



¹H-MRI of the Lung: Challenges



low proton density with low signal intensity

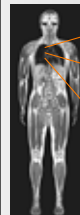
¹H-MRI of the Lung: Challenges



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low signal-to-noise ratio with short T2* (susceptibility artifacts at air-tissue interfaces)

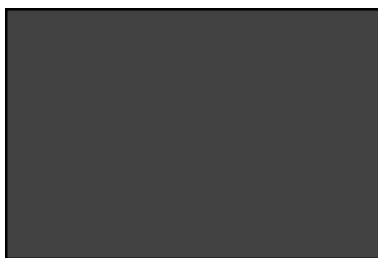
¹H-MRI of the Lung: Challenges



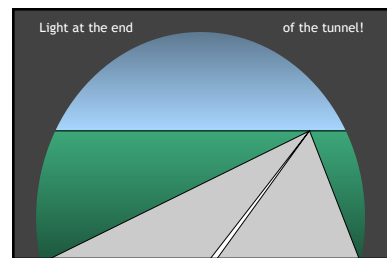
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low signal-to-noise ratio with short T2* (susceptibility artifacts at air-tissue interfaces)

motion artifacts (lung, heart, vessels)

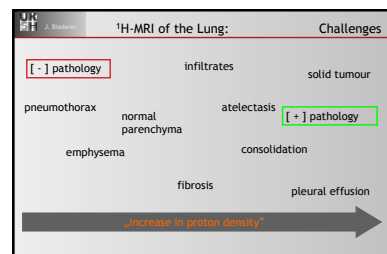
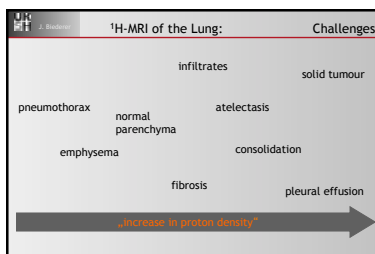


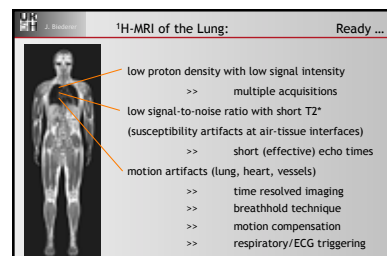
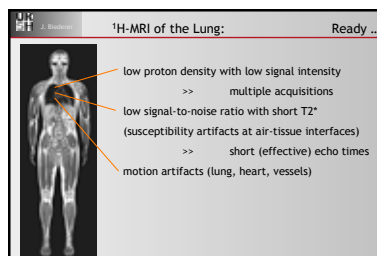
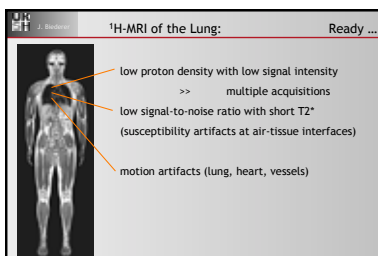
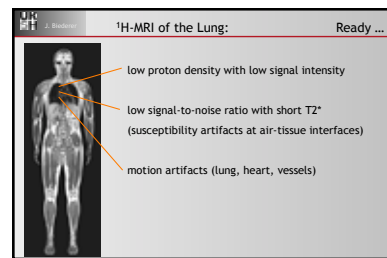
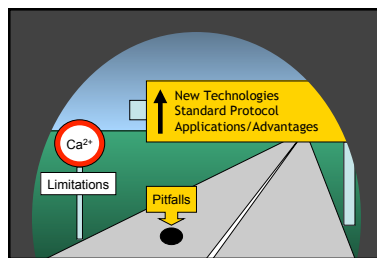
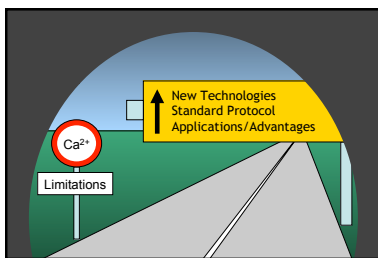
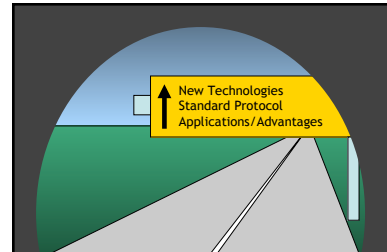
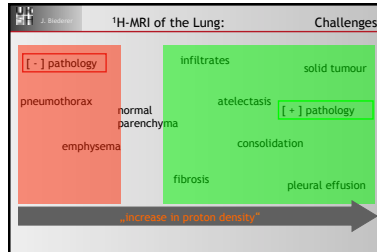
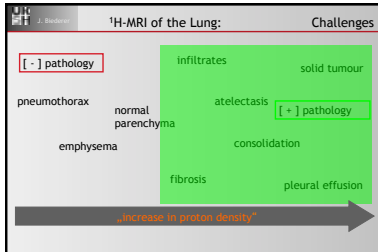
MRI of the lungs: Light at the end of the tunnel?




¹H-MRI of the Lung: Challenges

- infiltrates
- solid tumours
- atelectasis
- pneumothorax
- normal parenchyma
- consolidation
- emphysema
- fibrosis
- pleural effusion






¹H-MRI of the Lung: Ready ...



iPAT = Parallel Acquisition Technique

- low proton density
- multiple acquisitions
- low signal-to-noise ratio with short T2* (susceptibility artifacts at air-tissue interfaces)
- short (effective) echo times
- motion artifacts (lung, heart, vessels)
- time resolved imaging
- breathhold technique
- motion compensation
- respiratory/ECG triggering

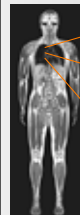
¹H-MRI of the Lung: Ready ...



VIBE = Volumetric interpolated Breathhold Imaging

- low proton density
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- short (effective) echo times
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- breathhold technique
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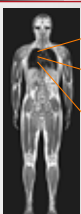
¹H-MRI of the Lung: Ready ...



syngo TWIST = echo sharing technique

- low proton density
- multiple acquisitions
- low signal-to-noise ratio with short T2* (susceptibility artifacts at air-tissue interfaces)
- short (effective) echo times
- motion artifacts (lung, heart, vessels)
- time resolved imaging
- breathhold technique
- motion compensation
- respiratory/ECG triggering

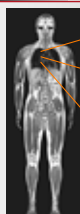
¹H-MRI of the Lung: Ready ...



syngo BLADE = rotating K-space sampling

- low proton density
- multiple acquisitions
- low signal-to-noise ratio with short T2* (susceptibility artifacts at air-tissue interfaces)
- short (effective) echo times
- motion artifacts (lung, heart, vessels)
- time resolved imaging
- breathhold technique
- motion compensation
- respiratory/ECG triggering

¹H-MRI of the Lung: Ready ...



syngo PACE = Prospective Acquisition CorrEction

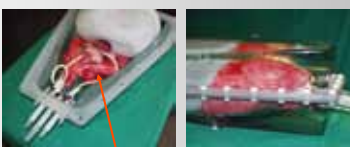
- low proton density
- multiple acquisitions
- low signal-to-noise ratio with short T2* (susceptibility artifacts at air-tissue interfaces)
- short (effective) echo times
- motion artifacts (lung, heart, vessels)
- time resolved imaging
- breathhold technique
- motion compensation
- respiratory/ECG triggering

MRI of the Lung: Key Clinical Questions

- 1) Detection of Inflammatory Disease
- 2) Nodule Detection
- 3) Assessment of Lung Nodule Dignity

¹H-MRI of the Lung: Challenges

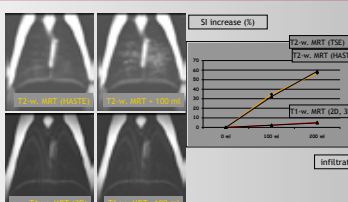
Artificial Chest



pig lung

Biederer et al., (2003 - I) Radiology 227-471-474

¹H-MRI of the Lung: Challenges

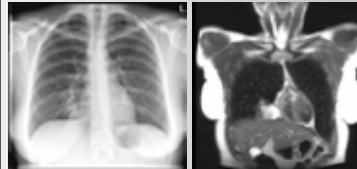


SI increase (%)

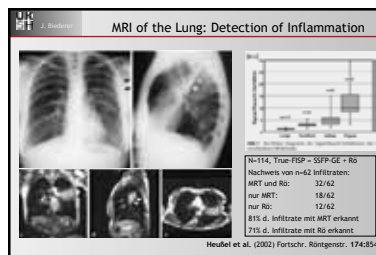
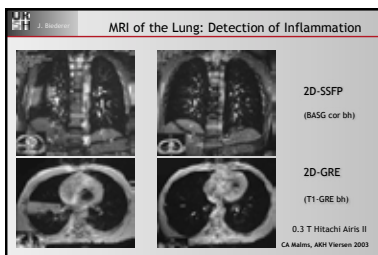
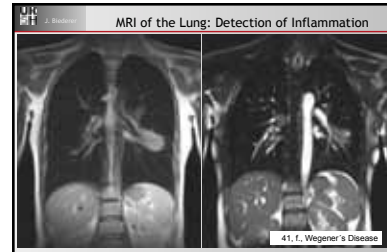
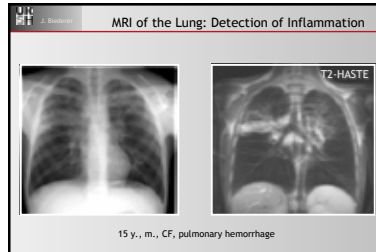
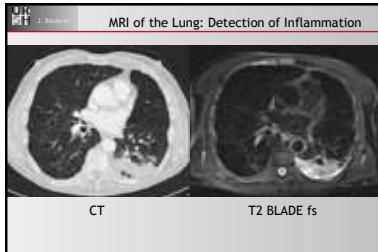
SI Increase (%)	0 ml	100 ml	300 ml
T2-w. MRT (TSE)	~10	~20	~30
T2-w. MRT (HASTE)	~10	~20	~30
T1-w. MRT (2D, 3D)	~10	~20	~30
infiltrate	~10	~20	~30

Biederer et al., (2002) RUFo 174:1033-105

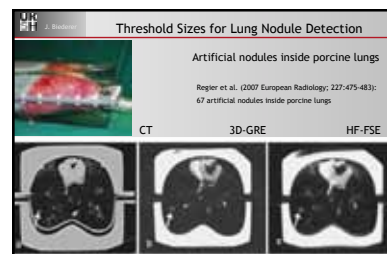
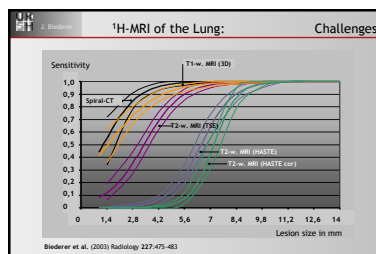
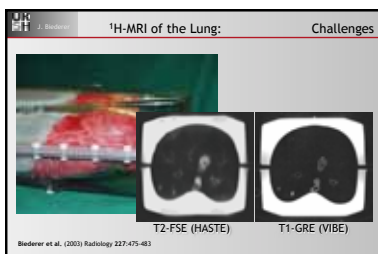
MRI of the Lung: Detection of Inflammation

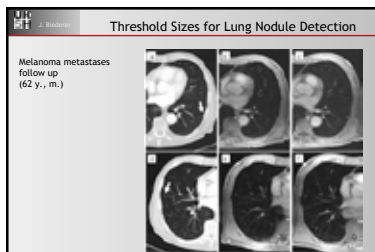
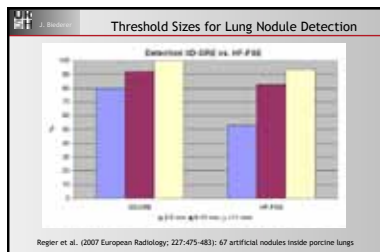


CXR T2-HASTE



- MRI of the Lung: Key Clinical Questions
- 1) Detection of Inflammatory Disease
 - 2) Nodule Detection
 - 3) Assessment of Lung Nodule Dignity



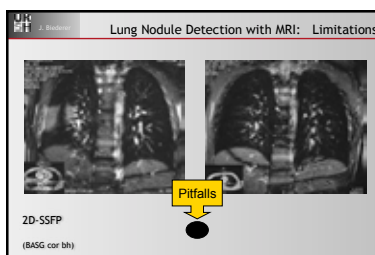
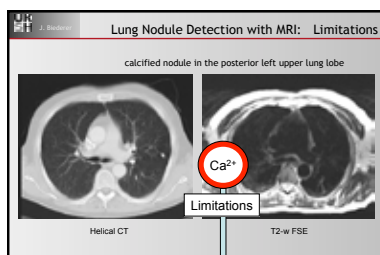


Threshold Sizes for Lung Nodule Detection

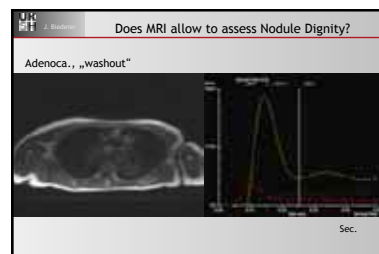
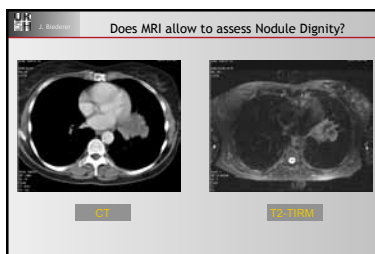
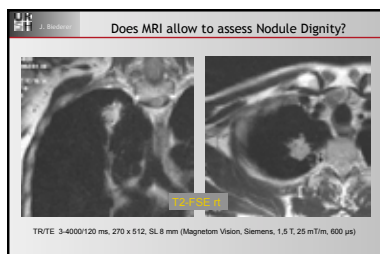
Sensitivity of MRI for nodules	3-5 mm	6-10mm	>10mm
MRI with T2-w. HASTE:	~ 75%	~ 95%	100%
MRI with T1-w. GRE (VIBE):	~ 90%	~ 100%	100%

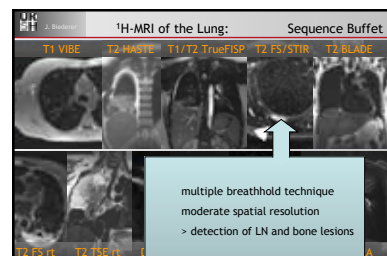
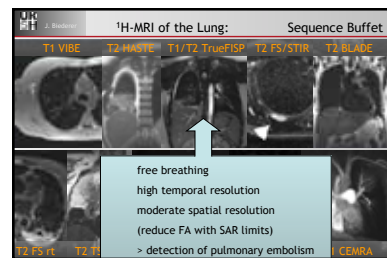
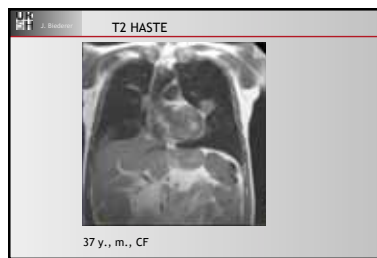
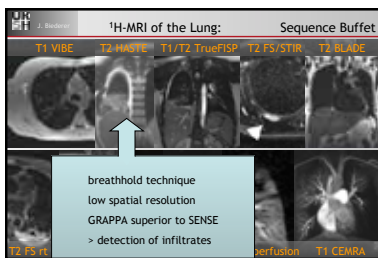
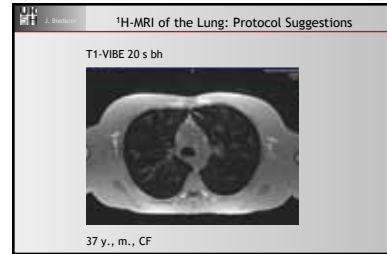
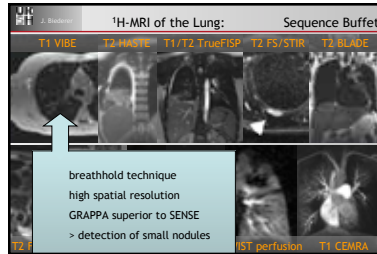
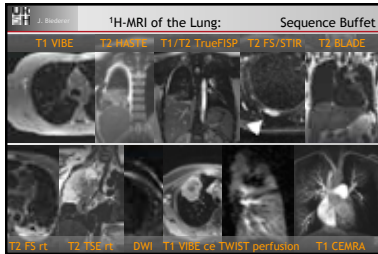
CXR: ~ 20-30% of 5-10 mm nodules (40% w/ CAD)
 CT: ~ 65-85% of 5-10 mm nodules (80-90% w/ CAD)

Schäfer JF et al. (2005 RoFo; 117-41-49); Comparison of MRI and CT
 Biederer et al. (2003 Radiology; 227-475-483); 364 artificial nodules inside 14 porcine lungs
 Regier et al. (2007 European Radiology; 227-475-483); 67 artificial nodules inside porcine lungs
 Schroeder T et al. (2000 AJR; 185-979-984); 1102 lesions <3 to >10mm in 30 patients



- ### MRI of the Lung: Key Clinical Questions
- 1) Detection of Inflammatory Disease
 - 2) Nodule Detection
 - 3) Assessment of Lung Nodule Dignity





T2 FS/STIR Cave

3D-GRE (VIBE) bh./insp. tra

TIRM multi-bh./insp. tra.

3D-GRE (VIBE) bh./insp. tra ce

¹H-MRI of the Lung: Sequence Buffet

T1 VIBE T2 HASTE T1/T2 TrueFISP T2 FS/STIR T2 BLADE

T2 FS rt T2 TSE rt DWI

multiple breathhold technique
moderate spatial resolution
> airways, nodules and masses

T2 BLADE

37 y., m., CF

T2 BLADE

T2 BLADE: differentiation of mediastinal masses

¹H-MRI of the Lung: Sequence Buffet

SP T2 FS/STIR T2 BLADE

navigator-triggered T2-technique
moderate to high spatial resolution
> for uncooperative patients!

T2 FS rt T2 TSE rt DWI T1 VIBE ce TWIST perfusion T1 CEMRA

T2 TSE rt. (high res.)

- interstitial lung disease, fibrosis
- lymphangitic spread of ca.
- diff. tumour/atelectasis
- masses with chest wall invasion

n.b.: ideal for adrenals/kidneys

Magnetom Avanto, Siemens, 1.5 T, 40 mT/m

¹H-MRI of the Lung: Sequence Buffet

T1 VIBE STIR T2 BLADE

breathhold technique
high spatial resolution
> nodules and masses
(DWI questionable)

T2 FS rt T2 TSE rt DWI T1 VIBE ce TWIST perfusion T1 CEMRA

Contrast-enhanced 3D-GRE (VIBE)

- lung carcinoma
- pleural spread of cancer
- unclear pleural effusion
- mesothelioma
- mediastinal mass
- mediastinitis
- vaskulitis (e.g. Wegener's)

n.b.: „backup-angiogram“

¹H-MRI of the Lung: Sequence Buffet

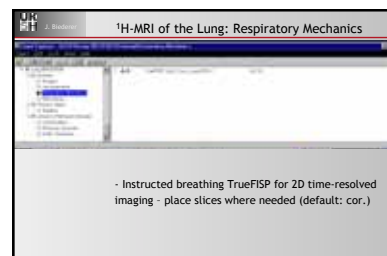
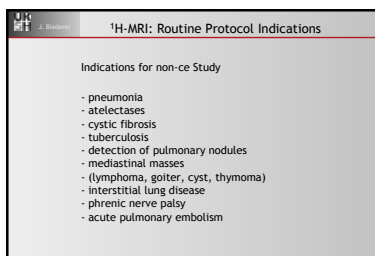
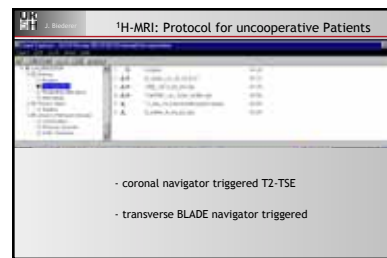
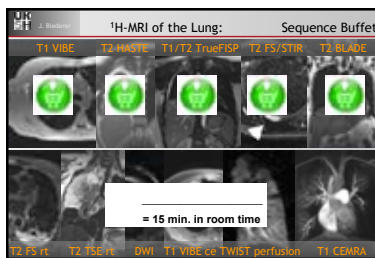
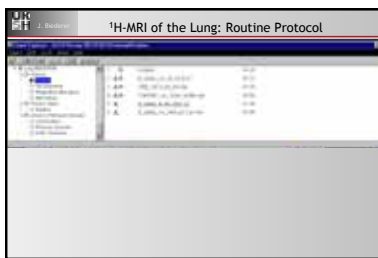
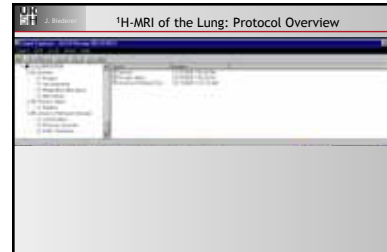
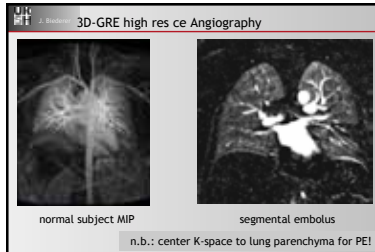
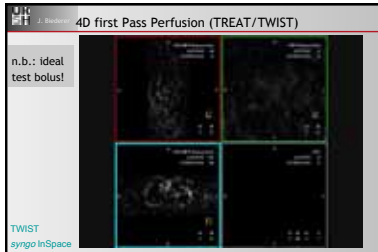
T1 VIBE T2 HASTE

breathhold technique angiograms

- 1.) high temporal resolution
- 2.) high spatial resolution

> vascular disease

T2 FS rt T2 TSE rt DWI T1 VIBE ce TWIST perfusion T1 CEMRA



¹H-MRI of the Lung: Respiratory Mechanics

T1 VIBE T2 HASTE T1/T2 TrueFISP T2 FS/STIR T2 BLADE

= 5 min. in room time

T2 FS rt T2 TSE rt DWI T1 VIBE ce TWIST perfusion T1 CEMRA

¹H-MRI: Thoracic Mass - Routine/DWI/CE

1.1	...	...
1.2	...	...
1.3	...	...
1.4	...	...
1.5	...	...
1.6	...	...
1.7	...	...
1.8	...	...
1.9	...	...
1.10	...	...
1.11	...	...
1.12	...	...
1.13	...	...
1.14	...	...
1.15	...	...
1.16	...	...
1.17	...	...
1.18	...	...
1.19	...	...
1.20	...	...

- plus coronal VIBE
- skips transverse T2-fs. (replaced by CE VIBE)
- includes DWI

¹H-MRI: Thoracic Mass - Routine/DWI/CE

T1 VIBE T2 HASTE T1/T2 TrueFISP T2 FS/STIR T2 BLADE

= 20 min. in room time

T2 FS rt T2 TSE rt DWI T1 VIBE ce TWIST perfusion T1 CEMRA

Contrast-enhanced 3D-GRE (VIBE)

Lung cancer

Contrast-enhanced 3D-GRE (VIBE)

Indications for ce Study (for angiography see below)

- Lung carcinoma
- pleural spread of cancer
- Pleural effusion of unclear origin
- mesothelioma
- neurogenic tumours of the mediastinum
- mediastinitis
- vaskulitis (e.g. Wegener's granulomatosis)
- „backup-angiogram“

¹H-MRI: Central Mass - Routine/DWI/CE/Angio

1.1	...	...
1.2	...	...
1.3	...	...
1.4	...	...
1.5	...	...
1.6	...	...
1.7	...	...
1.8	...	...
1.9	...	...
1.10	...	...
1.11	...	...
1.12	...	...
1.13	...	...
1.14	...	...
1.15	...	...
1.16	...	...
1.17	...	...
1.18	...	...
1.19	...	...
1.20	...	...

- „have it all“
- accounts for vessel involvement
- includes DWI
- includes T2w-fs

¹H-MRI: Central Mass - Routine/DWI/CE/Angio

T1 VIBE T2 HASTE T1/T2 TrueFISP T2 FS/STIR T2 BLADE

= 30 min. in room time

T2 FS rt T2 TSE rt DWI T1 VIBE ce TWIST perfusion T1 CEMRA

3D-GRE ce MRA high temporal/spatial res.

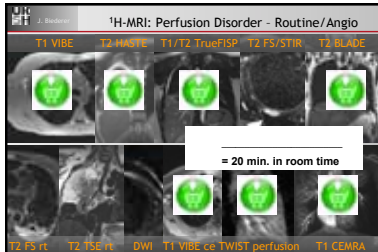
Indications for ce MRA

- acute and chronic pulmonary embolism (PE)
- AV-malformation (e.g. Osler's disease)
- lung sequestration
- pulmonary arterial aneurysm
- abnormalities of pulmonary venous drainage
- central masses, infiltration into PA or aorta
- interstitial lung disease with emphysema (indirect)
- pulmonary hypertension
- cystic fibrosis

¹H-MRI: Perfusion Disorder - Routine/Angio

1.1	...	...
1.2	...	...
1.3	...	...
1.4	...	...
1.5	...	...
1.6	...	...
1.7	...	...
1.8	...	...
1.9	...	...
1.10	...	...
1.11	...	...
1.12	...	...
1.13	...	...
1.14	...	...
1.15	...	...
1.16	...	...
1.17	...	...
1.18	...	...
1.19	...	...
1.20	...	...

- combines routine and Perfusion/Angio
- skips transverse T2-fs. (replaced by CE VIBE)



4D first Pass Perfusion (TREAT/TWIST)

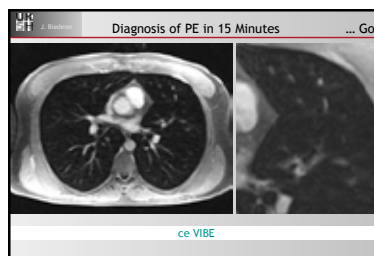
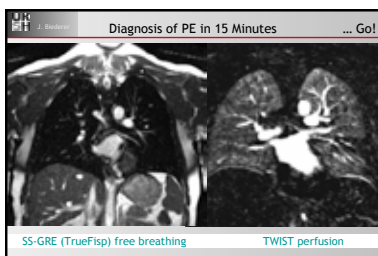
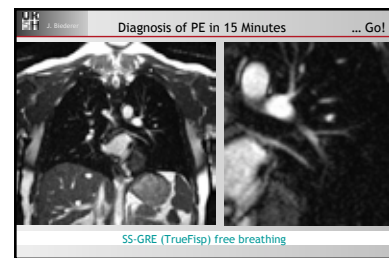
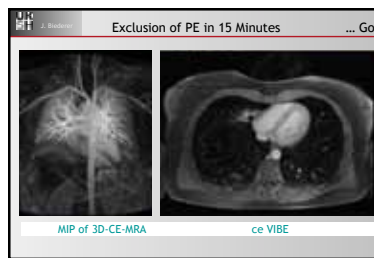
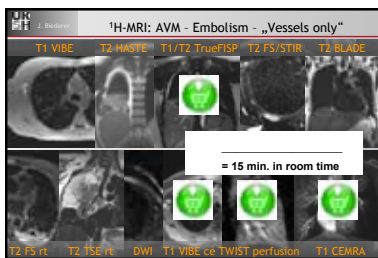
Indications for TREAT/TWIST first pass perfusion

- Interstitial lung disease with emphysema (indirect)
- pulmonary hypertension
- cystic fibrosis
- acute and chronic pulmonary embolism

n.b.: This is the ideal test bolus!

1H-MRI: AVM - Embolism - „Vessels only“

- combines free breath TrueFISP and Perfusion/Angio



1H-MRI of the Lung @ 1.5 T ...Go!

Take home points for practical use

- Sensitivity for infiltrates at least similar to X-ray and CT
- Lung nodule detection superior to X-ray, inferior to CT
- Database of MRI-CT comparisons growing
- Protocols are easy to set up (state-of-the-art 1.5T MRI)
- Lung MRI offers solutions for tricky problems of daily routine
- MRI is a good option for pediatrics and science

Lung MRI @ 3T: Is this still "No Go"?

Small image showing a lung MRI scan.

Lung MRI @ 3T: Is this still "No Go"?

Fink et al. (2007) Investigative Radiology, in press

¹H-MRI of the Lung: Sequence Buffet @ 3 T

T1 VIBE T2-HASTE T1/T2 TrueFISP T2 FS/STIR T2 BLADE

T2 FS rt T2 TSE ft DWI T1 VIBE ce TWIST perfusion T1 CEMRA

- lesion/background contrast improved @ 3Tesla
- Cnodule in VIBE
- Cinfiltrate in HASTE and STIR

T1 VIBE var. @ 3T (Siemens Verio)

TE/TR 2.45-3.48/5.98 SL 4
FOV 262x400 Mx 158px320

T2 Fast Spinecho blade cor @ 3T (Verio)

TE/TR 130/2000 ms
SL 5
FOV 480x480
Mx 320x320

¹H-MRI of the Lung: Sequence Buffet

T1 VIBE T2-HASTE T1/T2 TrueFISP T2 FS/STIR T2 BLADE

T2 FS rt T2 TSE ft DWI T1 VIBE ce TWIST perfusion T1 CEMRA

- no improvement in lesion/background contrast
- many motion- and flow-related artifacts at 3T

Steady State GRE @ 3T (Siemens Verio)

TE/TR 1.17/474 Mx 352x512.1
TE/TR 1.19/700 Mx 220x320
TE/TR 1.17/957 Mx 266x384
TE/TR 3.52/1355 Mx 352x512

SPACE STIR @ 3T instead of TrueFISP?


SPACE-STIR cor trig

Lung MRI @ 3T: Conclusions

Take home points for practical use


- Suitable protocols for 1.5 T are easily transferred to 3 T systems.
- Lung nodule signal increases for all sequences ...
- ... except for Steady State Gradient Echo imaging.
- A higher spatial resolution for 3D GRE techniques may be possible
- Experience in patients at 3T is still few, but growing
- Plans to do lung MRI are not a contraindication to buy a 3T system

¹H-MRI of the Lung: Literature

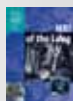


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¹H-MRI of the Lung: Literature



Edwin, B.; Lipson, D.: Functional Lung Imaging, Lung Biology and Health Disease, Vol. 200 Informa Healthcare, London 2005



Kauczor, H.-U.: MRI of the Lung Springer Verlag, Berlin 2008

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