Compressed SENSE Cardiac magnetic resonance (CMR) Imaging with the 1.5T Ambition X BlueSeal Magnet

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MDZ Medizinisches Diagnose-Zentrum

SPITAL USTER

Disclosures

- I have received MRI fellowship funding for 12 months from Philips in 2003
- I am the clinical lead for the participation of Spital Uster/MDZ Uster in the Philips «first of a kind» program since 10/2018
- I have been invited by Philips to present this talk

Overview – our first Ambition(s) month`s have been very eXciting

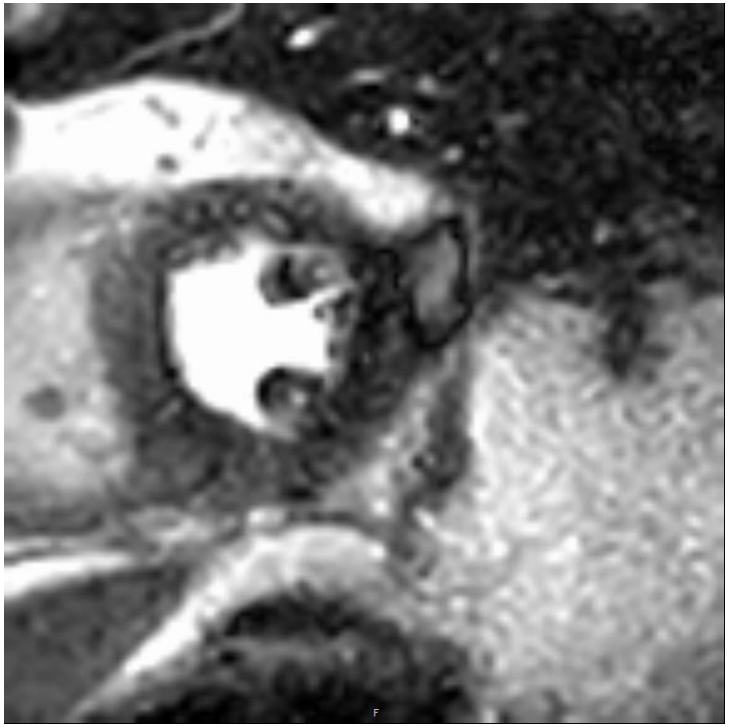
- The worlds first clinical cardiac MRI on this new platform (DICOM images)
- Comfort – Why we chose the Ambition X
- Speed - How we use Compressed SENSE (CS) for Cardiac Imaging
- Diagnostic Confidence - Case Examples
  - Ambition X – first Adenosin Stress Perfusion
  - Ambition X - first Cardiac Tumor Case
  - Non Cardiac Work (3D Knee, Liver MRI, MRCP)
  - Myocarditis or something else ? A diagnostic challenge
  - CS Adenosin Stress Perfusion – `A usual patient` from 06.02.2019
  - 2-Vessel disease, Stenosis Post-Intervention – What to do next?

Our first Cardiac MRI Patient – 140 kg male

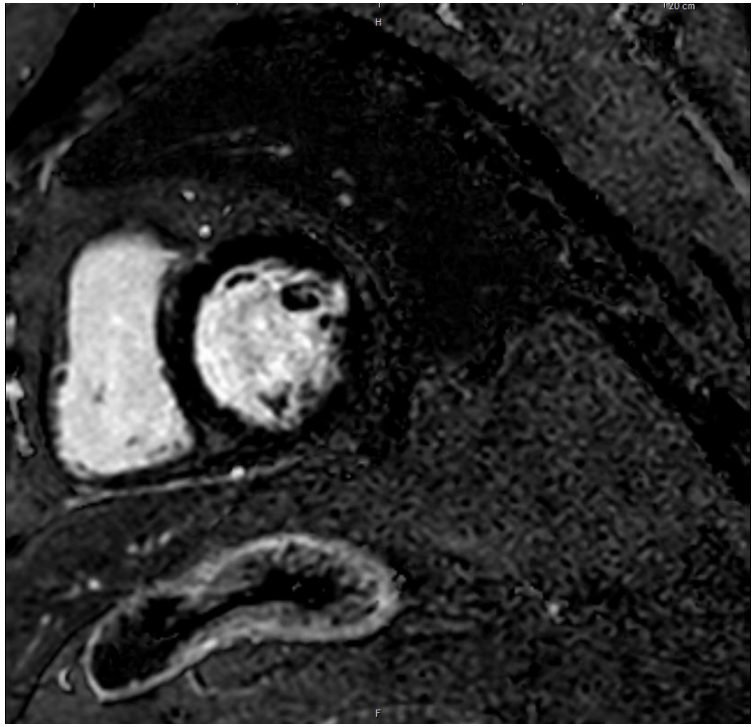
Problem/Diagnosis:

- Known IDH
- previous CABG and multiple stents
- last stent in the Cx 3 months ago
- again chest pain during minimal exercise
- significantly obese patient

Our first Cardiac MRI Patient (140 kg male) – Adenosin Stress CMR Study



CS 2.3 Adenosin Stress-Perfusion at 90 BPM



LGE

Ingenia Ambition X 1.5T – Our Decision for the Comfort of our Patients

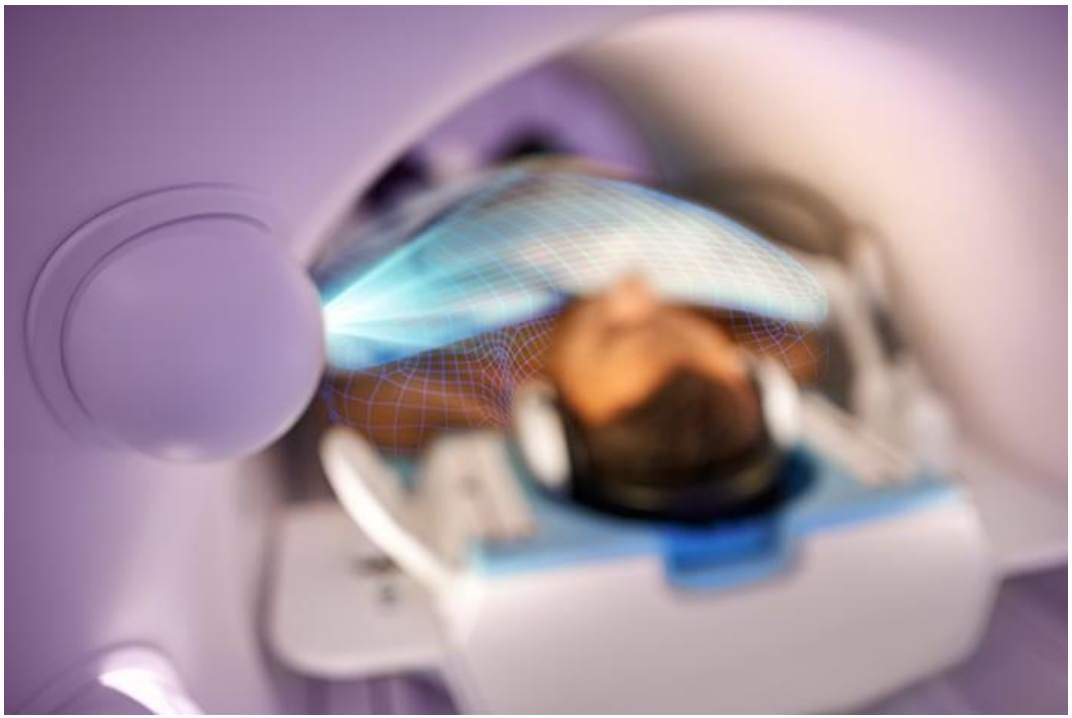
- 7 liters of helium vs 1500
- no quench pipe, fully sealed magnet, fits in rooms with low ceiling
- 900 kg lighter then predecessor, minimum siting limitation of 3,700 kg
- much improved patient comfort with the new table mattress
- combination with InBore Experience and Ambient Lighting
- 70 cm bore & 55cm FOV
- about 1 hour to ramp-down
- < 1 day to be back in operation
- exceptional field homogeneity
- VitalEye Patient Sensing Technology

Classic magnet technology
~1,500 liters of liquid helium

BlueSeal micro-cooling technology
~7 liters of liquid helium

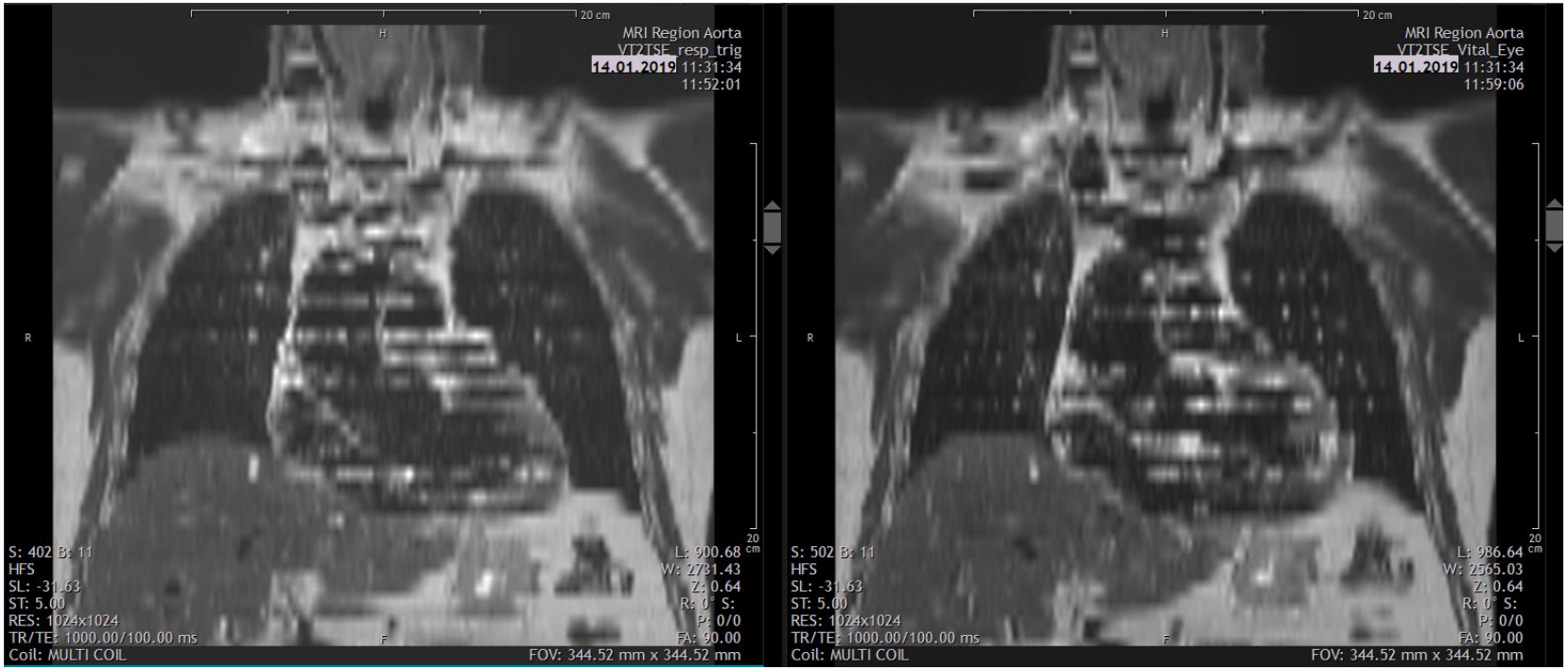
VitalEye Respiratory Motion tracking/triggering made easy

- We use this now extensively – no more ‘fiddeling’ with respiratory belt!



VitalEye – Our first images

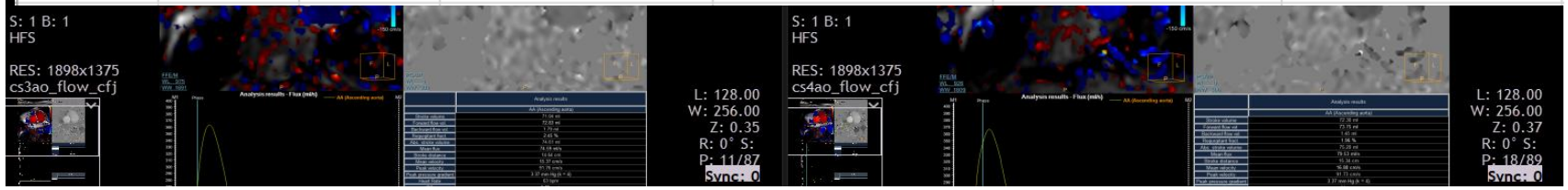
Respiratory Trigger vs VitalEye triggered axial T2 black blood Images – coronal reformat



Compressed Sense is very useful for Q-Flow Imaging

sequence	venc	phases	phase%	comp	TFE shots	shot dur.	ph acq. %	fov	oversamp.	acq v rl mm	acq v ap mm	voxel1 mm	voxel2 mm	sl mm	scan dur. sec.
Ao_qflow	150	40	60	s1.8	14	36	66.1	250	no	2.5	2.5	2.5	2.5	8	14.3
Ao_qflow	150	40	60	cs2	12	36	66.1	250	no	2.5	2.5	2.5	2.63	8	12.4
Ao_qflow	150	40	60	cs3	8	36	66.1	250	no	2.5	2.5	2.5	2.72	8	8.6
Ao_qflow	150	40	60	cs4	6	36	66.1	250	no	2.5	2.5	2.5	2.8	8	6.7

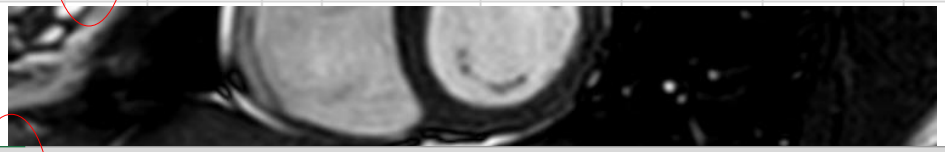
id	gender	age y/m	aos2/abs.sv ml/HR BPM	aocs2/abs.sv ml/HR BPM	aocs3/abs.sv ml/HR BPM	aocs4/abs.sv ml/HR BPM
vol1	male	50/2	93/51	85/52	87/52	85/56
vol2	male	66/5	68/72	66/74	68/74	68/72
vol3	male	32/2	96/52	97/51	88/52	99/48
vol4	female	34/7	94/50	85/52	91/52	93/54
vol5	male	26/10	76/64	78/64	74/63	75/66
vol6	female	45/5	56/65	54/66	55/65	56/65
vol7	male	41/2	89/54	94/55	92/54	89/55
vol8	male	28/5	118/59	111/60	111/58	117/58
vol9	male	51/1	89/61	82/62	86/65	87/66
vol10	female	30/8	68/66	65/66	65/69	67/69
vol11	male	53/3	98/59	92/59	97/58	99/60



You have now a multitude of options for adjusting your Cine Imaging to the needs of the patient – a few Examples

sequence	CCL ms	phases	phase%	comp	TFE shots	fov	oversampling	acq v rl mm	acq v ap mm	voxel1 mm	voxel2 mm	sl mm	scan duration sec.
4chv	1050	34	67	s1.8	7	300	50A+P	1.7	1.7	1.7	1.9	7	8.4
4chv	1084	34	67	cs2	6	300	50A+P	1.7	1.7	1.7	2	7	7.4
4chv	979	34	67	cs3	4	300	50A+P	1.7	1.7	1.7	2.1	7	5.3
4chv	1070	34	67	cs4	3	300	50A+P	1.7	1.7	1.7	2.1	7	4.2

sequence	CCL ms	phases	phase%	comp	TFE shots	fov	oversampling	acq v rl mm	acq v ap mm	voxel1 mm	voxel2 mm	sl mm	scan duration sec.
4chv	1045	22	67	s1.8	4	300	50A+P	1.7	1.7	1.7	1.9	7	5.3
4chv	1038	22	67	cs2	4	300	50A+P	1.7	1.7	1.7	2	7	5.3
4chv	1008	22	67	cs3	2	300	50A+P	1.7	1.7	1.7	3	7	3.2
4chv	1026	22	67	cs4	2	300	50A+P	1.7	1.7	1.7	2	7	3.2



sequence	CCL ms	HR	slices	sl. per BH	phases	act phase %	comp	TFE factor	shot dur.	fov	oversamp.	acq v1 mm	acq v1 mm	voxel1 mm	voxel2 mm	sl mm	scan dur. sec.	total scan time
sLVSA11sl	1054	56	11	1	34	70.6	s1.8	17	44.6	300	20L/20R	1.7	1.7	1.7	1.7	7	8.6	1:34 min
cs33LVSA10sl	990	57	10	5	25	69.6	cs3.3	23	60.5	300	20L/20R	1.9	1.8	1.9	2.6	8	15.8	31.6 sec
cs3LVSA12sl	1014	57	12	3	22	95.2	cs3	22	61.3	300	20L/20R	1.7	1.7	1.7	1.8	7	12.6	50.5 sec

eg. 11 x 4 sec breath holds = 11 slices to cover the LV
eg. 2 x 15 sec. breath holds = 10 slices to cover the LV
eg. 3 x 13 sec breath holds = 12 slices to cover the LV

Adenosin Stress Perfusion Imaging with Compressed SENSE – a few Examples

slices	shot mode	temporal res.	HR BPM	comp	fov	oversamp.	acq v1 mm	acq v2 mm	sl mm	scan dur. sec.
3	single-shot	every HB	90	cs2.3	160	139L/19R	2	2	10	30
3	single-shot	every HB	65	cs2.3	160	57P/92A	1.6	1.6	10	30
3	single-shot	every HB	75	cs2.3	145	83P/63A	1.7	1.7	10	30
3	single-shot	every HB	85	cs2.9	176	95P/30A	1.6	1.6	10	30

`The Compressed SENSE numbers` to try initially……..2.3-2.5 cine, 3 for Qflow and STIR, 2.3-2.9 for perfusion …… we like a FOV of 160-180 mm

Adjusting the CS Factor at times by 0.1 has big effects on breath hold times and voxel sizes (as you are essentially moving the boundries of K-Space undersampling)

CS 3 – STIR imaging of the LV (short axis) is 40% shorter then with conventional SENSE!

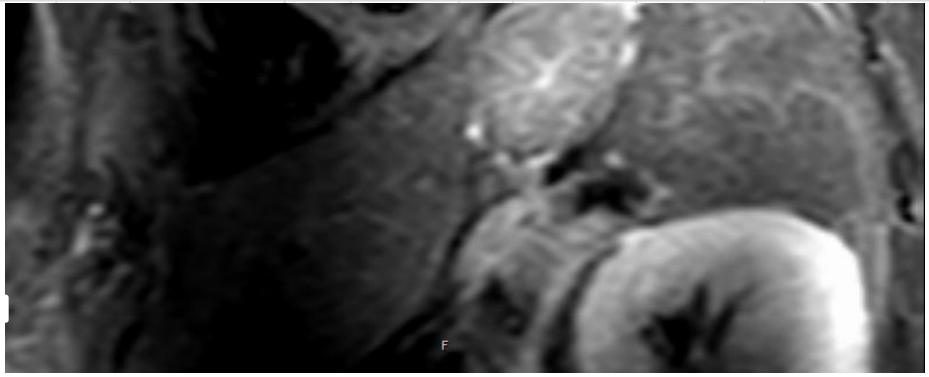
sequence	HR BPM	phases	shot mode	scan%	max heart phas	comp	TSE factor	fov	oversamplin	acq v fh mm	acq v rl mm	voxel1 mm	voxel2 mm	sl mm	scan dur. sec.
LVSA_STIR	<67	1	multishot	80.5	6	s1.6	30	250	50A+50P	1.5	1.7	1.5	1.9	8	10
LVSA_STIR	<67	1	multishot	69.8	6	cs2	30	250	50A+50P	1.5	1.7	1.5	2	8	8
LVSA_STIR	<67	1	multishot	67.5	6	cs3	30	250	50A+50P	1.5	1.7	1.5	2.2	8	6
LVSA_STIR	<67	1	multishot	67.8	6	cs4	30	250	50A+50P	1.5	1.7	1.5	2.2	8	6

sequence	HR BPM	phases	shot mode	scan%	max heart phas	comp	TSE factor	fov	oversamplin	acq v fh mm	acq v rl mm	voxel1 mm	voxel2 mm	sl mm	scan dur. sec.
4CHV_STIR	<67	1	multishot	66.7	6	s1.6	30	300	no	1.4	1.75	1.4	2	8	8
4CHV_STIR	<67	1	multishot	69.8	6	cs2	30	300	no	1.4	1.75	1.4	1.8	8	8
4CHV_STIR	<67	1	multishot	67.5	6	cs3	28	300	no	1.4	1.75	1.4	1.8	8	6
4CHV_STIR	<67	1	multishot	67.8	6	cs4	21	300	no	1.4	1.75	1.4	1.9	8	6

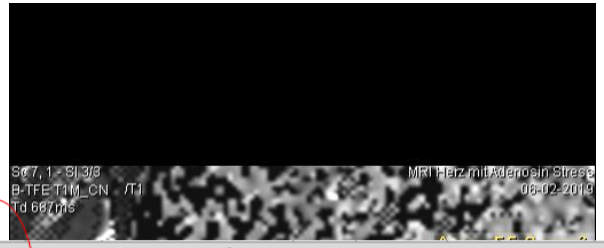
Comments

only small time gain, on balance we use use cs3

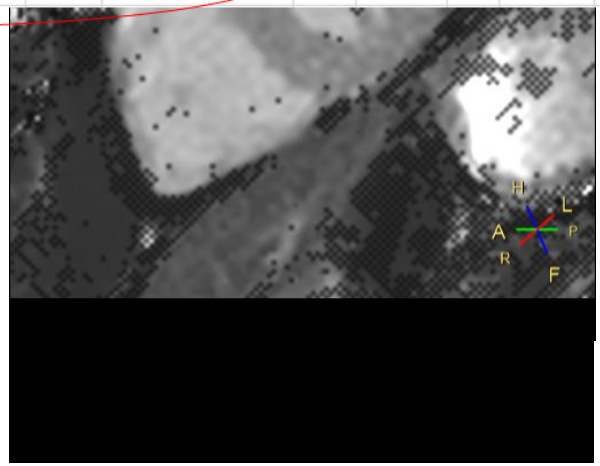
need to consider the effect of oversampling on voxel size and scan duration



T1 Mapping with Compressed SENSE 3 – Our acquisitions are not shorter, but we get better T1 data due to arround 20-25% reduction in shot length for the same resolution



sequence	slices	shot mode	scan%	HR BPM	shot dur. ms	acq ms	trigg. del. max/act. ms	comp	TSE factor	fov	oversamp.	acq v fh mm	acq v rl mm	voxel1 mm	voxel2 mm	sl mm	scan dur.sec.
s2T1_MOLLI	1	single-shot	101	60 (<67)	216.4	193.2	900/777	s2	85	250	35H/84F	2	2	2	2	10	11
cs3T1_MOLLI	1	single-shot	100.5	64 (<70)	166.5	143.3	857/749	cs3	63	250	35H/84F	2	2	2	2	10	12.4
Comments																	
Shot duration with CS3 shortens significantly and that has a positive effect on the T1 errors shown in the pixel map																	
rategies																	



About 70% of our T1 mapping data looks like that

Non-Cardiac Case Examples

Ambition X 3D Erika Brüllmann Knee MRI PD SPAIR 0.6 mm isotropic Voxels - ACL Rupture

CS 3D PD SPAIR – 5.5 minutes

CS 2D T1 cor – 2 minutes

Ambition X 3D Knee Imaging Workflow – Use compressed SENSE to speed up your work flow!

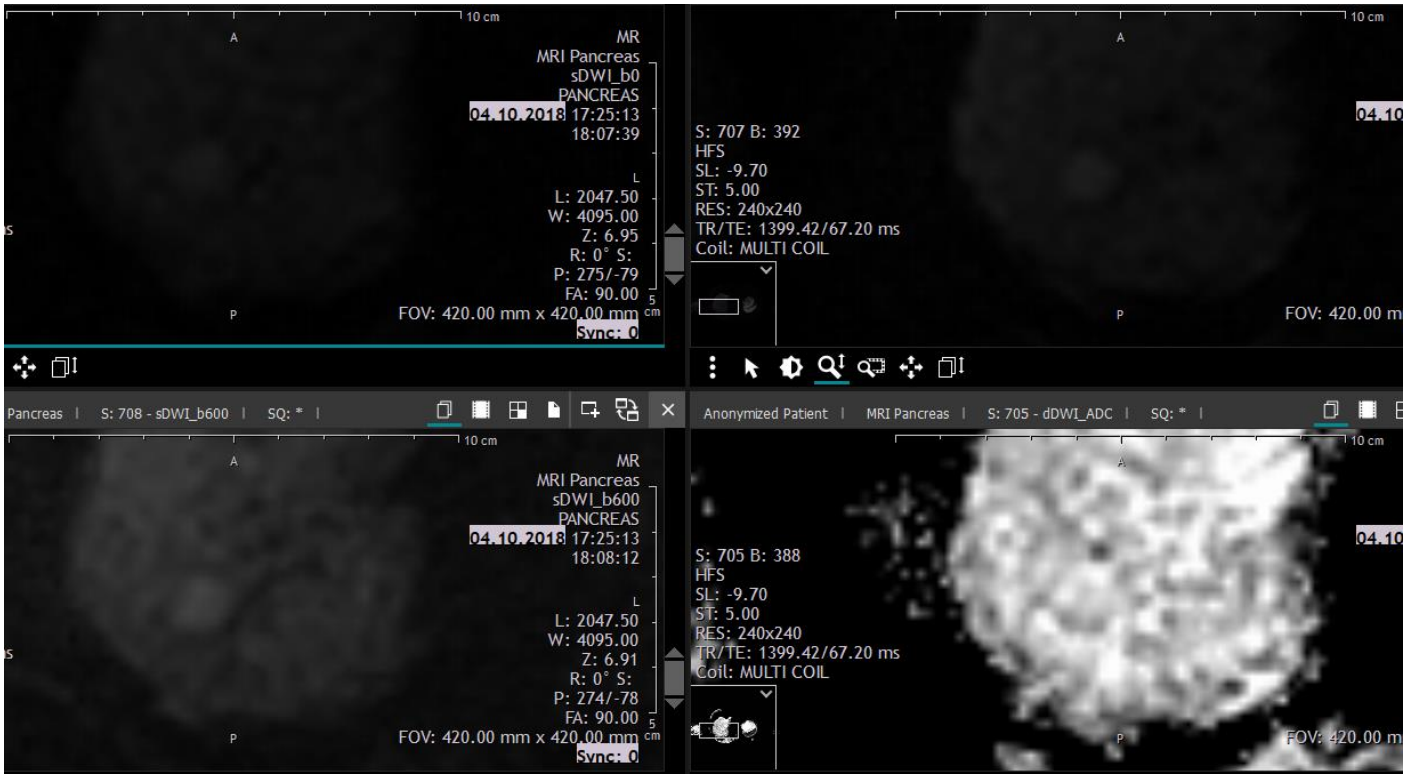
- Radiographer puts patient on the table
- Protocol / Localiser sequence is started in the MRI room
- Use auto planning feature for the knee anatomy
- **2 Sequences**

1. 3D PD SPAIR 0.6 mm isotropic voxels = 5:30 min with auto Reconstructions cor/axial/sagittal (2 mm slice thickness)

2. 2D T1 2:30 min

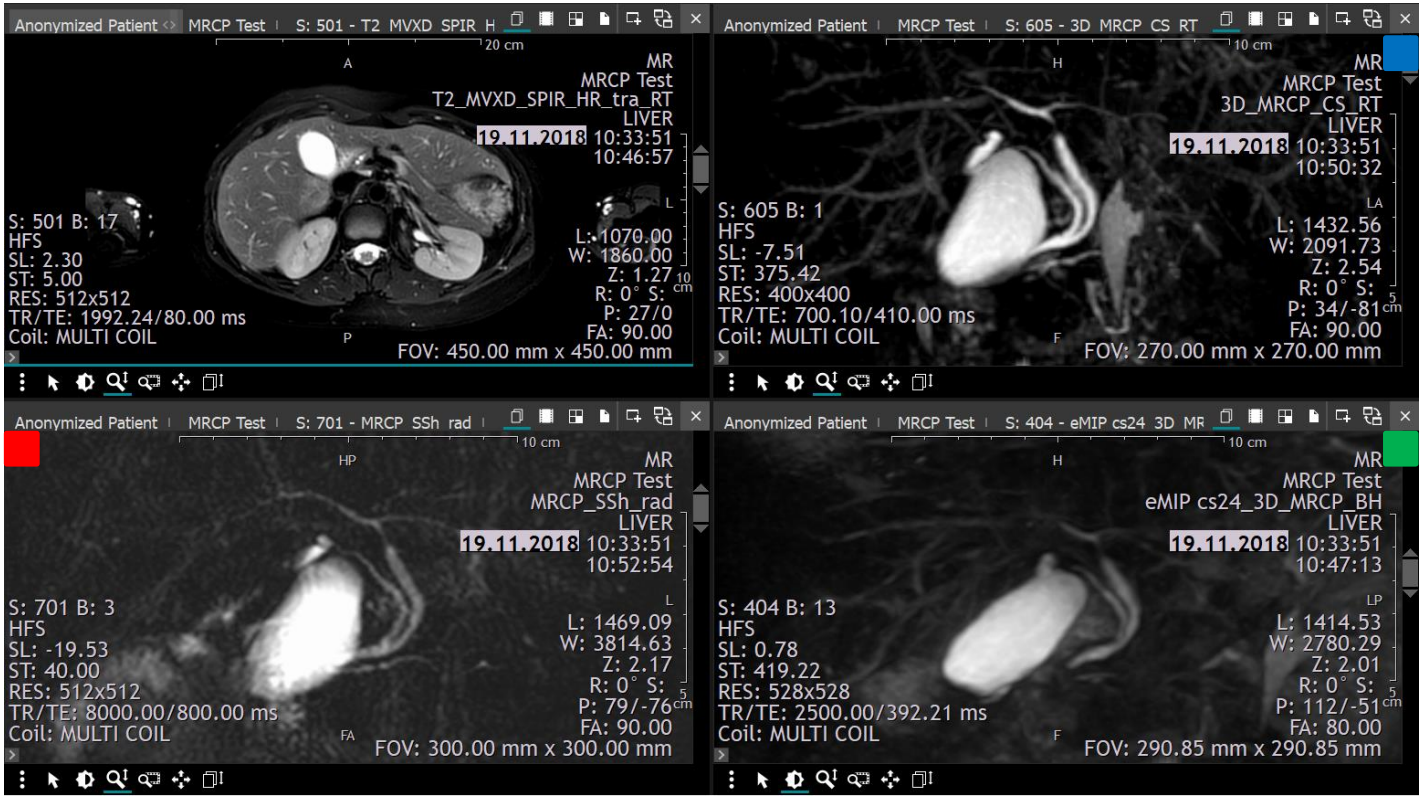
8 Minutes Scan Protocol = 4 Knee MRIs per hour possible

Ambition X – 10 mm Liver Adenoma



11 mm ADC negative subcapsular lesion in segment 7

Ambition X – First Attempt of a single breath hold 3D MRCP CS24 (TU München Sequence)



Bottom right - 12x breath hold single shot, top left - free breathing cs3, bottom left - single breath hold cs24 3D MRCP

This sequence is courtesy of PD Dr Rickmer Braren, Klinikum rechts der Isar der TU München, Institut for Radiology

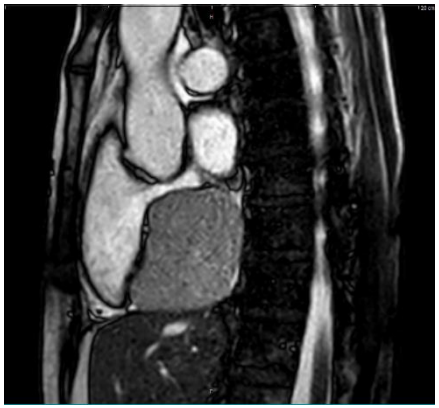
More Cardiac Case Examples

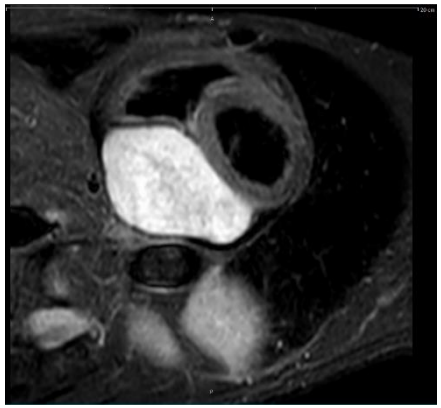
Ambition X - First cardiac tumor, a very rare entity

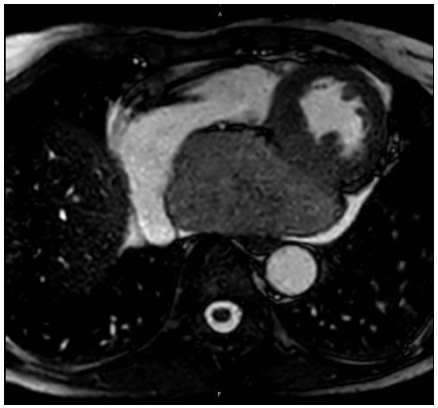
Problem/Diagnosis:

- Acute onset of sharp left sided central chest pain 30-09-2018
- CPK: 43 (30.09.2018 22:23:00)
- Troponin: 0.013 (30.09.2018 22:23:00)
- CTPA showed large soft tissue mass in the pericardium

Ambition X - First cardiac tumor, a very rare entity





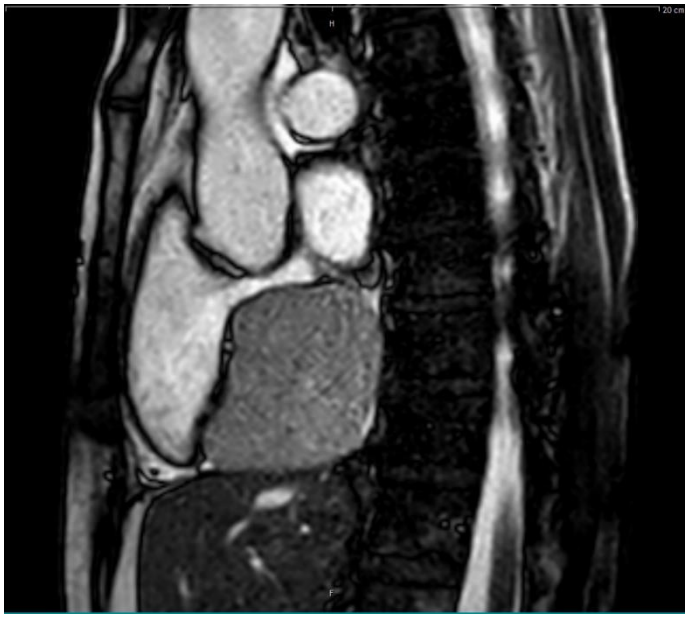


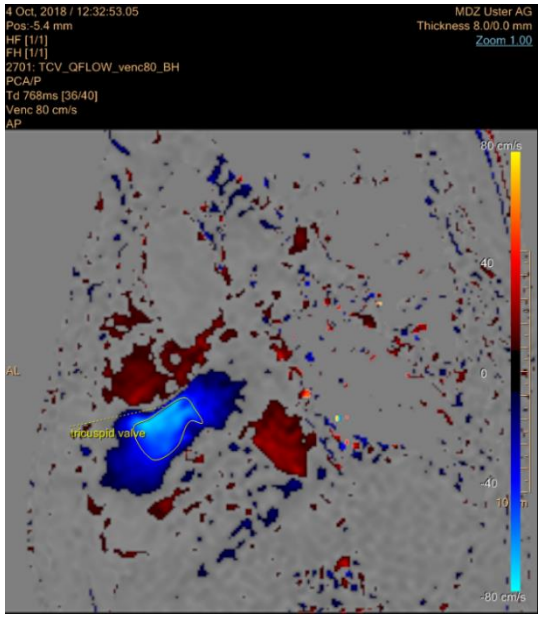
bTFE RV sag

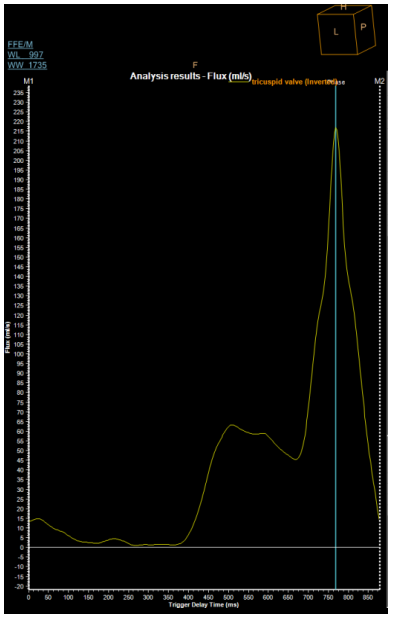
bTFE RV tra

STIR

Ambition X - First cardiac tumor, a very rare entity



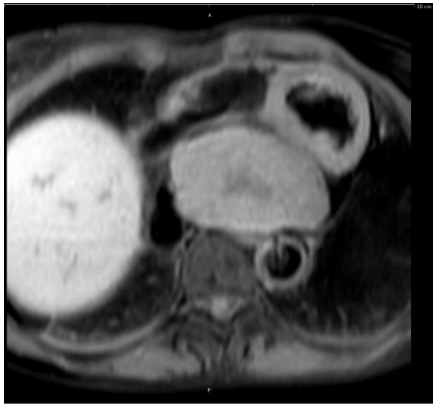


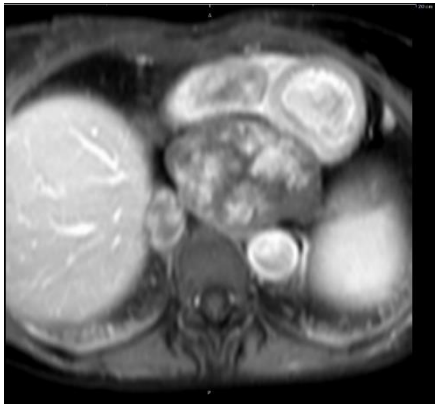


	Range results
	tricuspid valve
Volume inside	37.61 ml
Volume outside	0.06 ml
Maximum velocity	24.27 cm/s
Minimum velocity	-74.27 cm/s

Ambition X - First cardiac tumor, a very rare entity

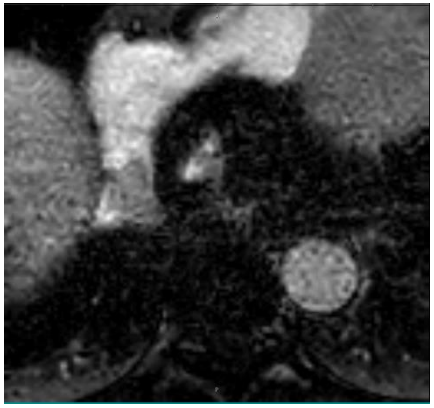
T1 SPIR pre Gd

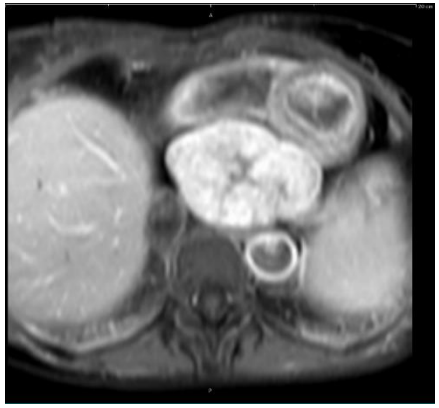




T1 SPIR 4 min

Perfusion





T1 SPIR 20 min

Ambition X - First cardiac tumor, a very rare entity

Cavernous Hemangioma

(image courtesy of Prof. Dr. med. Isabelle Schmitt-Opitz, Consultant Thoracic Surgeon, Thoracic Surgery Department, University Hospital Zürich, Switzerland)

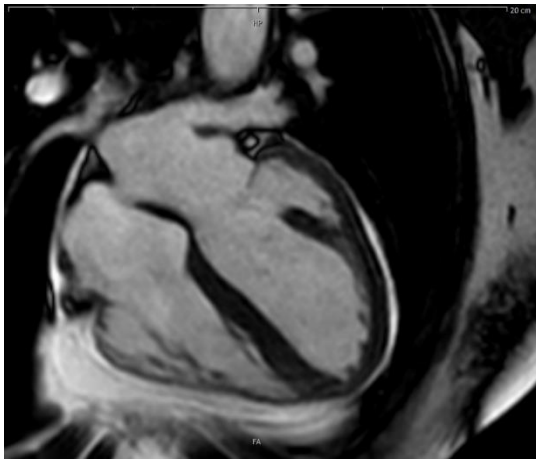
Myocarditis or something else?

Problem/Diagnosis:

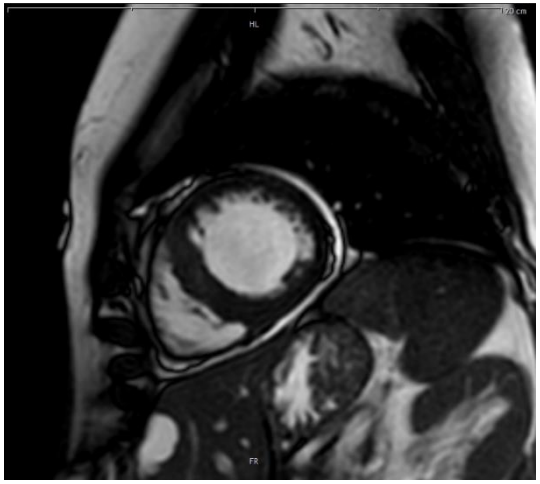
- akute onset of chest pain ED 09.10.2018
- normal coronary arteries (Coronary-CT was done on admission)
- good LV function (LVEF 57%), apikal Akinesia
- small pericardial effusion
- ?Cardiomyopathy, DD Peri-Myocarditis

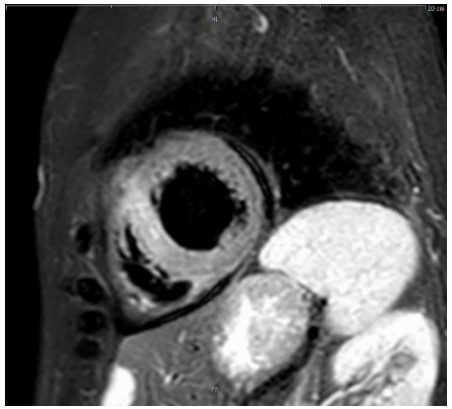
CPK: 65
Troponin: 0.019 (11.10.2018 07:47:00)
Quick: >100 (11.10.2018 07:47:00)
Thrombocyts: 168 (11.10.2018 07:47:00)
CRP: 7.5 (11.10.2018 07:47:00)
Krea: 77 (11.10.2018)

Myocarditis or something else?

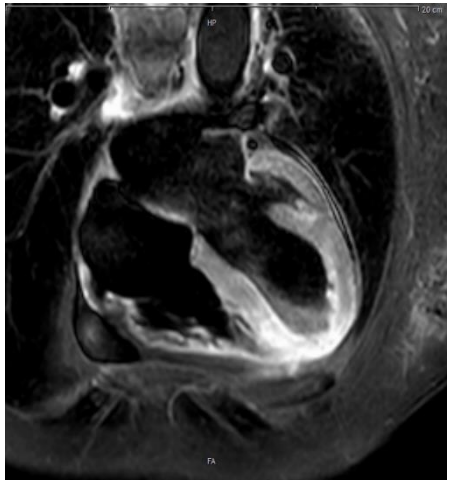


Cine

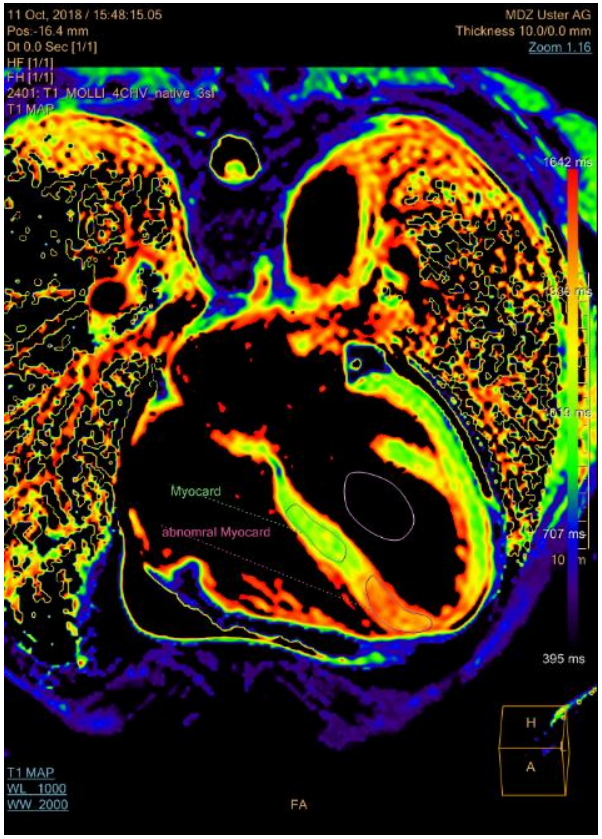




STIR



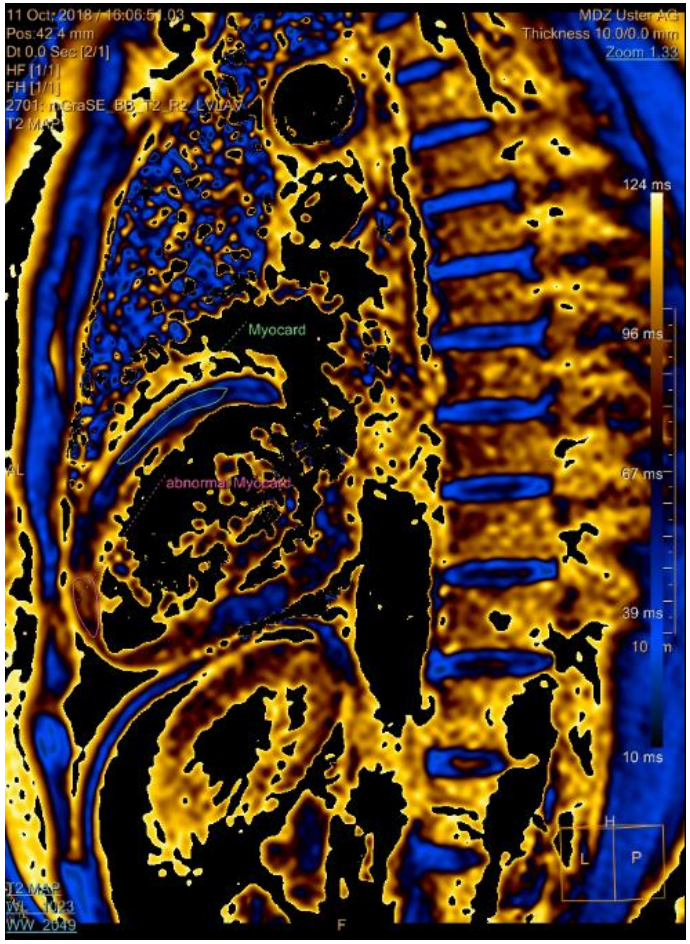
Myocarditis DD Tako-Tsubo Cardiomyopathy with LGE



	T1 Mapping: Local Result-2401	
	Myocard sl.1	abnomral Myocard sl.1
T1 Native	1059±49.0 ms	1415±60.1 ms
R1 Native	0.95±0.04 Hz	0.71±0.03 Hz
T1 Enhanced	N/A ms	N/A ms
R1 Enhanced	N/A Hz	N/A Hz
ε	N/A %	N/A %
ROI Area Native	159 mm²	209 mm²
ROI Area Enhanced	N/A Hz	N/A Hz
Hematocrit	N/A %	N/A %
Field Strength	1.5 T	1.5 T

T1 native map

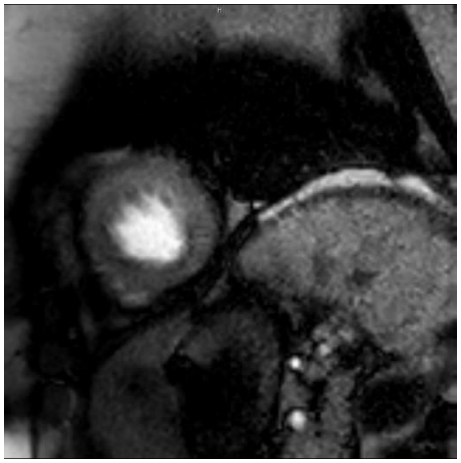
Myocarditis DD Tako-Tsubo Cardiomyopathy with LGE

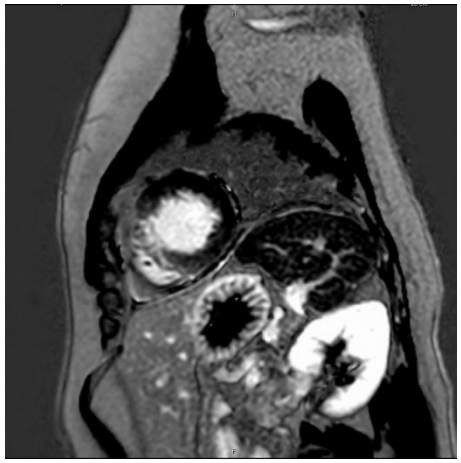


	T2 Mapping: Local Result-2701	
	Myocard sl.1	abnormal Myocard sl.1
T2	55.1±4.82 ms	85.2±7.46 ms
R2	18.3±1.55 Hz	11.8±1.09 Hz
ROI Area	124 mm²	87.9 mm²
Field Strength	1.5 T	1.5 T

T2 map

Myocarditis DD Tako-Tsubo Cardiomyopathy with LGE





Rest Perfusion

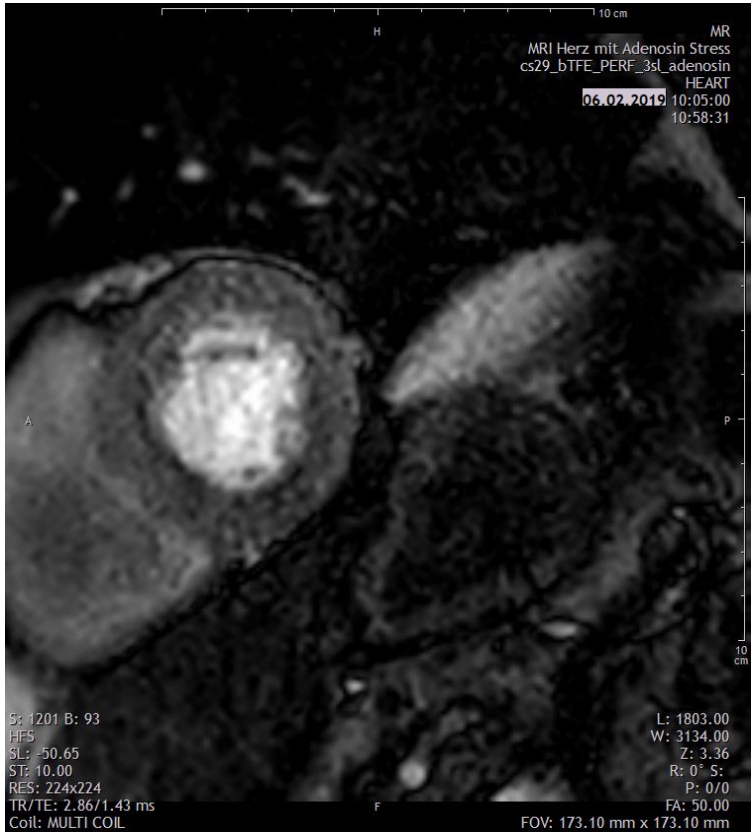
LGE

A usual Patient – 80 kg male

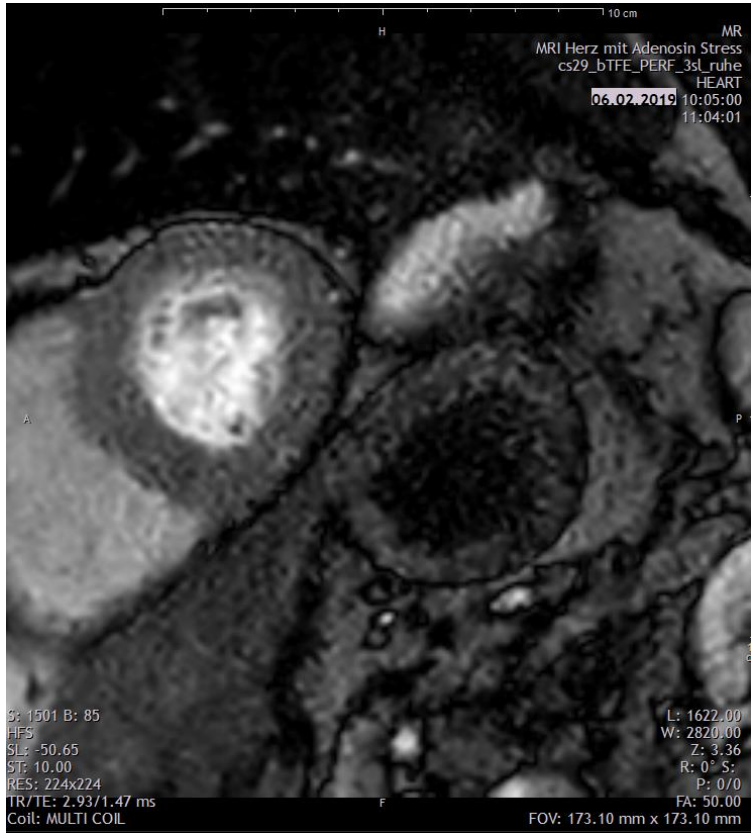
Problem/Diagnosis:

- 71y old male, known IDH
- previous coronary intervention
- again chest pain during exercise
- ETT showed no ST changes, fatique, short runs of bigeminy and short runs of VT at 75 watts
- Limited compliance with breath holding instructions during CMR
- CS 2.9, Adenosin Stress CMR (85 BPM, 1.6 x 1.6 mm in-plane resolution)

A usual Patient – 80 kg male (using bTFE Perf Sequence with CS Factor 2.9)



CS 2.9 Adenosin Stress Perfusion 1.6x1.6 mm , 3SL, 173x173 mm FOV

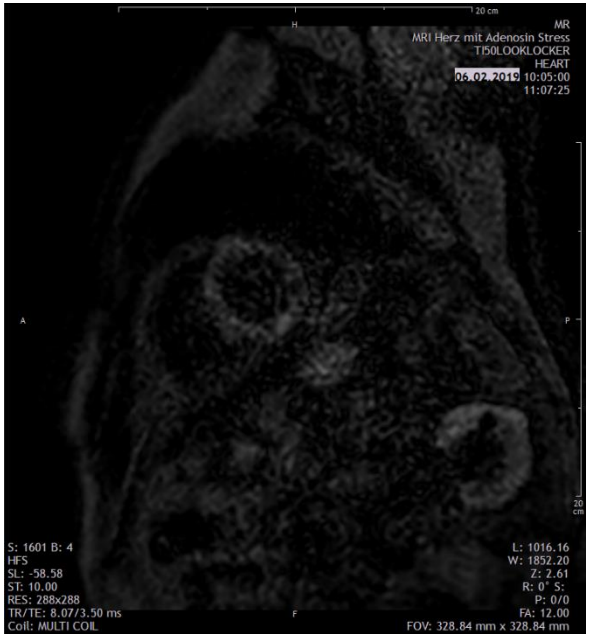


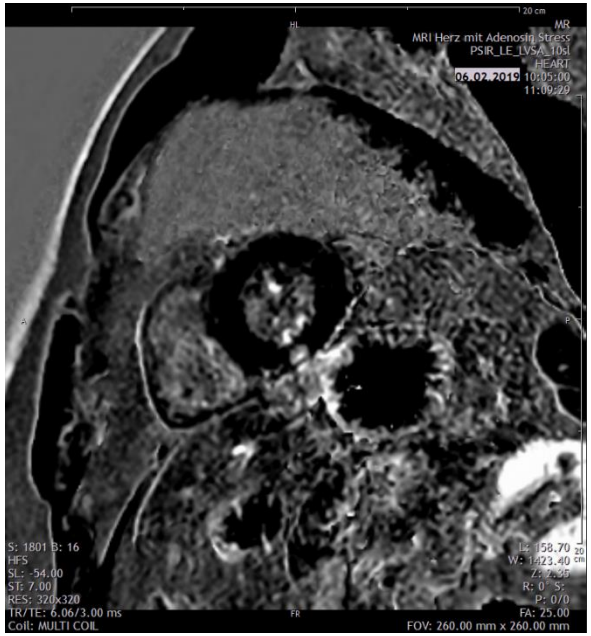
CS 2.9 Rest Perfusion 1.4x1.4 mm , 3SL, 173x173 mm FOV

A usual Patient – 80 kg male

CMR Summary:

- Adenosin stress perfusion, no evidence of reversible ischaemia
- Incidentally, small inferobasal subepicardial LE patch





LookLocker TI 50 ms for the first ECHO – changed from 150 ms (standard sequence setting)

The reason for the LookLocker sequence adjustment

Holtackers *et al. Journal of Cardiovascular Magnetic Resonance* (2017) 19:64
DOI 10.1186/s12968-017-0372-4

Journal of Cardiovascular Magnetic Resonance

TECHNICAL NOTES Open Access

Dark-blood late gadolinium enhancement without additional magnetization preparation

Robert J. Holtackers[1,2*], Amedeo Chiribiri[1], Torben Schneider[3], David M. Higgins[3] and René M. Botnar[1,4]

Abstract

Background: This study evaluates a novel dark-blood late gadolinium enhancement (LGE) cardiovascular magnetic resonance imaging (CMR) method, without using additional magnetization preparation, and compares it to conventional bright-blood LGE, for the detection of ischaemic myocardial scar. LGE is able to clearly depict myocardial infarction and macroscopic scarring from viable myocardium. However, due to the bright signal of adjacent left ventricular blood, the apparent volume of scar tissue can be significantly reduced, or even completely obscured. In addition, blood pool signal can mimic scar tissue and lead to false positive observations. Simply nulling

2-Vessel Disease, Stenosis Post-Intervention – What to do next?

Problems/Diagnosis

Asymptomatic patient

Known 2-vessel disease / dominant right coronary artery

Coronary Intervention & Findings on 25.09.2018:

- POBA (plain old balloon angioplasty) no stenting of a heavily calcified 90-99% stenosis of the proximal RCA and of a long 70-90% stenosis of the distal in der distalen RCA. During this intervention => spiral dissection of the mid to the distal heavily calcified RCA, good flow

Follow up Coronary Angiogram 02.11.2018:

- RCA dissection unchanged with good flow
- Remaining 70-90% ostial RCX-Stenosis, chronic occlusion OM2/PLA (collateralised, Rentrop 3)
- LAD with diffuse wall irregularities, no significant stenosis

2-Vessel Disease, Stenosis Post-Intervention – What to do next?

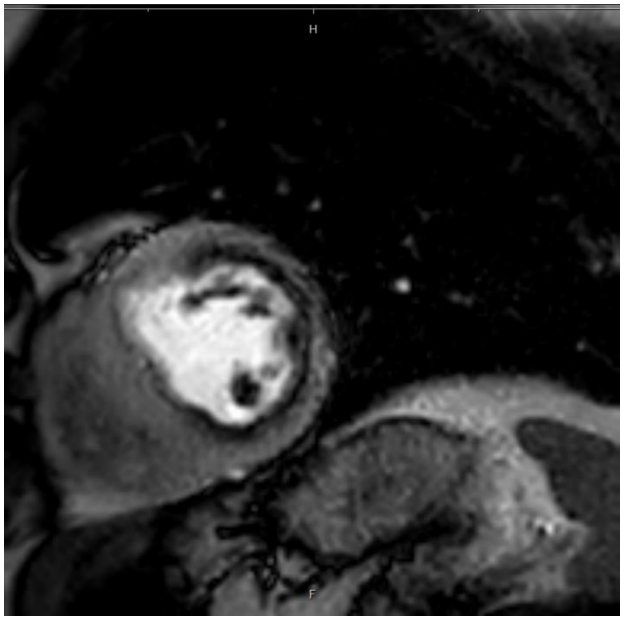
Question for CMR: Inducible ischemia yes/no?

- Cardiology team had decided, in view of the good flow in the disected RCA and no symptoms, no further attempt to intervene in the RCA. No„relevant stenosis seen“ in der follow up angiogram on 02.11.2018

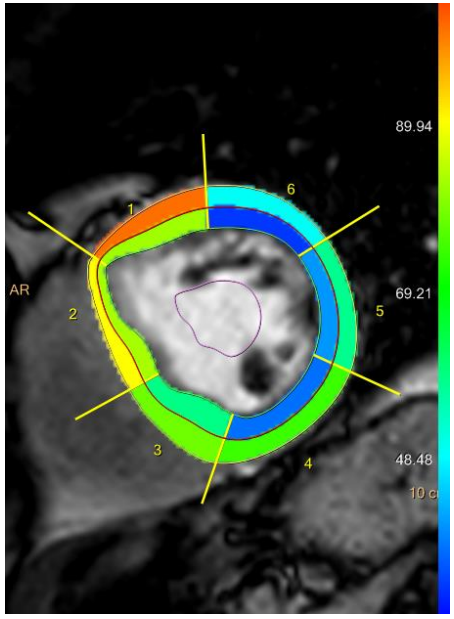
- In case there is inducible ischemia in the RCA-teritory they would reconsider PTCA/stenting vs surgical revascularisation

- No inducible ischemia – they would do nothing

2-Vessel Disease, Stenosis Post-Intervention – What to do next?



CS 2.3 Adenosin Stress Perfusion (1.6 x 1.6 mm in plane resolution, 3-slices, HR 75 BPM)



Stress Perfusion Colour Map

2-Vessel Disease, Stenosis Post-Intervention – What to do next?

Decision => Surgical Revascularisation in view of the extensive reversible perfusion defect (9 segments affected with relative sparing of the septum)

Despite Rentrop 3 Collateralisation as shown in the coronary angiogram!

CMR made the difference in this asymptomatic patient!

Take Home Message

- I hope you agree…..the Ambition X is delivering amazing images
- Our patients are more comfortable and compliant during the exam due to the InBore Information system

- VitalEye Respiratory Sensing is very useful (e.g. Liver Diffusion Imaging, MRCP)
- We use CS extensively. CS is a robust acceleration technology
- Thanks to CS we have major improvements of the diagnostic quality of our CMR perfusions studies…….that's the end of the dark rim artefact!
- We as a team would like to particularly thank Mrs. Erika Brüllmann, Philips Application Specialist for her dedicated support during this implementation phase

Thank you