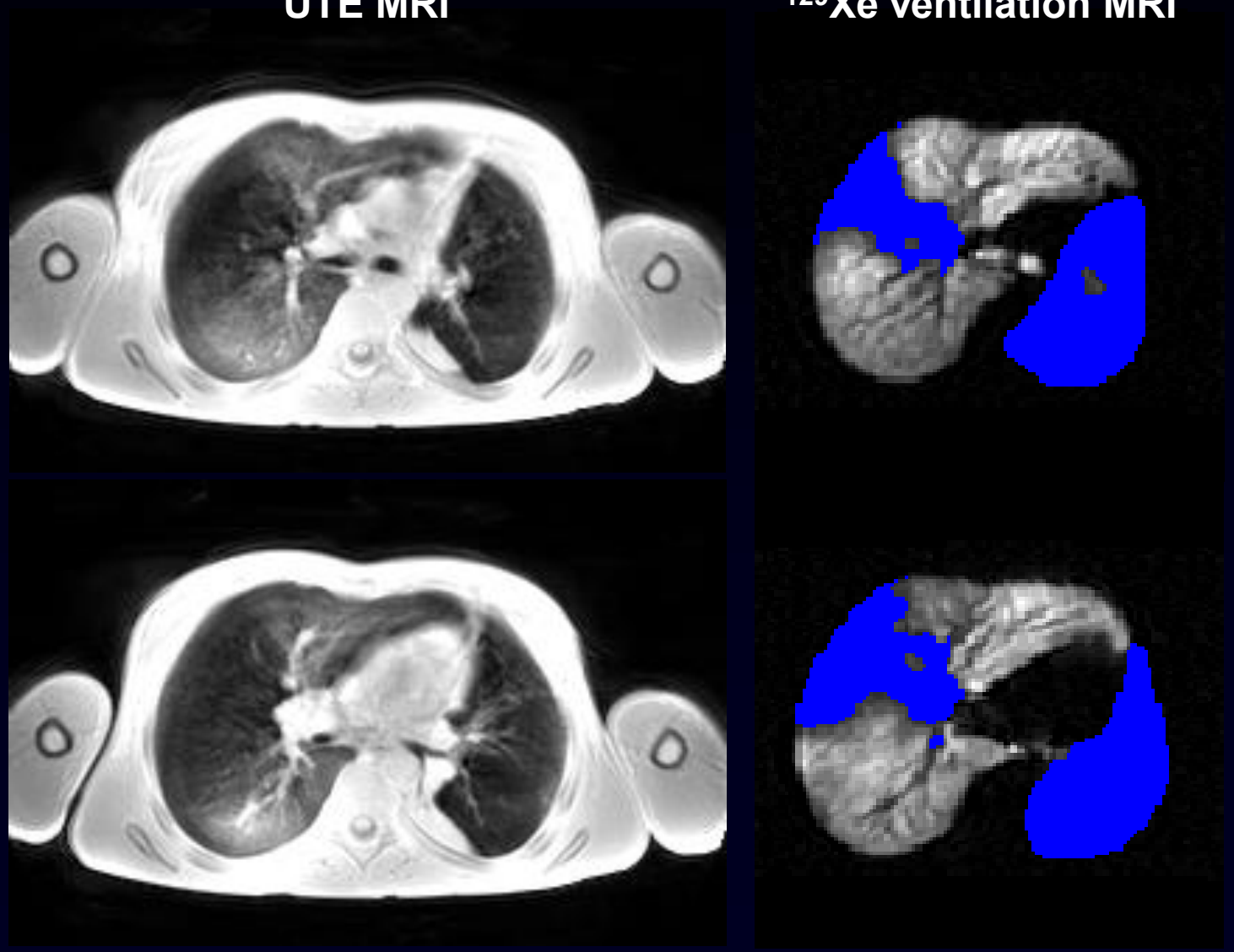


Use for chILDs

A post-infectious BOS case…

UTE MRI

^{129}Xe ventilation MRI



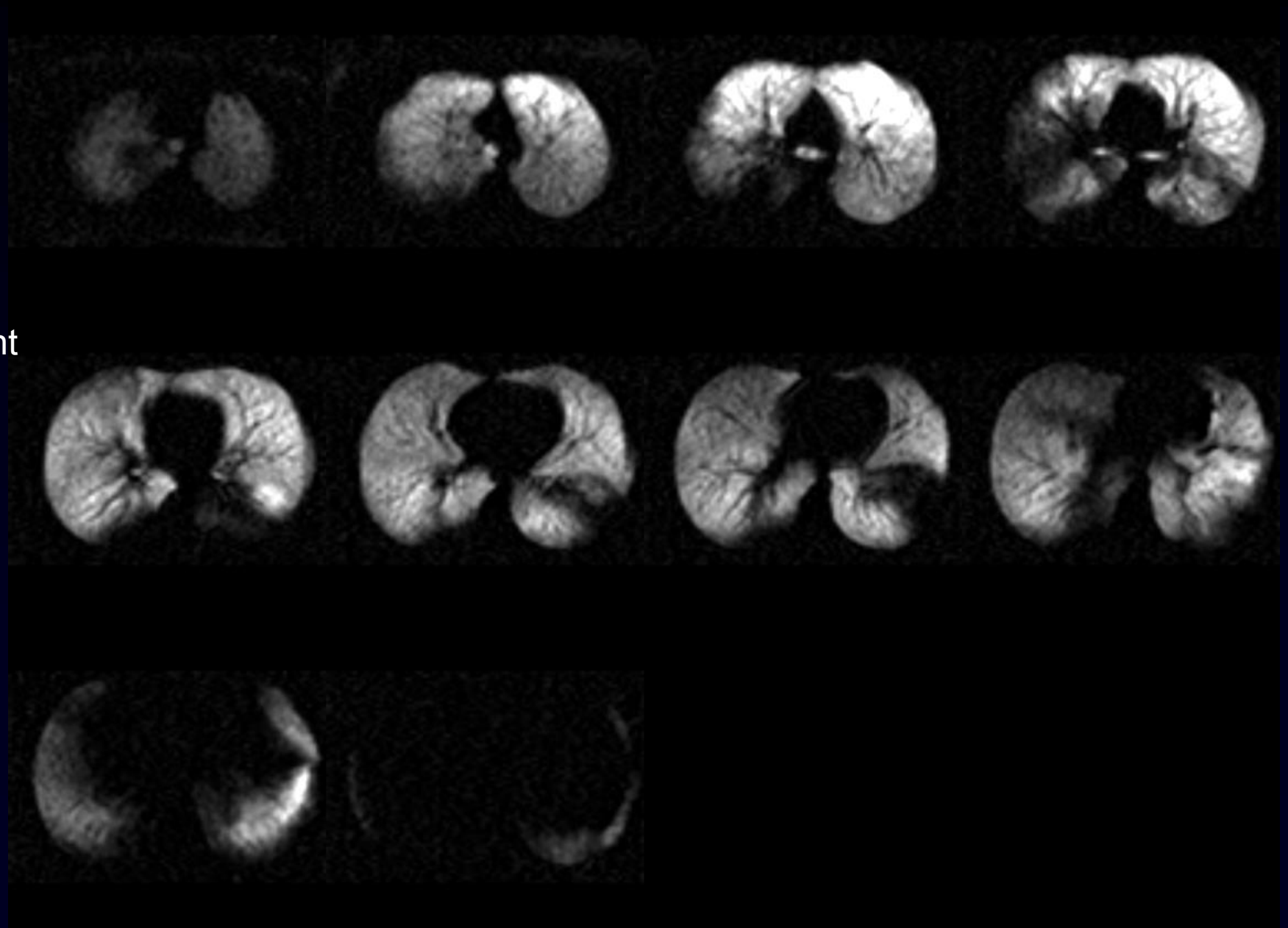
Threshold & quantify ventilation deficits (blue)

^{129}Xe VDP = 40.7%

IRC186H-**38**: 12 y.o. male BOS patient (post-infectious)
FEV_1%-pred = 34%

A milder BOS case…(hyperpolarized ^{129}Xe MRI)

10 y.o. male BOS patient
FEV_1%-pred = 60%
^{129}Xe VDP = 22.3 %



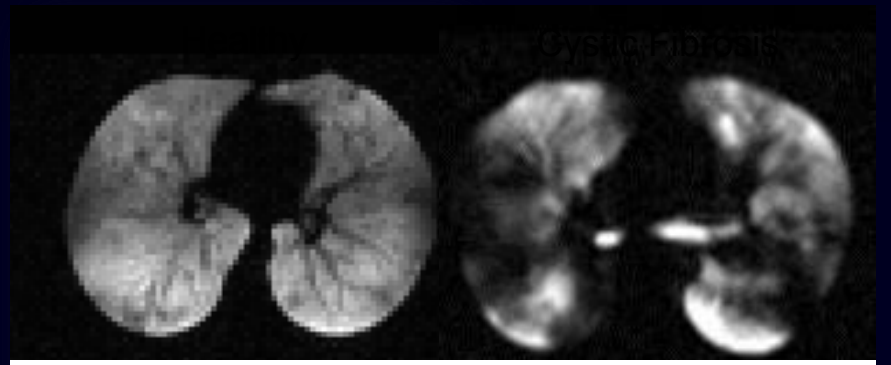
Conclusions

Pulmonary MRI is feasible, practical

- UTE MRI can depict lung structural abnormalities
- Hyperpolarized-gas MRI can depict and quantify ventilation abnormalities
  - High sensitivity compared to FEV1 (even higher than LCI)

Early results in BOS, NEHI indicate structure-function MRI may be used to quantify earliest forms of disease

Potential to monitor therapeutic efficacy



FEV_1 = 98% FEV_1 = 102%

CPIR - People

Core Faculty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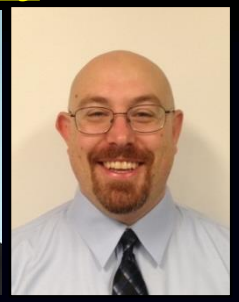
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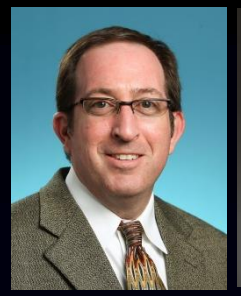
Stephanie Merhar, MD, Neonatology


Chris Towe, M.D. Pulmonary Med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Bruce Trapnell, M.D. Pulmonology (adult)

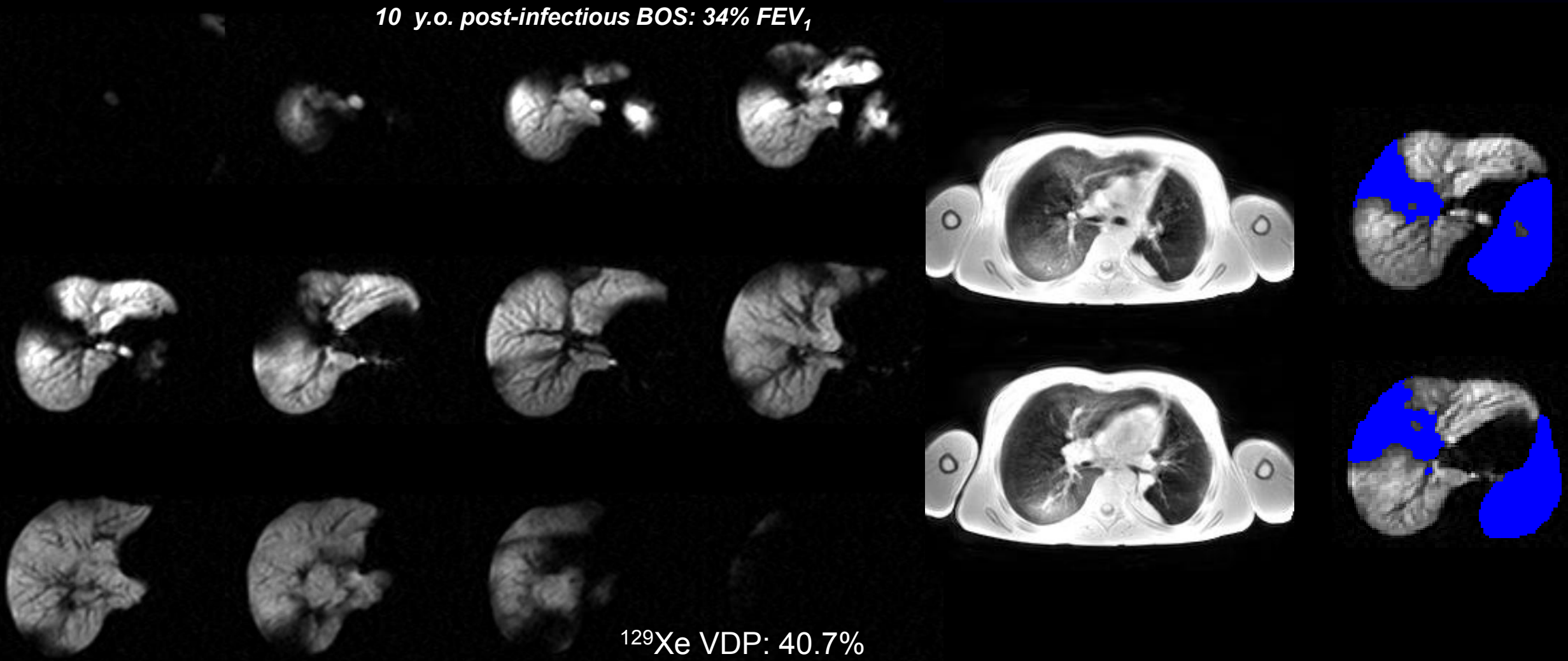

Frank McCormack, M.D. Pulmonology (adult)

Supplemental slides

Rare-lung diseases: bronchiolitis obliterans syndrome (BOS)

Regional structure (UTE MRI) and function (^{129}Xe ventilation MRI)
Potential applications in lung- and bone-marrow transplantation

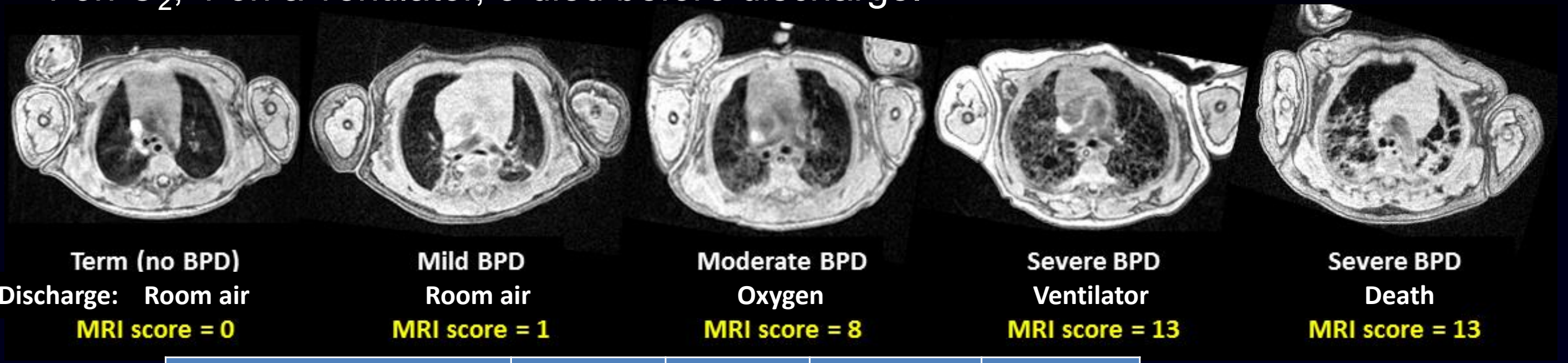
10 y.o. post-infectious BOS: 34% FEV_1



^{129}Xe VDP: 40.7%
Near absence of ventilation in left lung!

Predicting short-term outcomes via MRI

Respiratory support at discharge in 27 patients: 16 discharged on room air, 4 on O_2, 4 on a ventilator, 3 died before discharge.



Respiratory support at discharge (or death)	Room air (N=16)	O_2 (N=4)	Ventilator (N=4)	Death (N=3)
MRI Ochiai score	1.2 ± 2.2	4.8 ± 2.1	11.5 ± 1.7	12.7 ± 0.6

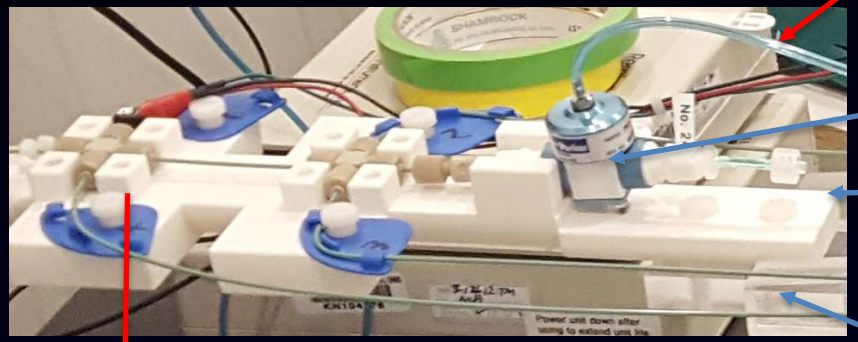
Scores correlated significantly with length of hospital stay (slope = 0.06 [score]/day, P<0.0001).

NS Higano, *et al.* , "Early-life MRI of bronchopulmonary dysplasia predicts short-term outcomes", manuscript in preparation

HP Gas Compatible Ventilator

3D Printed Cradle

Teflon Pneumatic Valve



O_2

HP ^{129}Xe

Pressure Transducer

Exhale