



Semmelweis Egyetem

KARDIOLÓGIAI
KÖZPONT

Kardiológiai Központ, Radiológia

**Klinikai kardiovaszkuláris
fiziológia MR-rel**

Mágneses rezonancia

- Történelem
 - Steady-state free precession in nuclear magnetic resonance
 - **Phys Rev 112(5):1693-1701 (1958)**, HY Carr
 - Gadolinium-DTPA as a contrast agent in MRI: initial clinical experience in 20 patients
 - **Am J Roentgenol 143(2):215-227 (1984)**
 - Magnetic resonance imaging of the heart: a review of experience in 172 subjects
 - **Radiology 155(3):671-679 (1985)**, CB Higgins

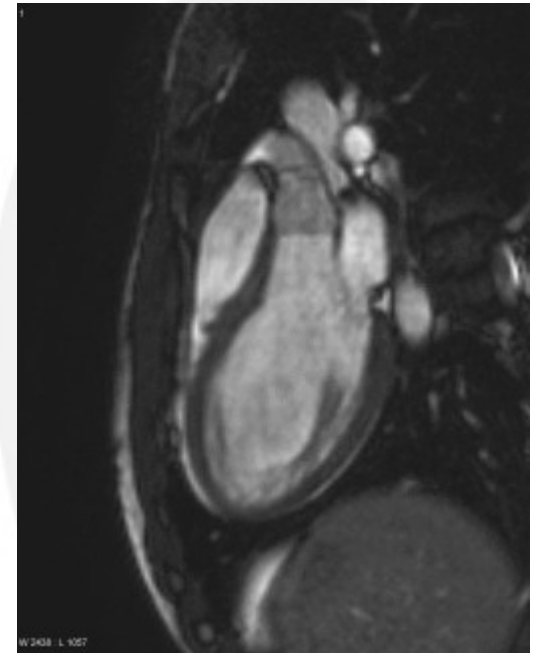
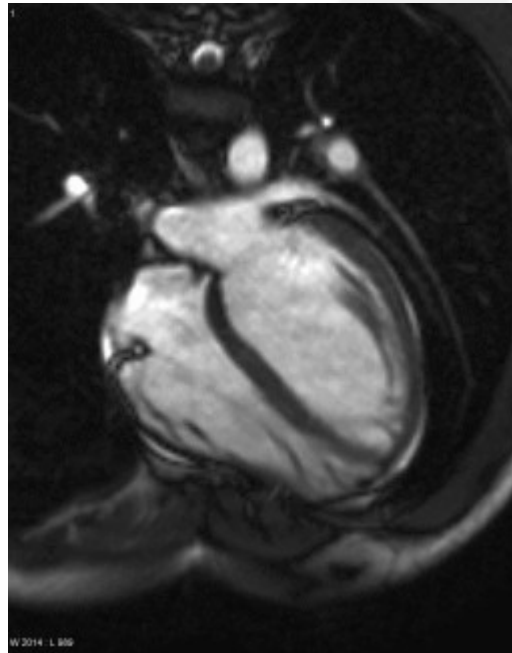
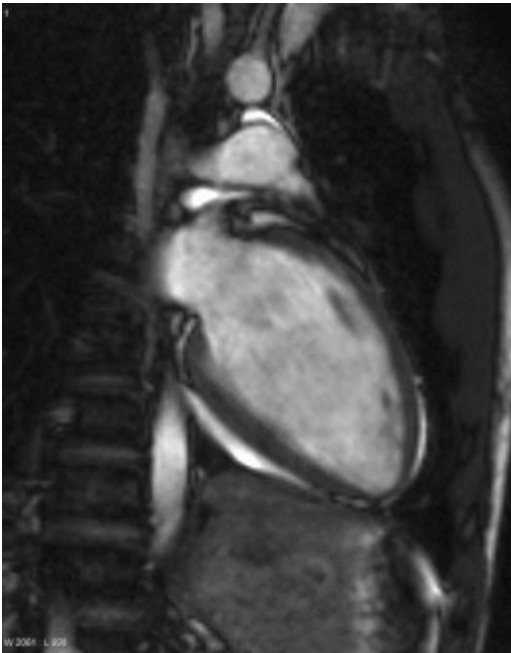


Mágneses rezonancia

- Nincs ionizáló sugárzás
- Kiváló kontraszt
- Pontos
- Áramlás mérés
- Időigányes
- Monitorozás
- Kooperáció szükséges
- Komplikált



Hossztengely

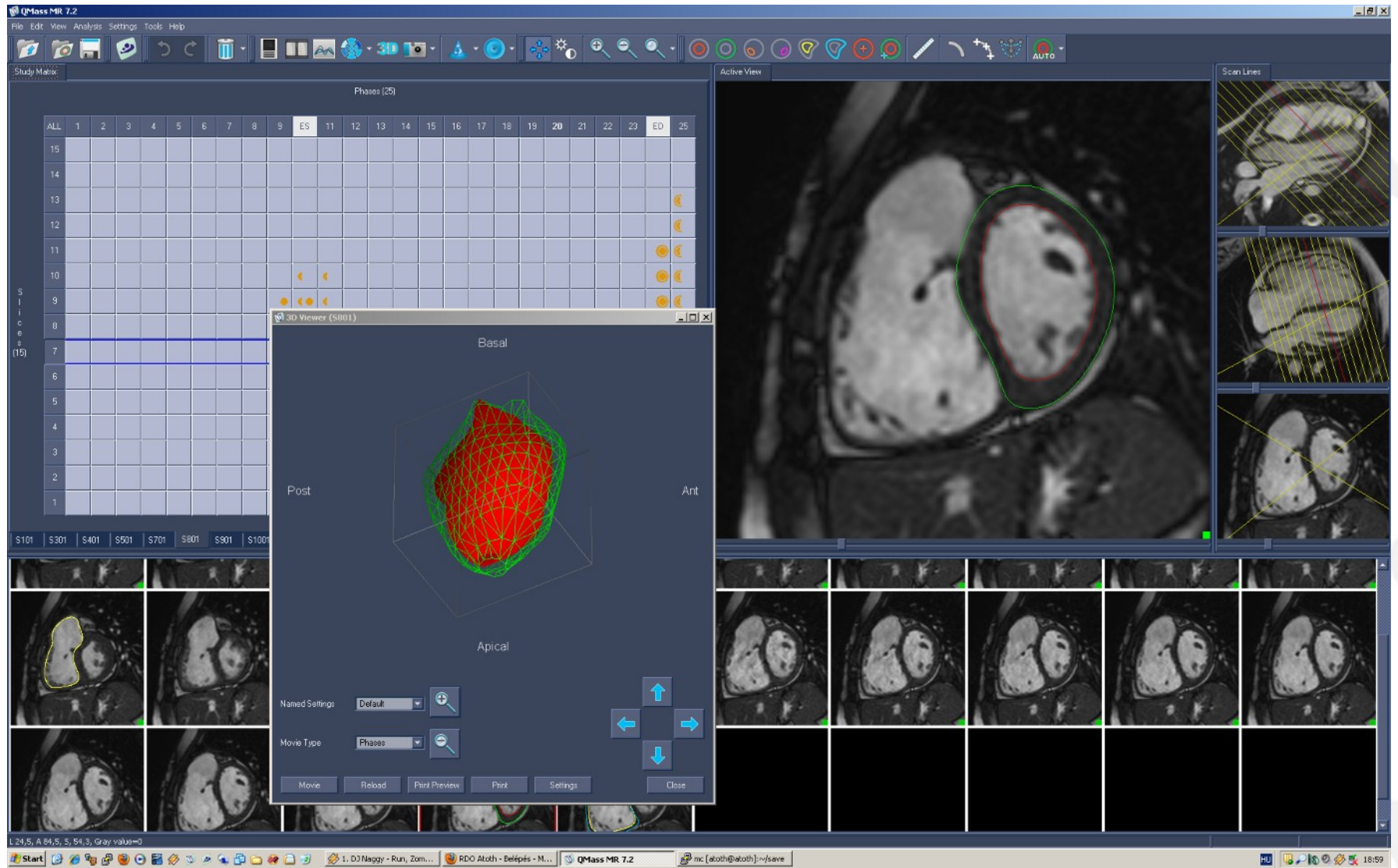


Térfogat állandóság felismerése

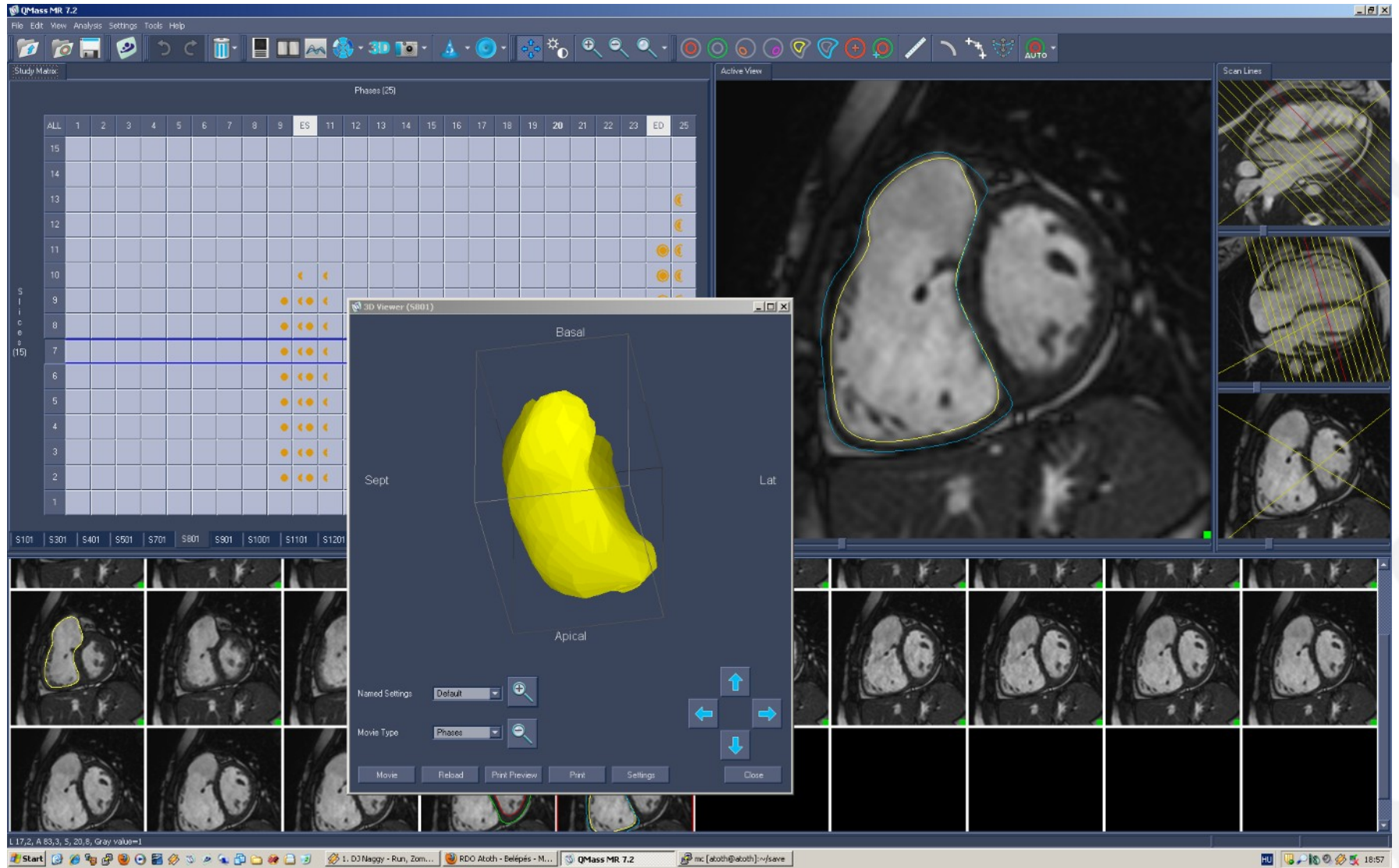
- A perikardium zsák kiterjedése majdnem konstans a szív ciklus során
 - Normál esetben kevesebb, mint 5%-os kitérést mutat
 - Prof Kovács J Sándor
 - **AJP Heart Circ Physiol 285(5):H2027 (2003)**
 - **<http://cbl1.wustl.edu>**



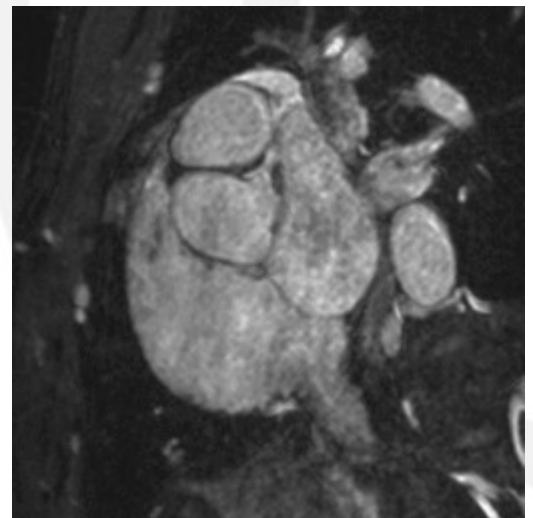
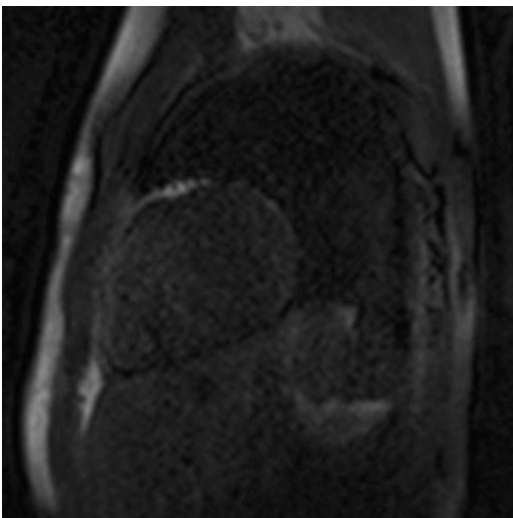
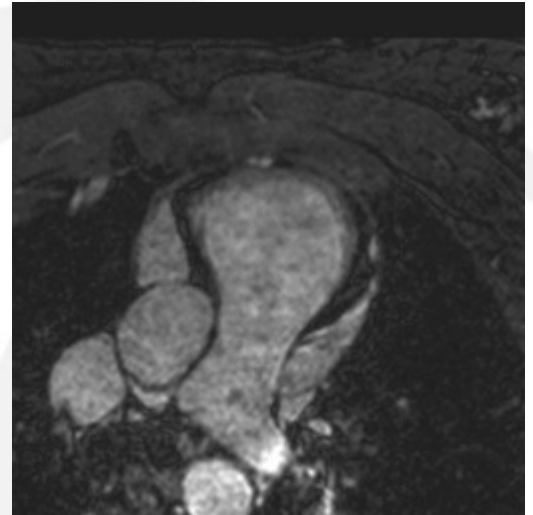
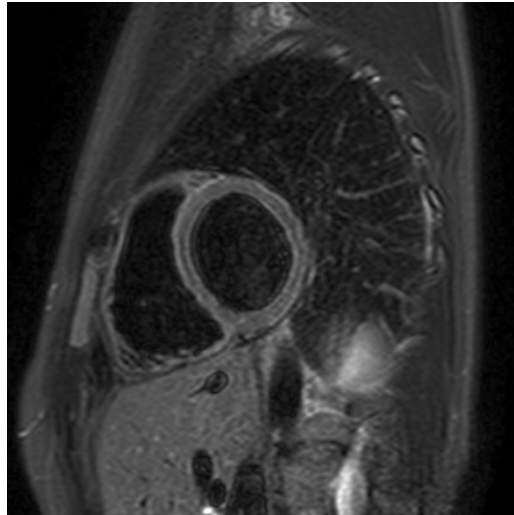
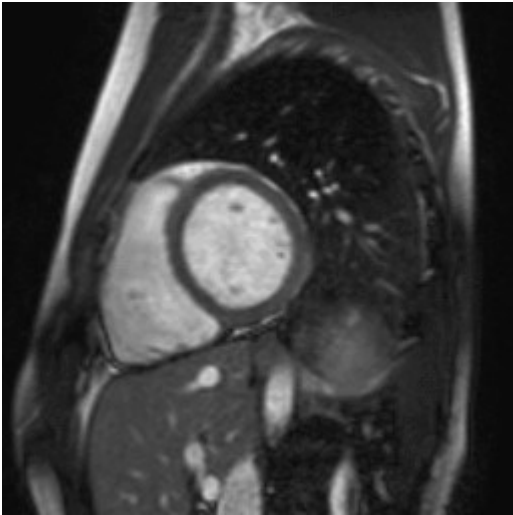
Bal kamrai kiértékelés



Jobb kamrai kiértékelés

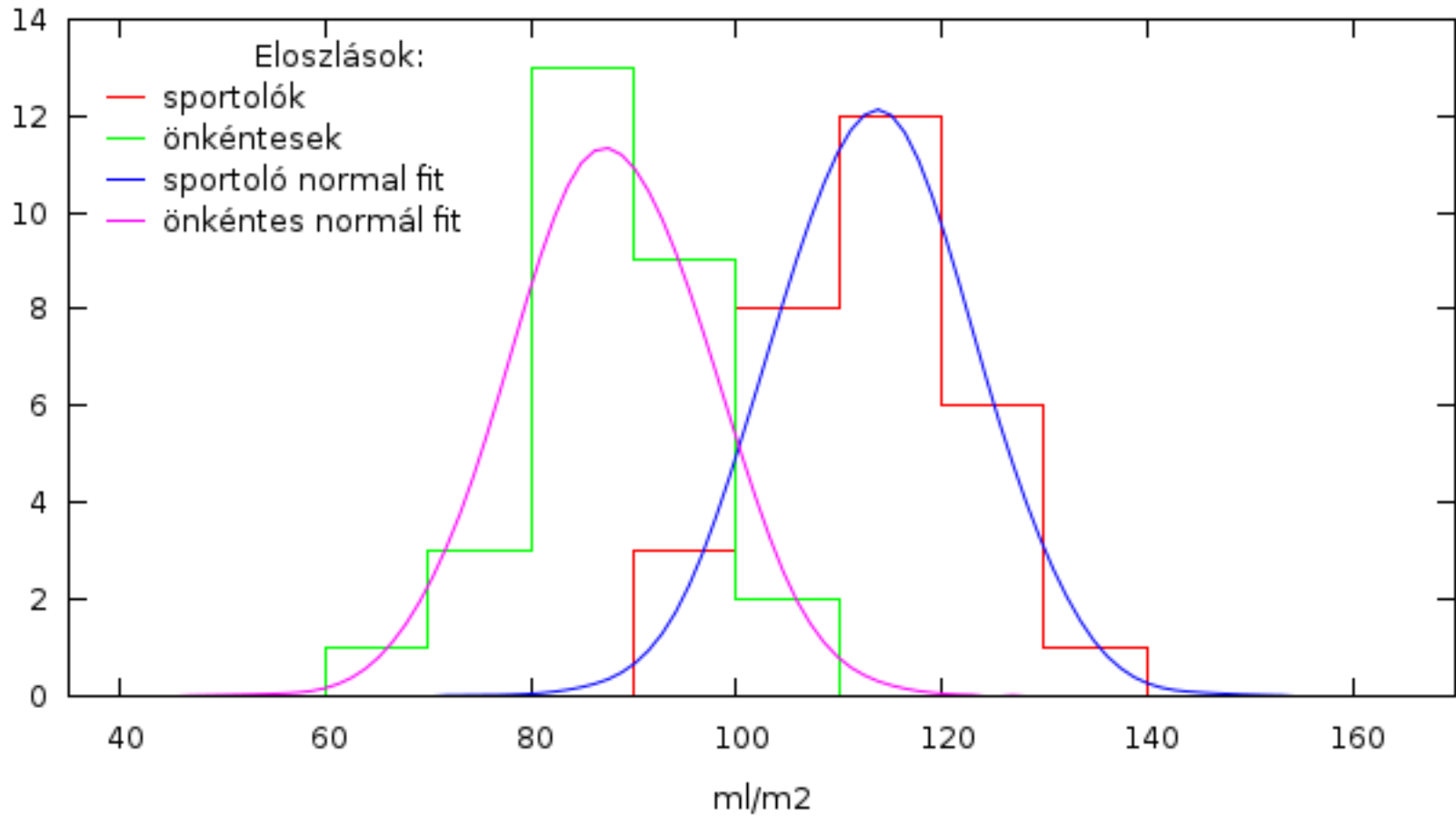


Női vízilabda játékos

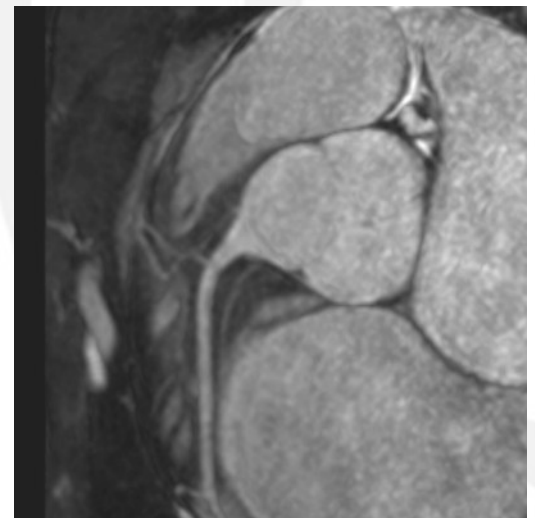
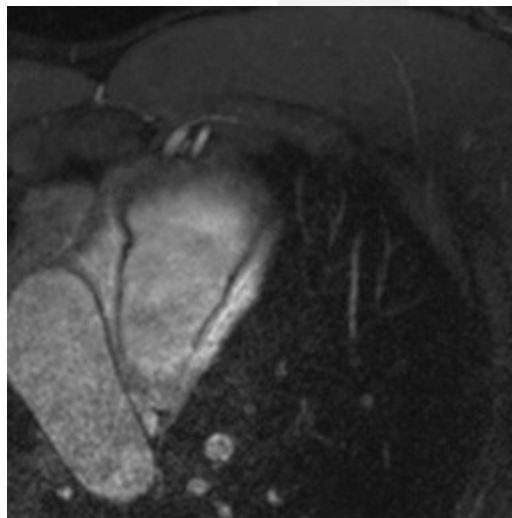
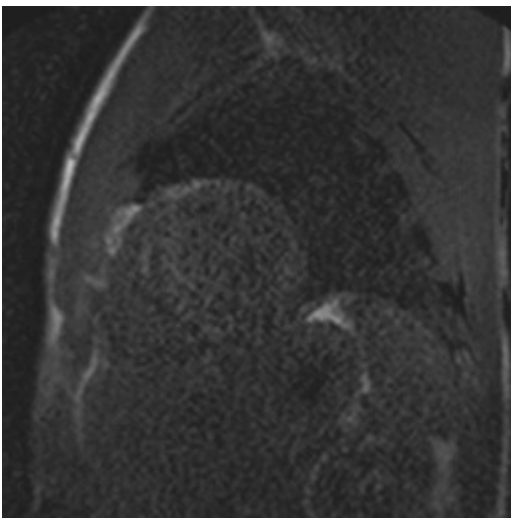
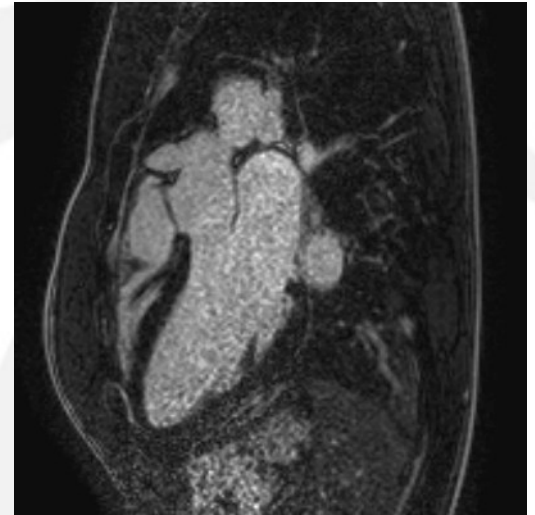
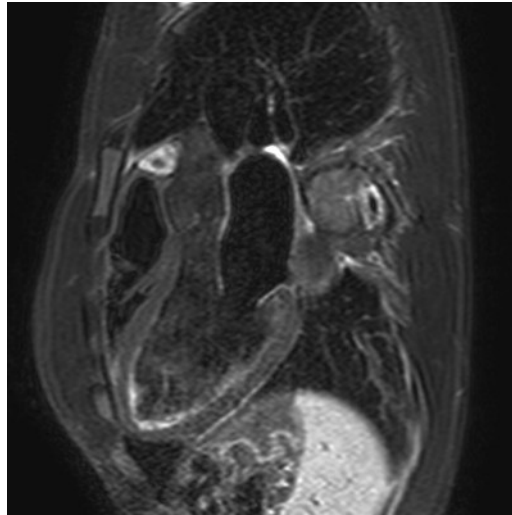


LV EDV index – nők

LVEDVi - nők

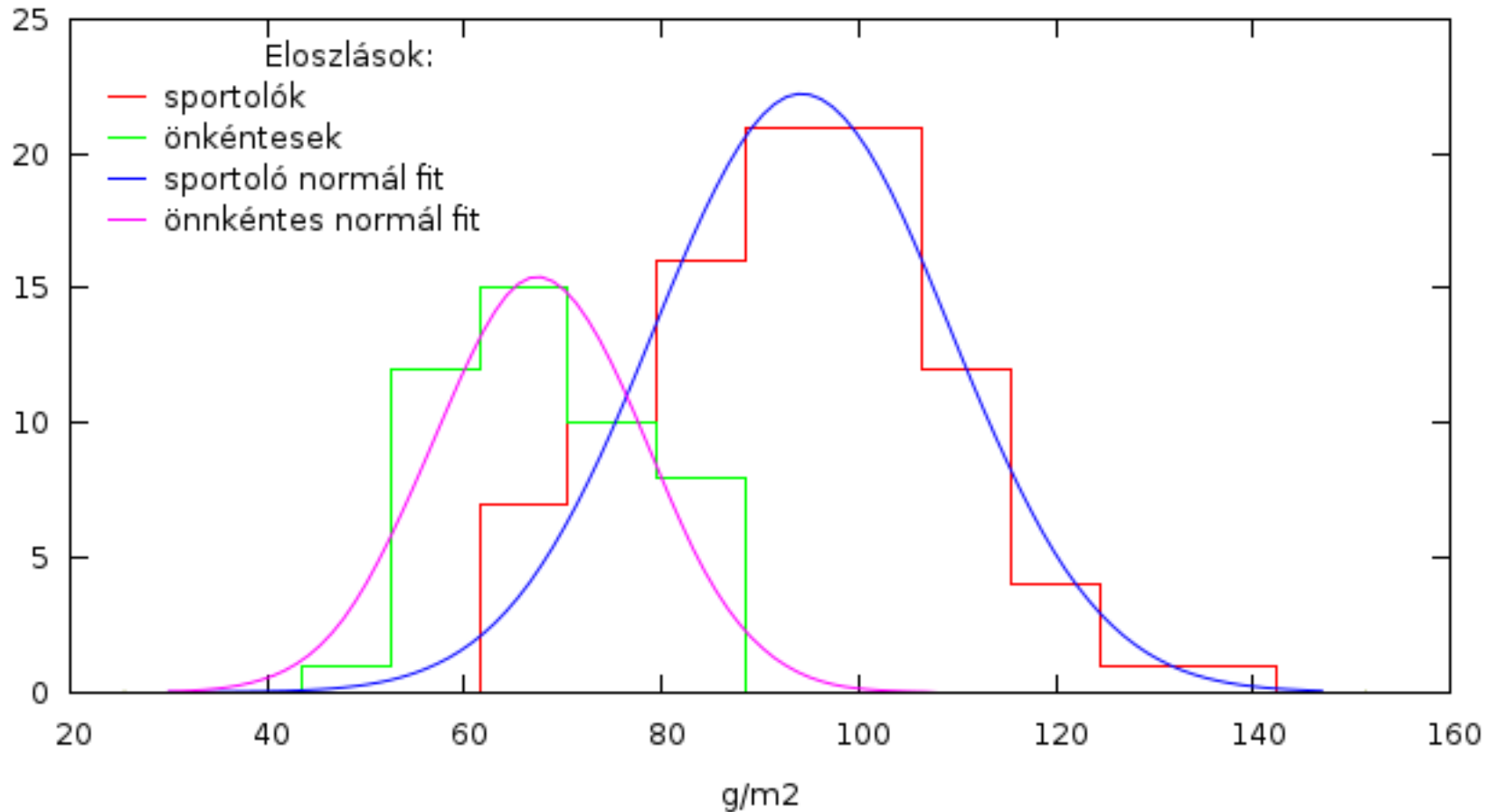


Férfi kajakos



Bal kamra izomzat tömeg index – ffi

LVMi - férfiak



Férfi normál értékek

Paraméter	Önkéntes (48)	Vízilabdázó (N = 23)	Kajakos (N = 21)	Kenus (N = 15)	Kerékpáros (N = 9)	Ultrafutó (N = 5)	Evezős (N = 15)	Csörgőlabda (N = 6)
BSA (m ²)	2.04 ± 0.18	2.33 ± 0.09	2.08 ± 0.13	2.00 ± 0.08	1.87 ± 0.10	1.82 ± 0.08	2.00 ± 0.11	2.13 ± 0.19
LVEF	60.2 ± 5.3	57.0 ± 3.4	57.7 ± 4.8	56.9 ± 3.4	56.8 ± 3.5	58.1 ± 3.5	56.2 ± 4.0	58.7 ± 4.4
LVESVi	38.1 ± 8.3	53.0 ± 8.0	52.2 ± 10.5	56.5 ± 8.7	54.3 ± 5.9	46.9 ± 2.8	54.8 ± 9.2	41.6 ± 8.0
LVEDVi	95.2 ± 12.1	123.0 ± 13.3	122.5 ± 14.7	131.0 ± 14.6	125.3 ± 6.4	112.1 ± 5.0	124.5 ± 12.5	99.8 ± 12.2
LVSVi	57.1 ± 7.0	70.0 ± 7.8	70.3 ± 7.6	74.5 ± 8.2	71.1 ± 4.8	65.2 ± 6.3	69.6 ± 5.9	58.3 ± 6.0
LVMi	63.5 ± 10.3	86.4 ± 14.7	95.7 ± 11.1	102.2 ± 13.4	78.1 ± 15.4	79.5 ± 9.7	90.2 ± 9.0	62.6 ± 7.2
RVEF	59.1 ± 4.8	56.2 ± 4.4	55.7 ± 4.3	53.6 ± 3.9	55.1 ± 4.8	57.9 ± 3.0	54.6 ± 3.9	57.1 ± 1.2
RVESVi	40.1 ± 8.3	56.3 ± 11.6	58.1 ± 11.6	64.3 ± 8.9	60.1 ± 10.1	51.4 ± 10.5	59.8 ± 9.4	42.1 ± 5.2
RVEDVi	97.5 ± 13.2	127.7 ± 17.4	130.4 ± 16.7	138.5 ± 14.4	133.3 ± 9.6	122.1 ± 10.5	131.0 ± 12.9	98.3 ± 12.7
RVSVi	57.4 ± 7.7	71.4 ± 8.5	72.3 ± 7.8	74.2 ± 9.0	73.2 ± 5.3	70.7 ± 8.3	71.2 ± 6.2	56.2 ± 7.6
RVMi	24.9 ± 3.6	30.6 ± 3.7	34.2 ± 5.2	34.5 ± 4.9	34.5 ± 4.4	28.2 ± 2.8	33.6 ± 2.7	22.0 ± 2.4
LVED FVS	11.02 ± 1.38	13.17 ± 1.64	13.52 ± 1.91	12.87 ± 1.60	12.00 ± 1.23	12.25 ± 1.26	13.07 ± 1.39	10.50 ± 0.55
Sport index	.118 ± .0246	.107 ± .0149	.112 ± .0231	.099 ± .0181	.096 ± .0122	.109 ± .0119	.106 ± .0150	.106 ± .0115

HCM és DCM példa

Parametér	Önkéntes	Élsportoló	DCM	HCM
HR	66,74 (11,24)	59,52 (10,10)	46	53
BSA	2,056 (0,191)	2,046 (0,184)	2,08	2,04
LVEF	59,53 (5,57)	57,51 (4,26)	40,4	63,78
LVESVi	38,72 (8,69)	53,50 (9,63)	112,45	39,99
LVEDVi	95,09 (12,77)	125,25 (13,87)	188,57	110,41
LVSVi	56,37 (7,53)	71,76 (7,21)	76,13	70,42
LVMi	62,93 (11,21)	88,09 (17,66)	125,98	160,90
RVESVi	41,30 (8,10)	59,19 (11,45)	68,52	36,86
RVEDVi	98,37 (13,61)	132,66 (15,40)	144,45	102,08
RVSVi	57,08 (8,33)	73,46 (7,28)	75,94	65,22
RVMi	25,11 (3,97)	34,16 (5,17)	34,30	36,17
ED WT	11,09 (1,46)	12,78 (1,93)	–	29
Sport index	0,119 (0,026)	0,103 (0,021)	–	0,26

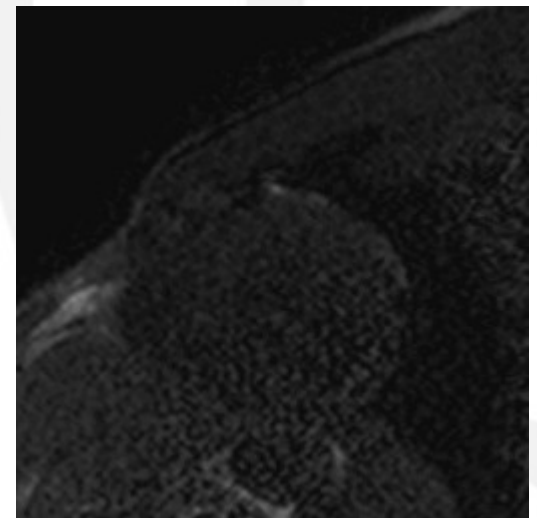
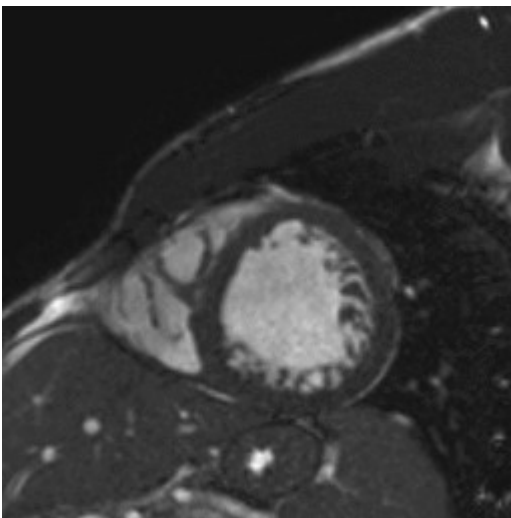
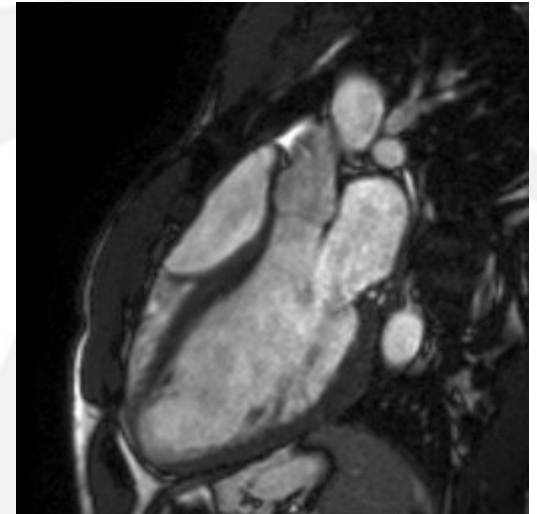
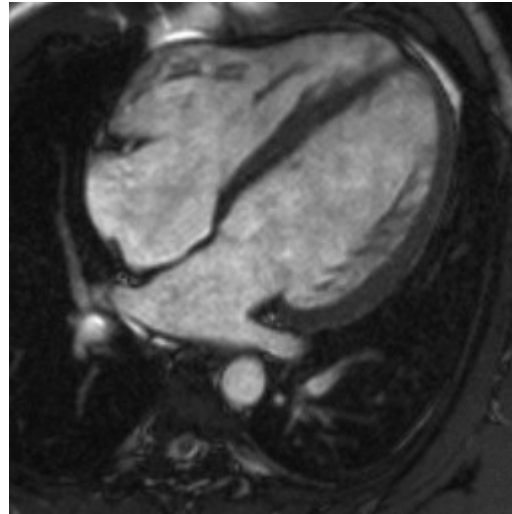
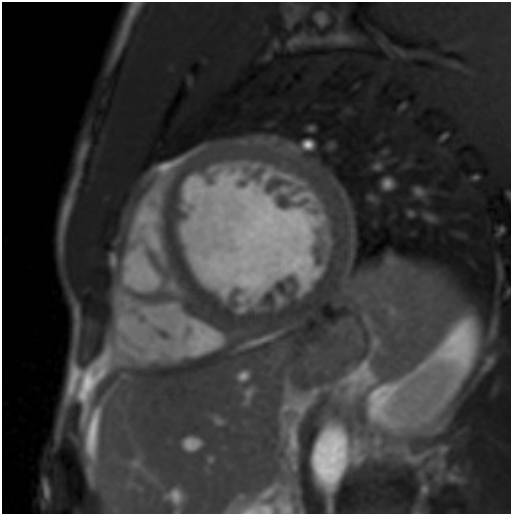


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Hoki játékos: dilatatív CMP



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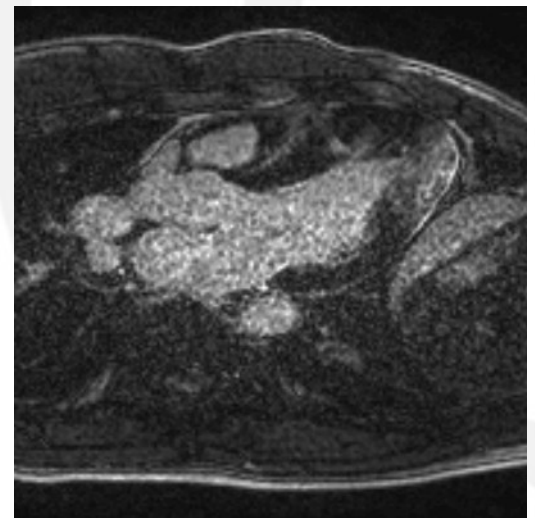
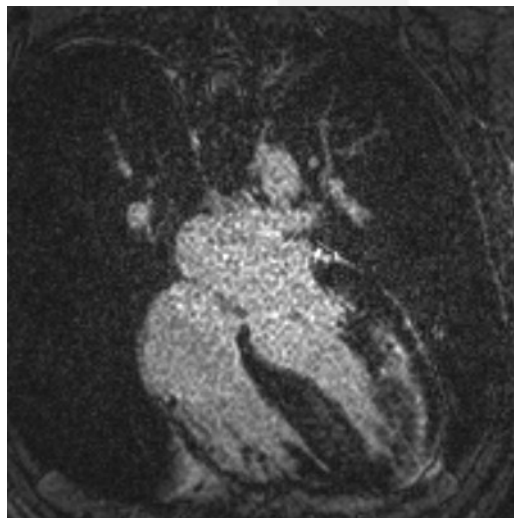
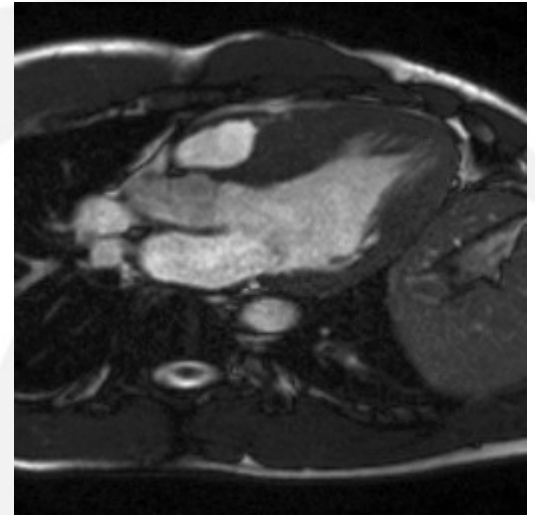
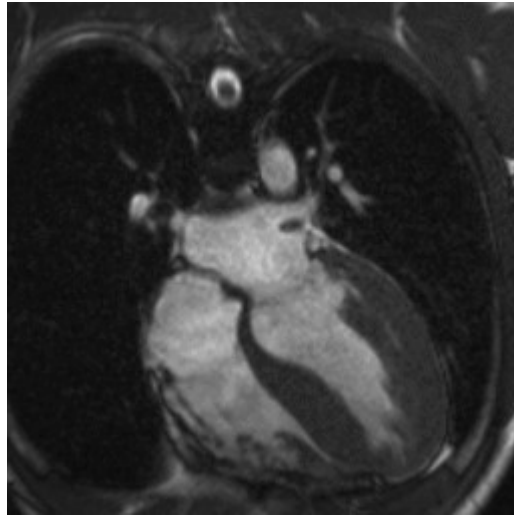
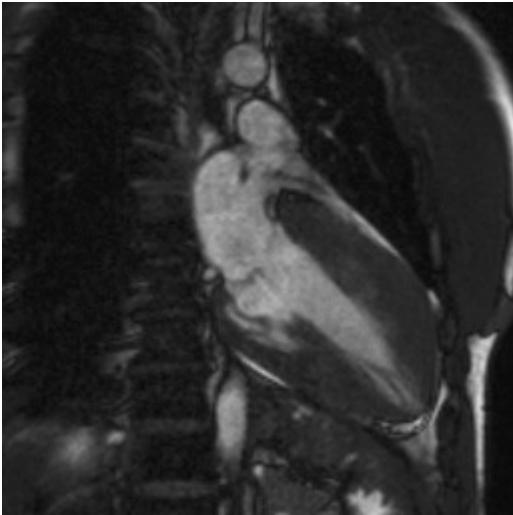


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HCM élsportolónál



LGE kiértékelés: 63g heg 360g-ból

The screenshot displays the QMass MR 7.2 software interface. The main window shows a cardiac MRI slice with a red contour for the myocardium and a green contour for the scar tissue. The software has calculated the following results:

Parameter	Value
Total myocardial mass	360,33 g
Scar tissue mass	63,20 g
Scar tissue volume	60,19 ml
Scar tissue percentage	18 %
Nonviable mass	5,33 g
Nonviable volume	5,08 ml
Nonviable percentage	1 %
Transmurality threshold	50 %

Technical parameters for the scan are listed below the main image:

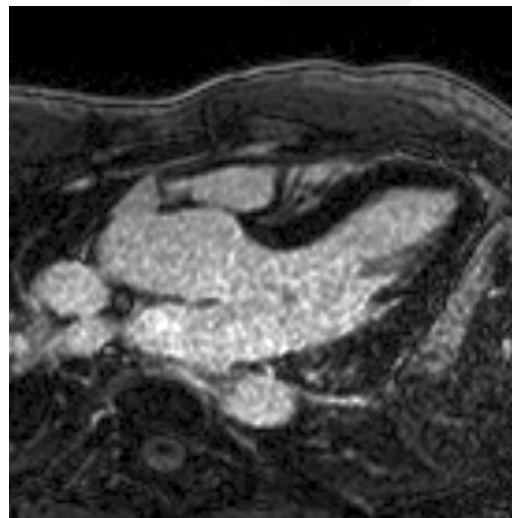
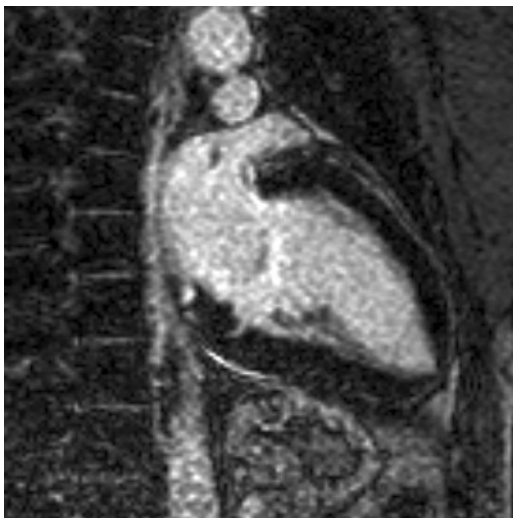
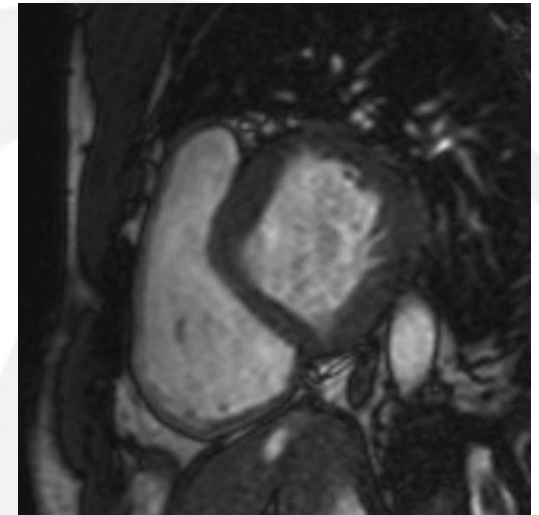
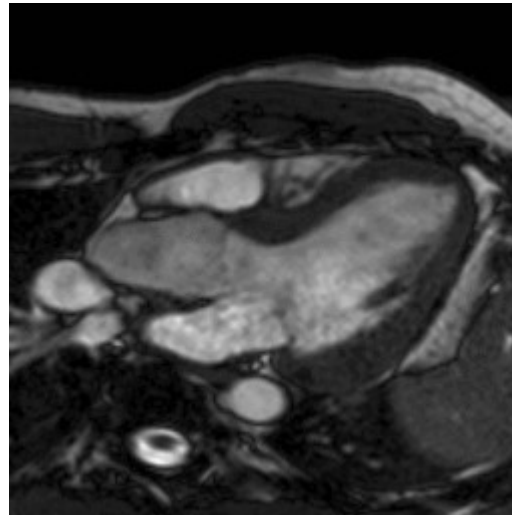
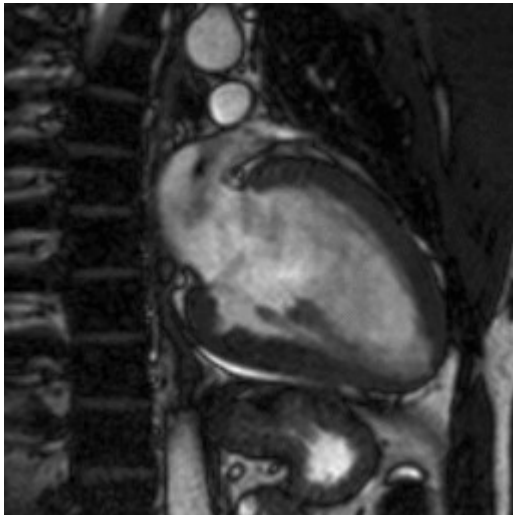
- TR: 5,49ms
- TE: 2,52ms
- Ti: 0,00ms
- TD: 773ms
- SL: 12
- PH: 1
- SP: 88,00mm
- SI th: 8mm

Summary statistics at the bottom right of the main image:

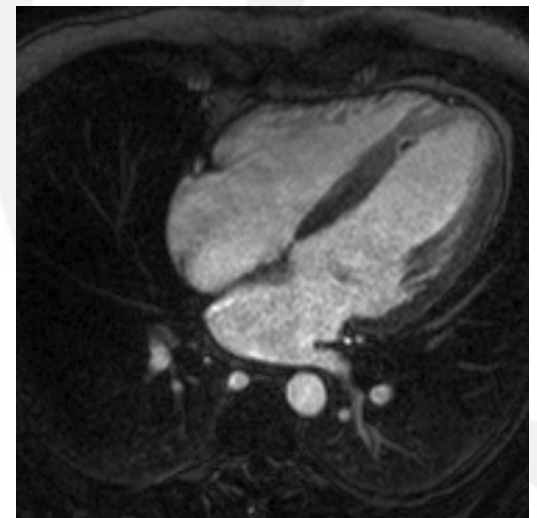
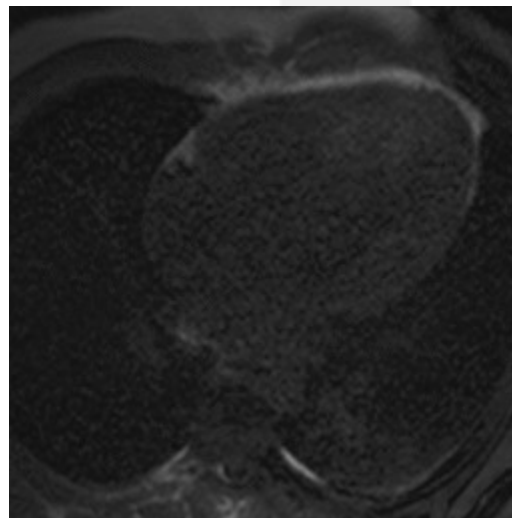
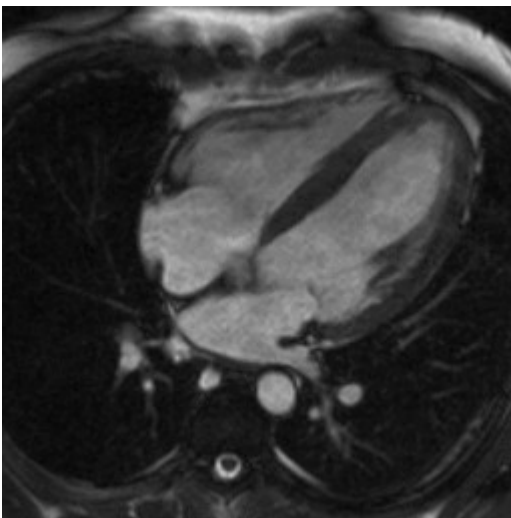
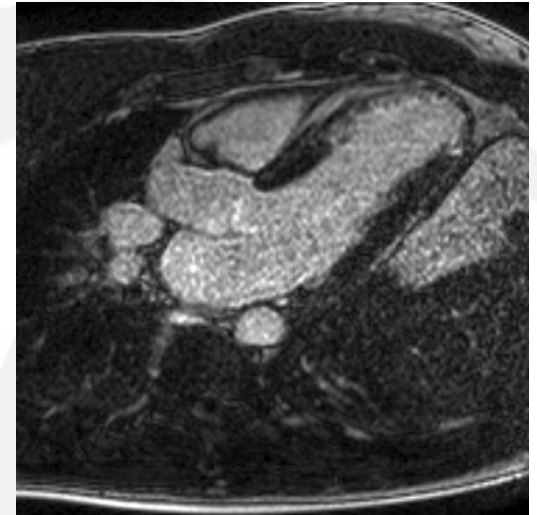
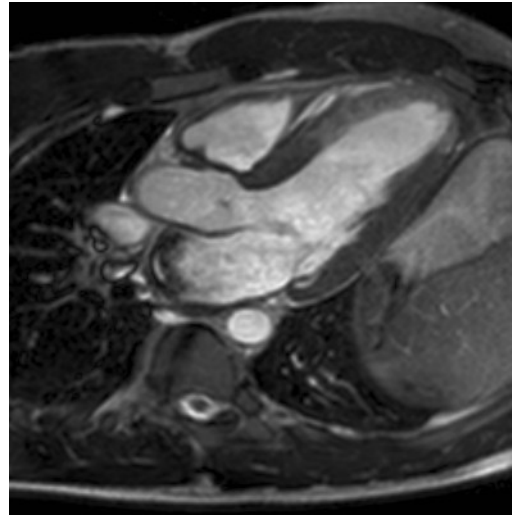
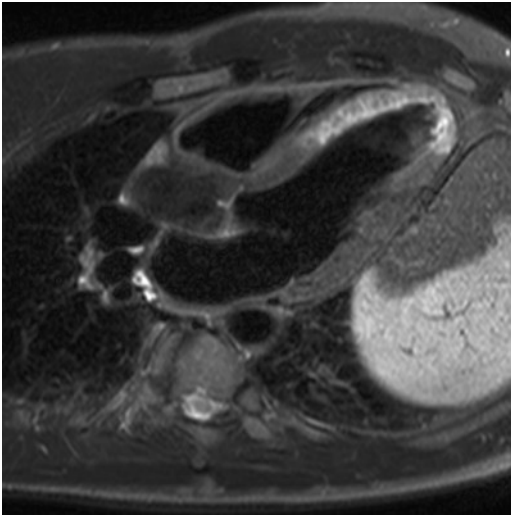
- Total mass: 360,33g
- Scar tissue: 63,20g / 18%
- WW: 138
- WL: 2 090
- Zoom: 175%

The interface also shows a grid of 18 small images at the bottom, representing different slices or views of the heart. The software title bar indicates 'QMass MR 7.2' and the user is logged in as 'mr - atoth@atoth.sote.h...'. The system tray at the bottom shows the date and time as 21:21.

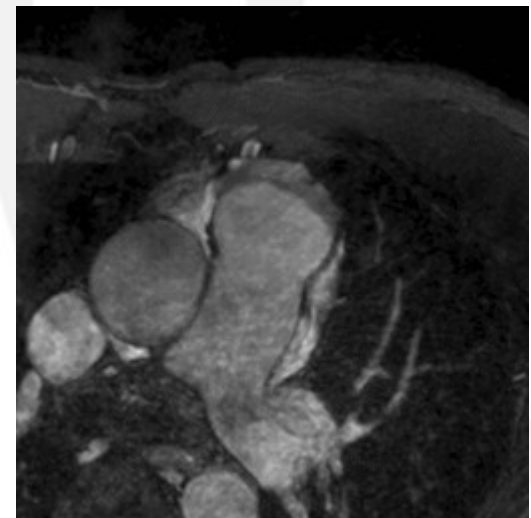
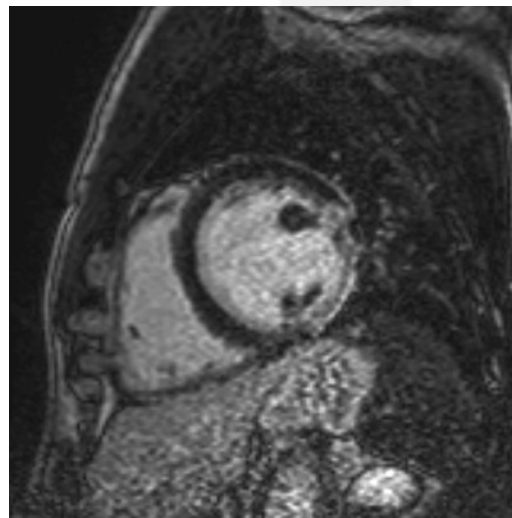
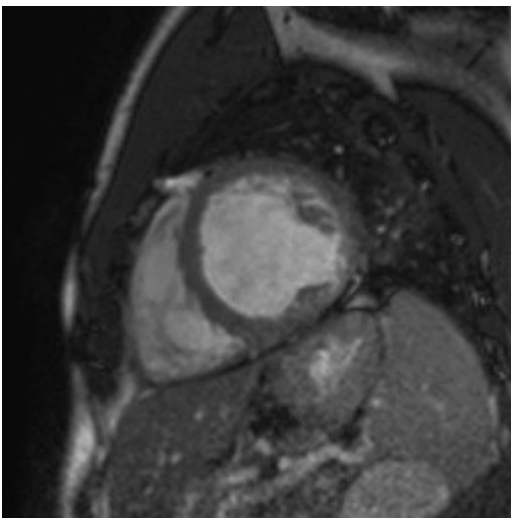
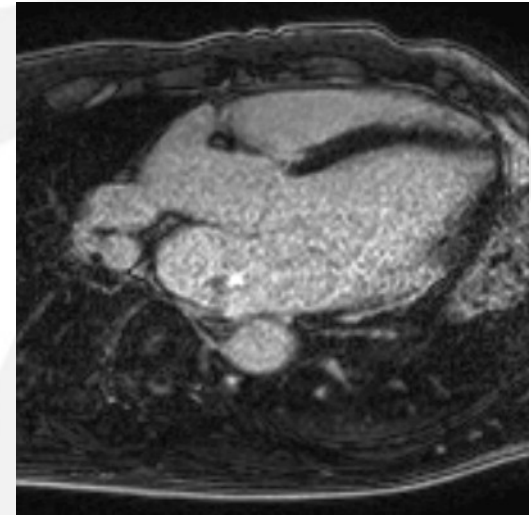
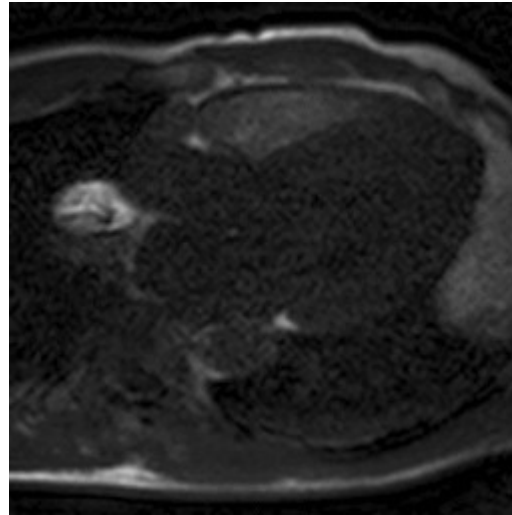
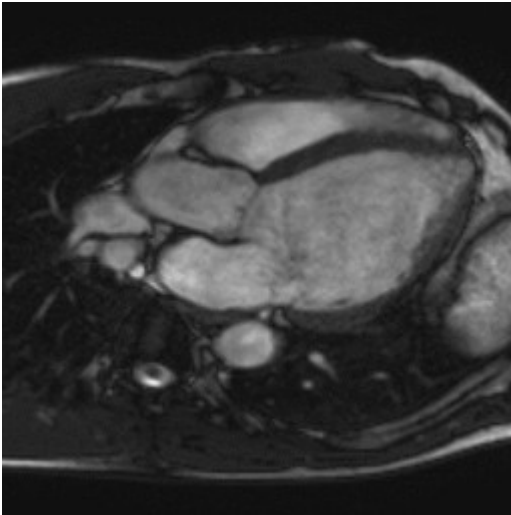
Muaj thai: Anderson-Fabry (19mm)



Akut infarktus: 21% nem viabilis



Duathlon, ultra-marathon: chrn infarctus

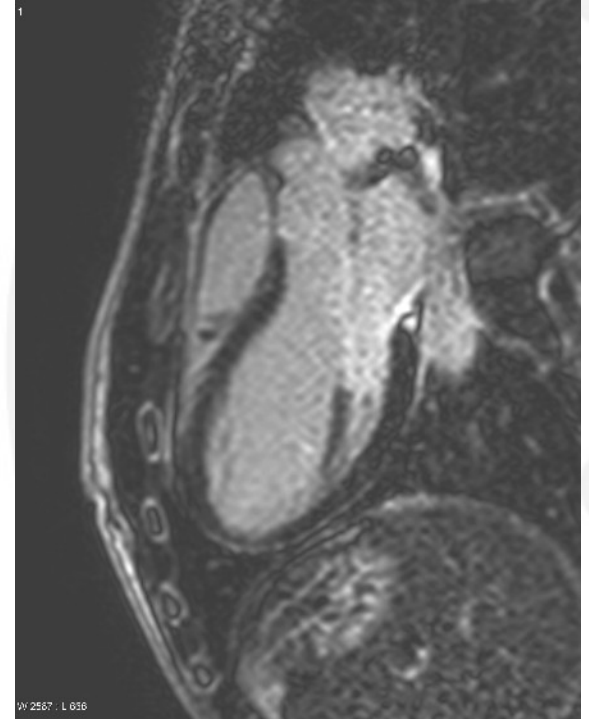
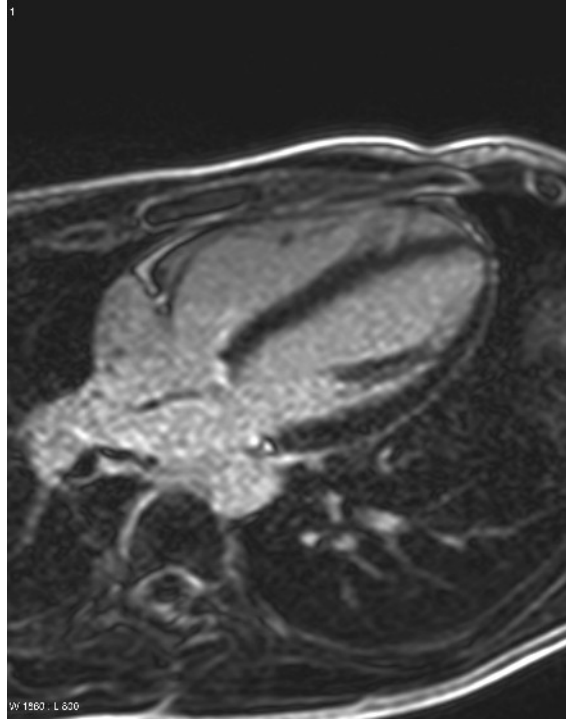


Késői halmozás

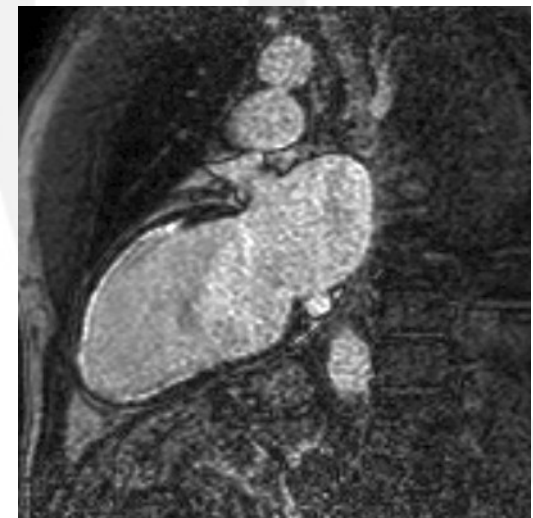
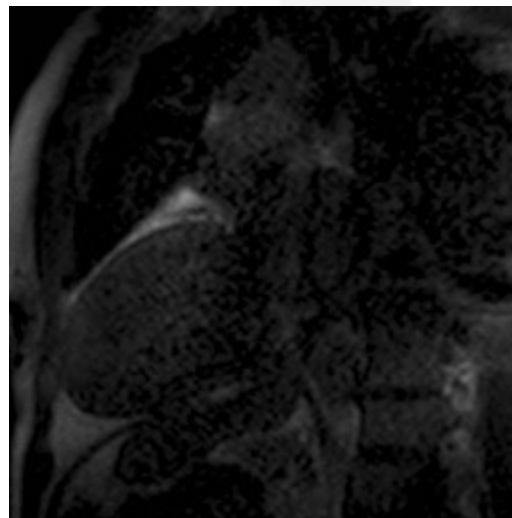
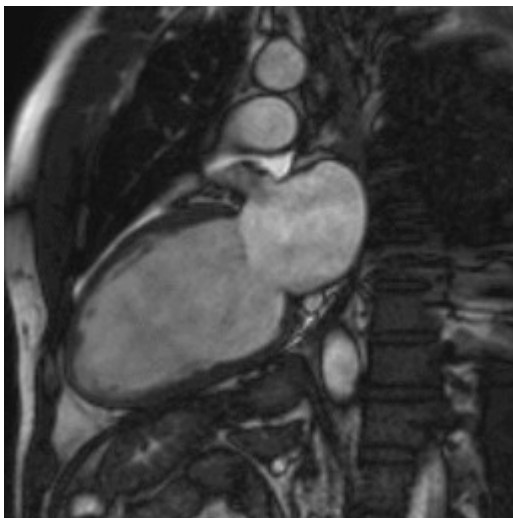
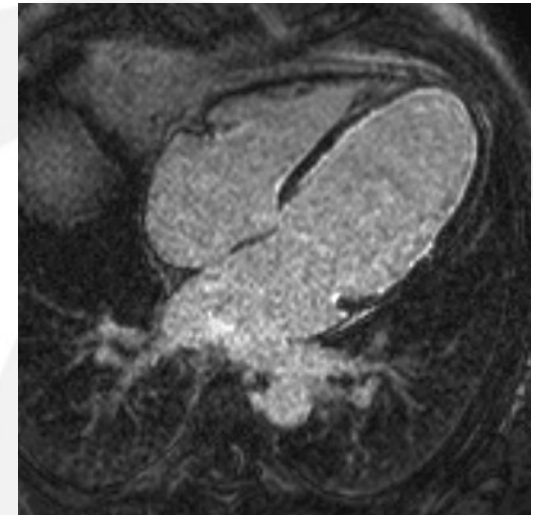
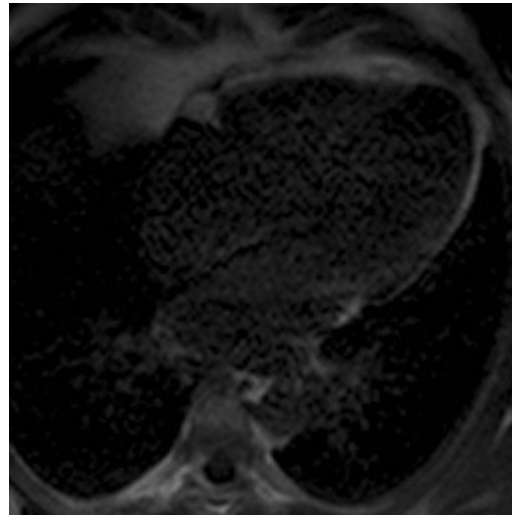
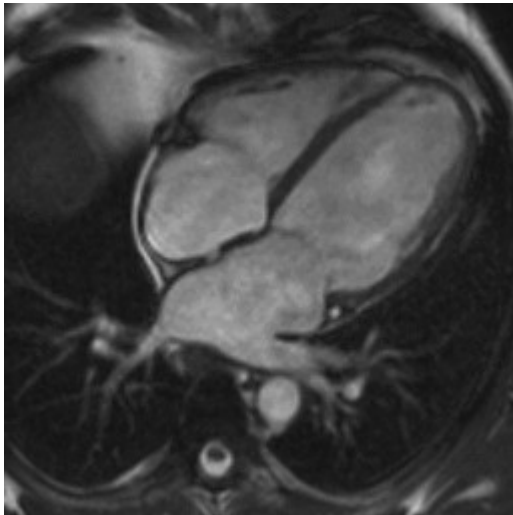
- Circulation 104:1101-1107 (2001)
 - Raymond J Kim, Romert M Judd
 - Transzmuralitás ~ Viabilitás



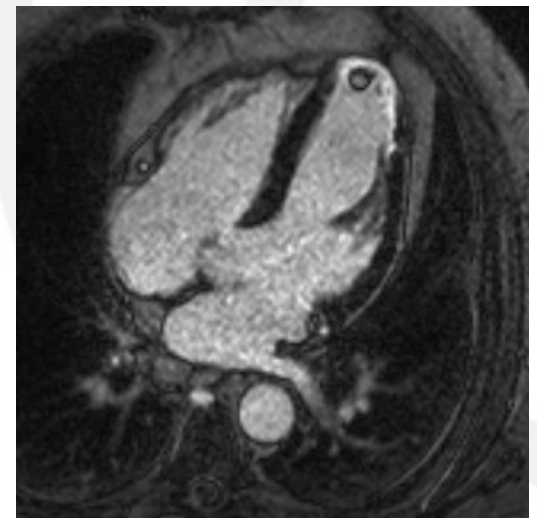
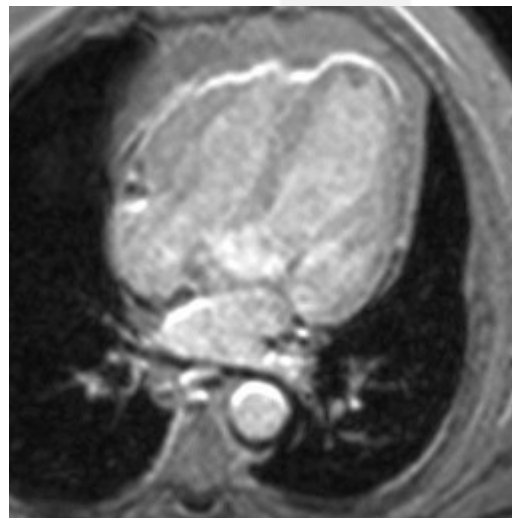
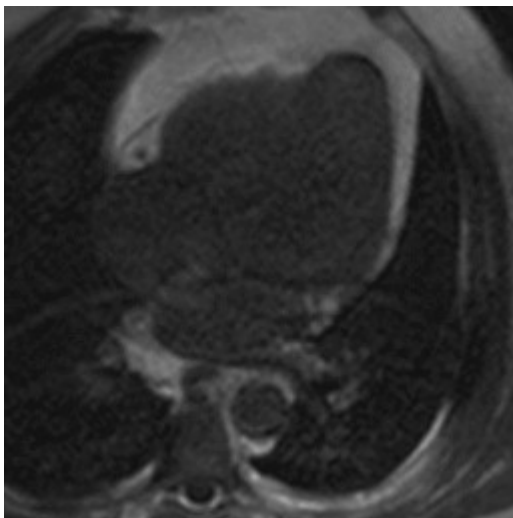
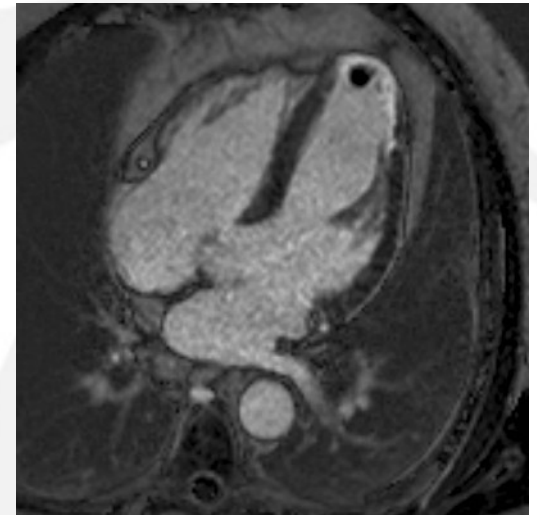
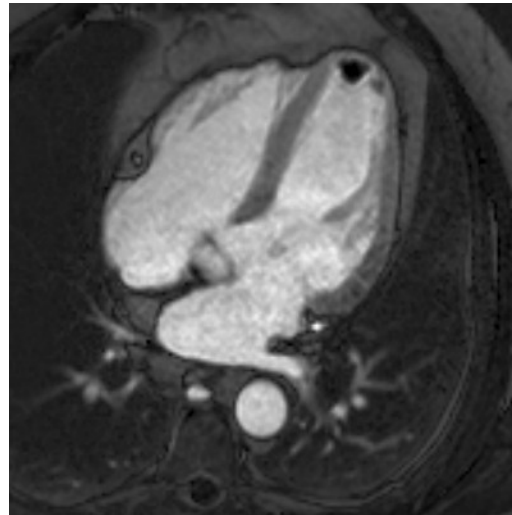
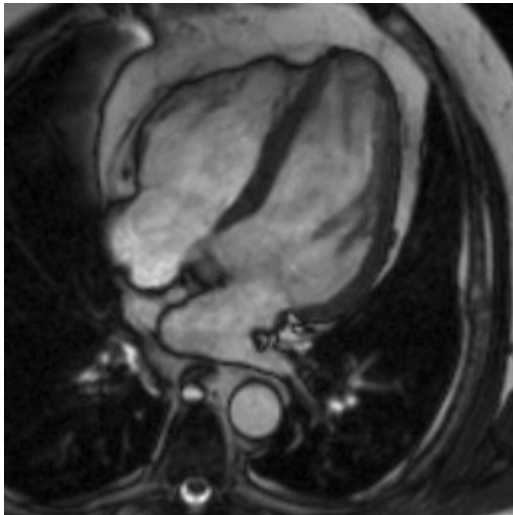
Késői halmozás



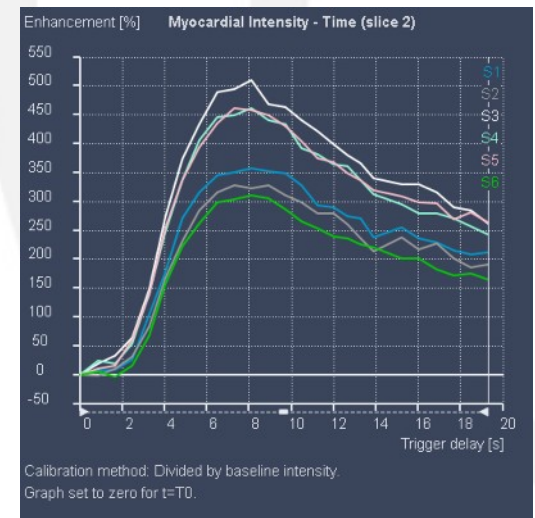
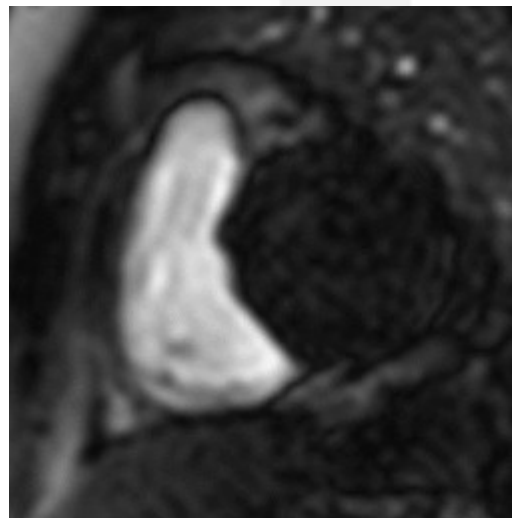
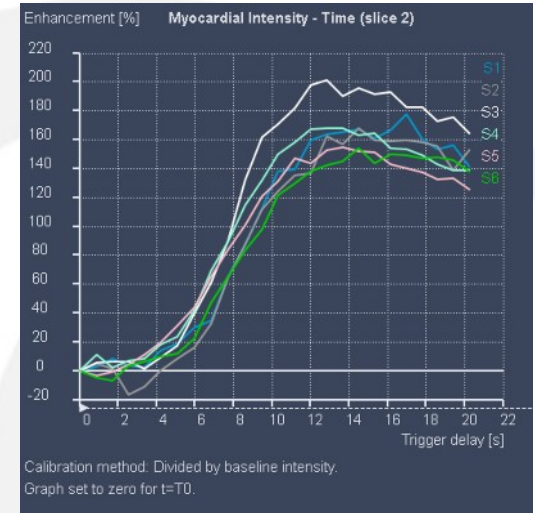
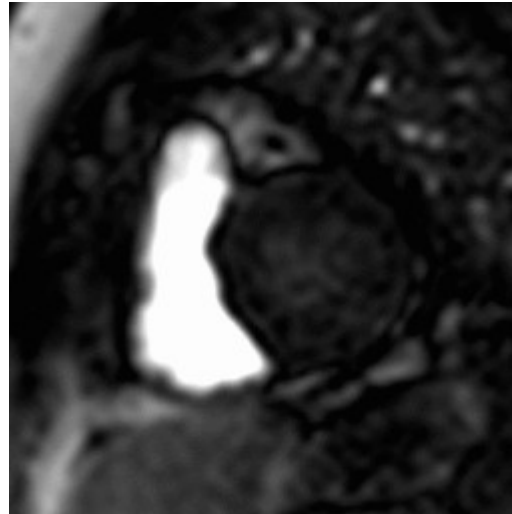
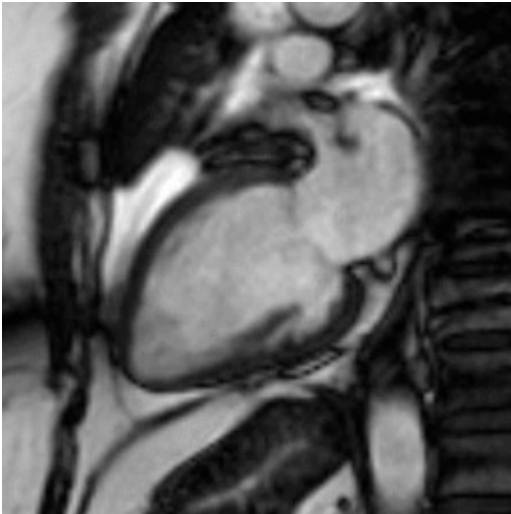
RCA & LCX CTO, LMA & LAD stenosis



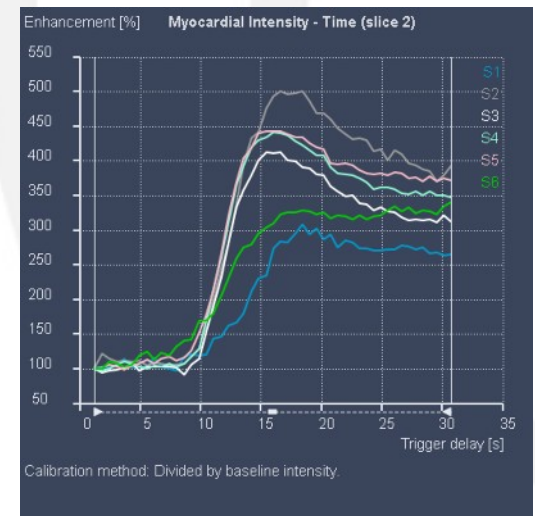
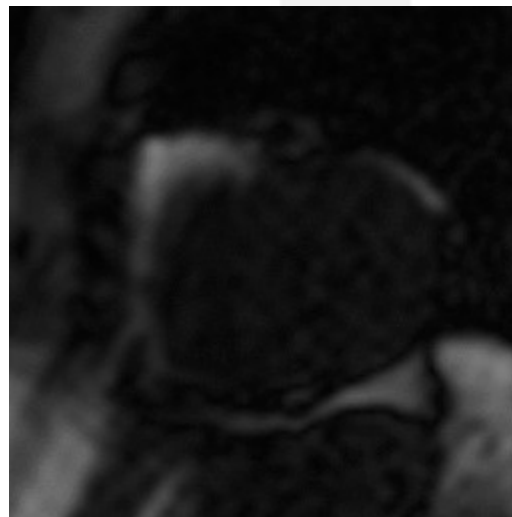
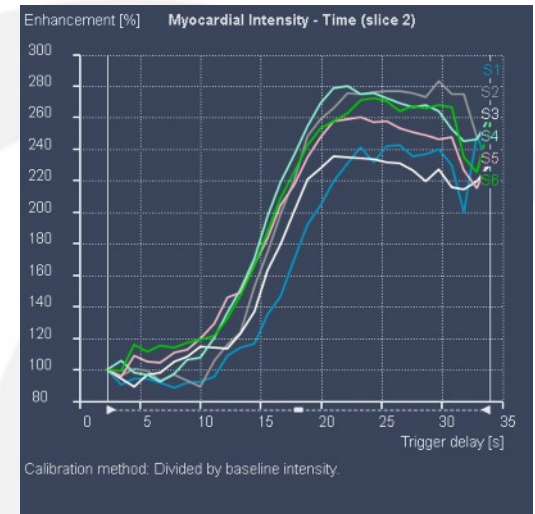
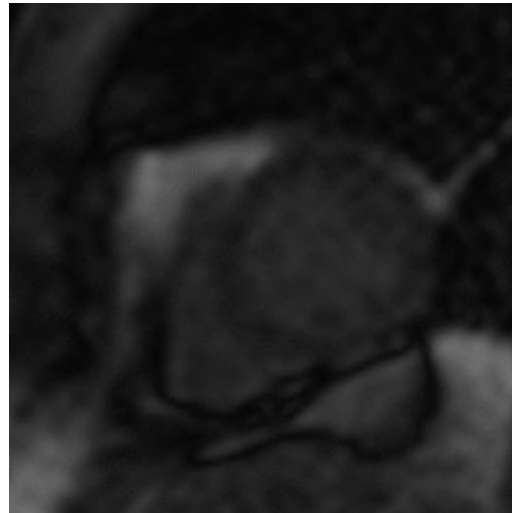
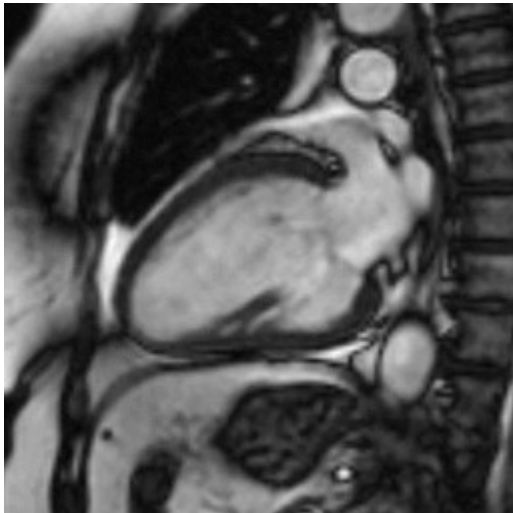
Apical infarct & thrombus (4CH)



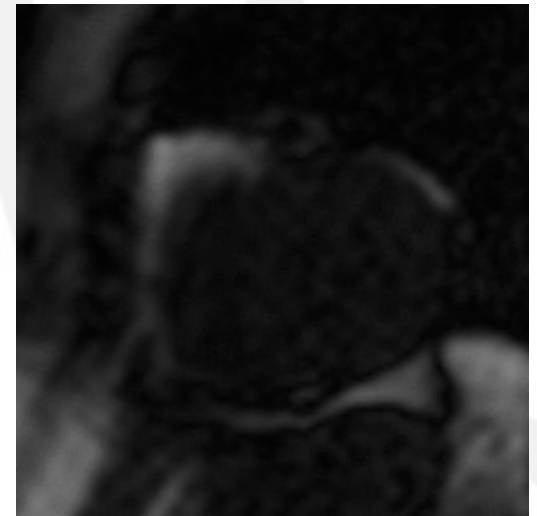
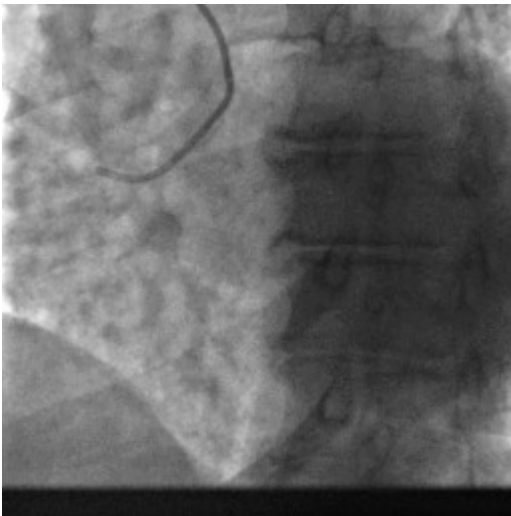
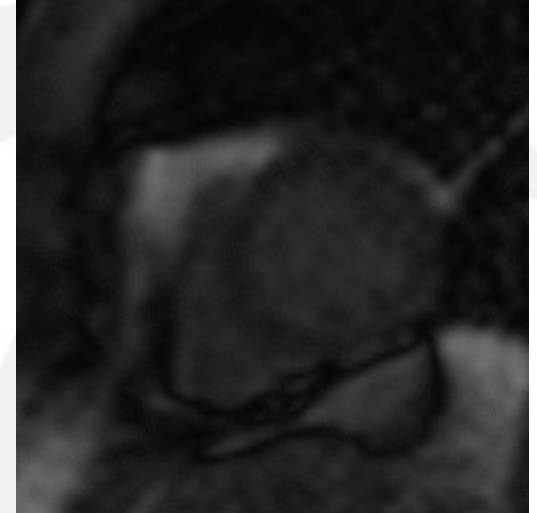
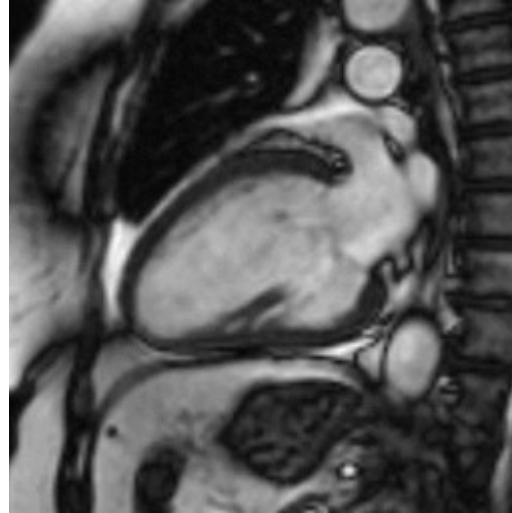
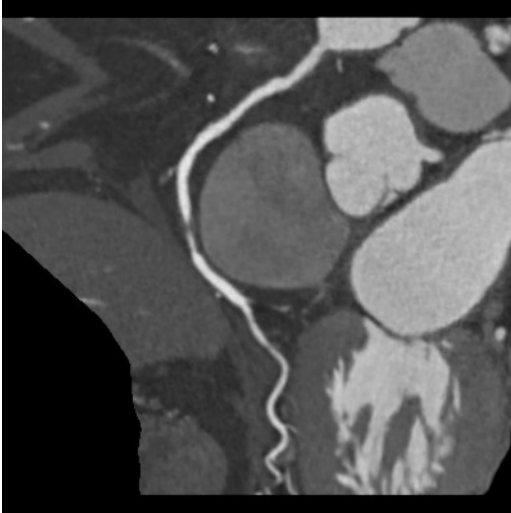
Upslope analízis: MPRI



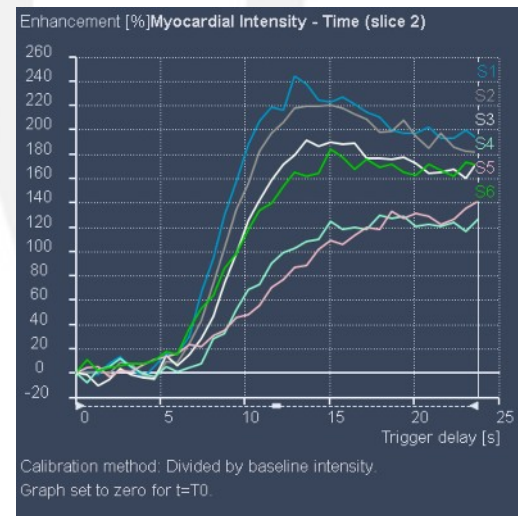
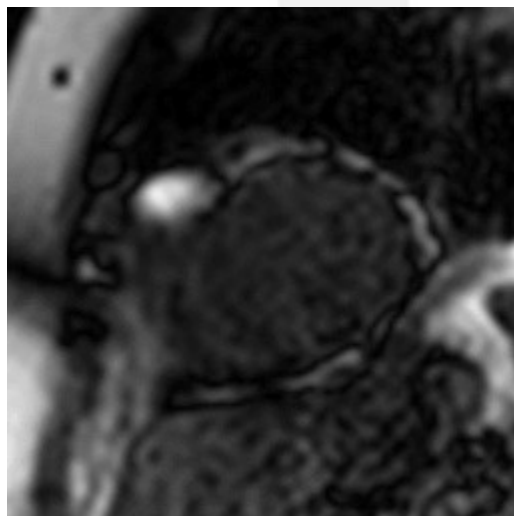
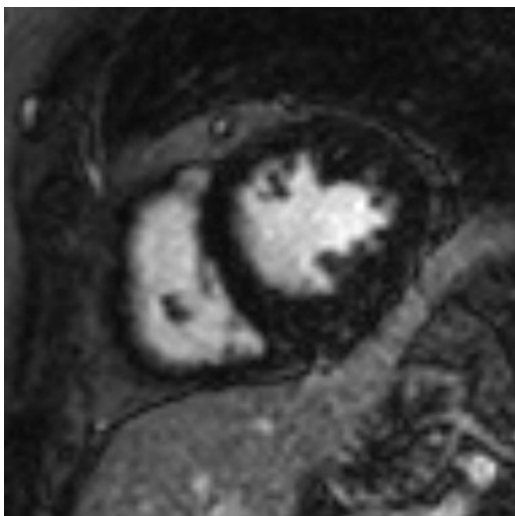
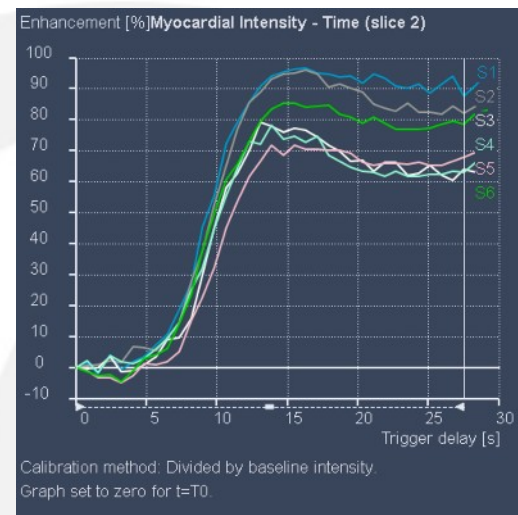
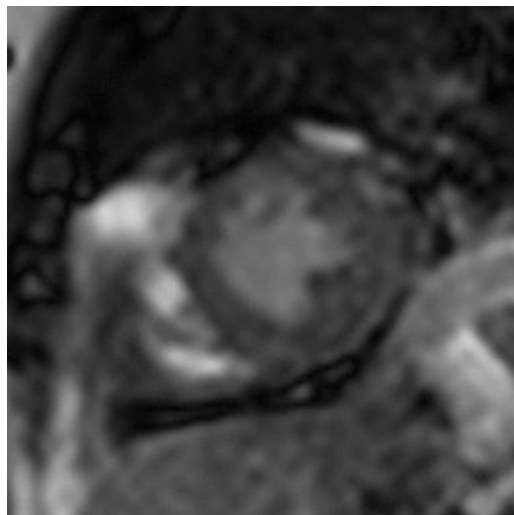
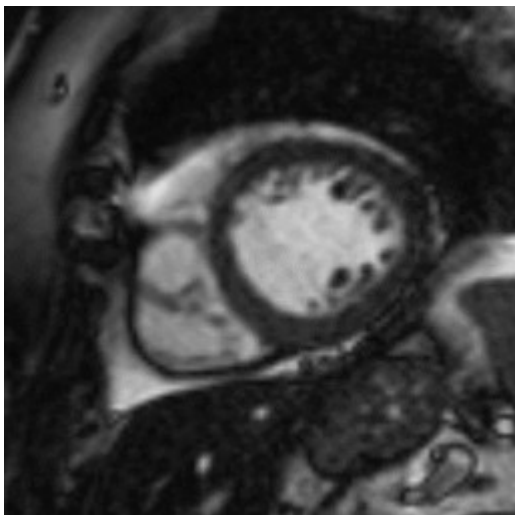
Inferoseptalis stress perfúziós zavar



Inferoseptalis stress perfúziós zavar



Indukálható LAD ischaemia



Légzési manőverek + oxigén érzékeny MR

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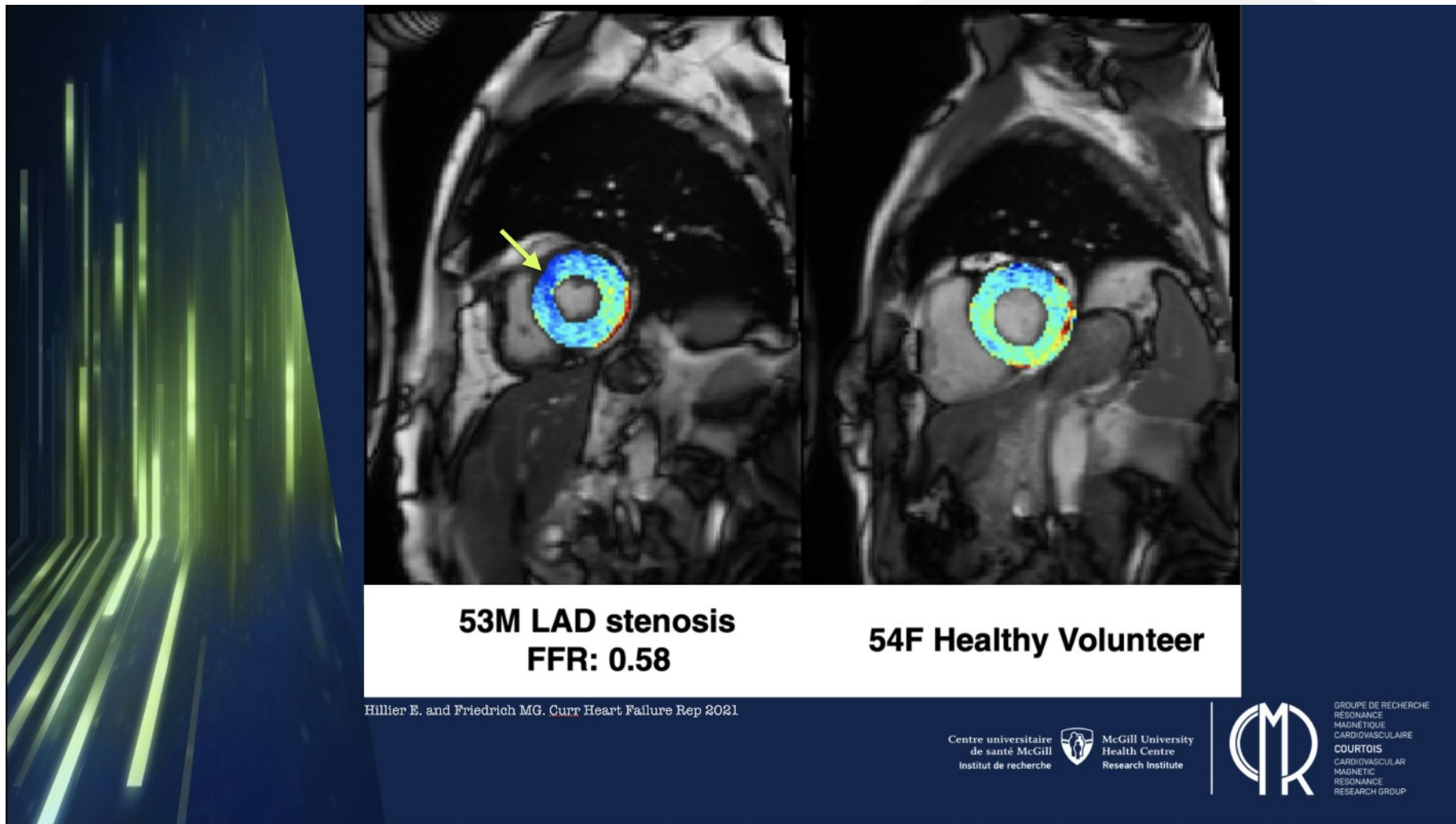


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KARDIOLÓGIAI
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Légzési manőverek + oxigén érzékeny MR



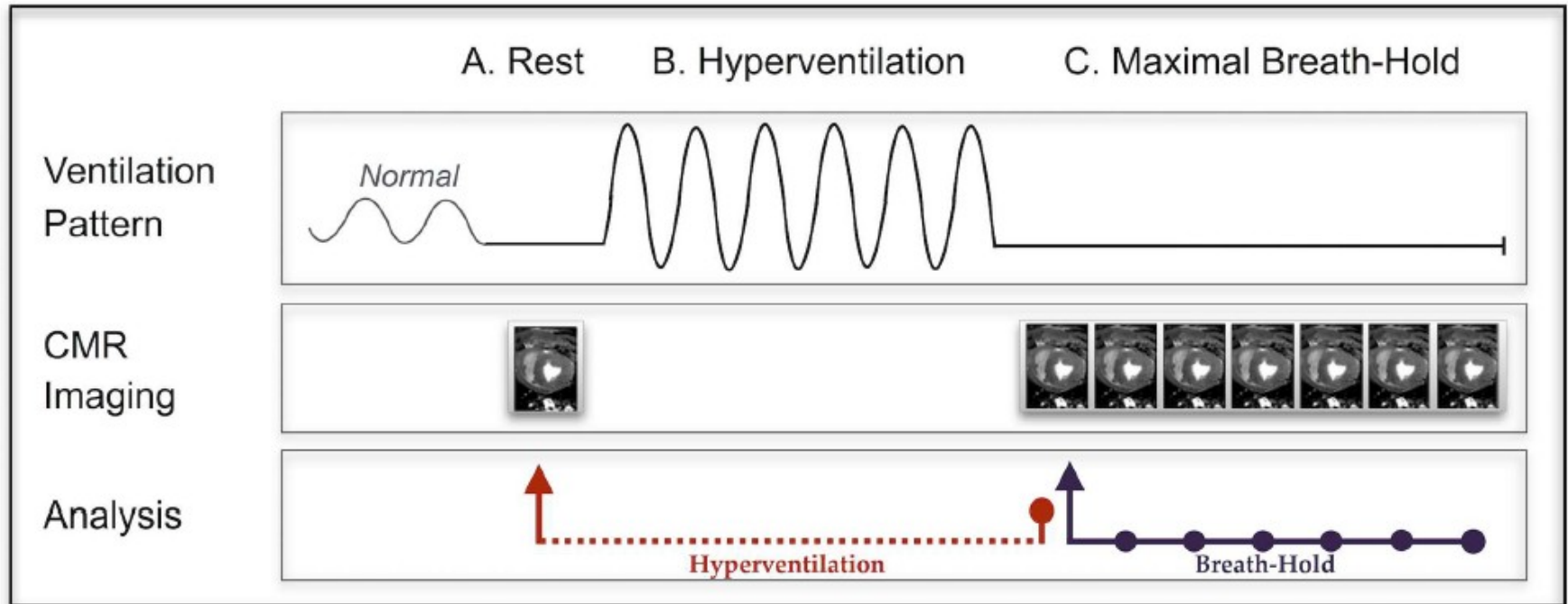


Fig 2. Breathing maneuver protocol. For the combined hyperventilation breath-hold (HVBH) maneuver, a single rest measurement was obtained in a short breath-hold (A). The animal was then manually hyperventilated for 60s (B) followed immediately by a long breath-hold (C) that was imaged throughout, with a repeating OS sequence. Hyperventilation analysis was always compared between rest and the start of the breath-hold (red arrow), while the breath-hold could be analyzed at multiple time points with comparison to data obtained at the beginning of the breath-hold (purple arrow). The long breath-hold (LBH) followed step C, starting after a normal ventilation pattern.

doi:10.1371/journal.pone.0164524.g002

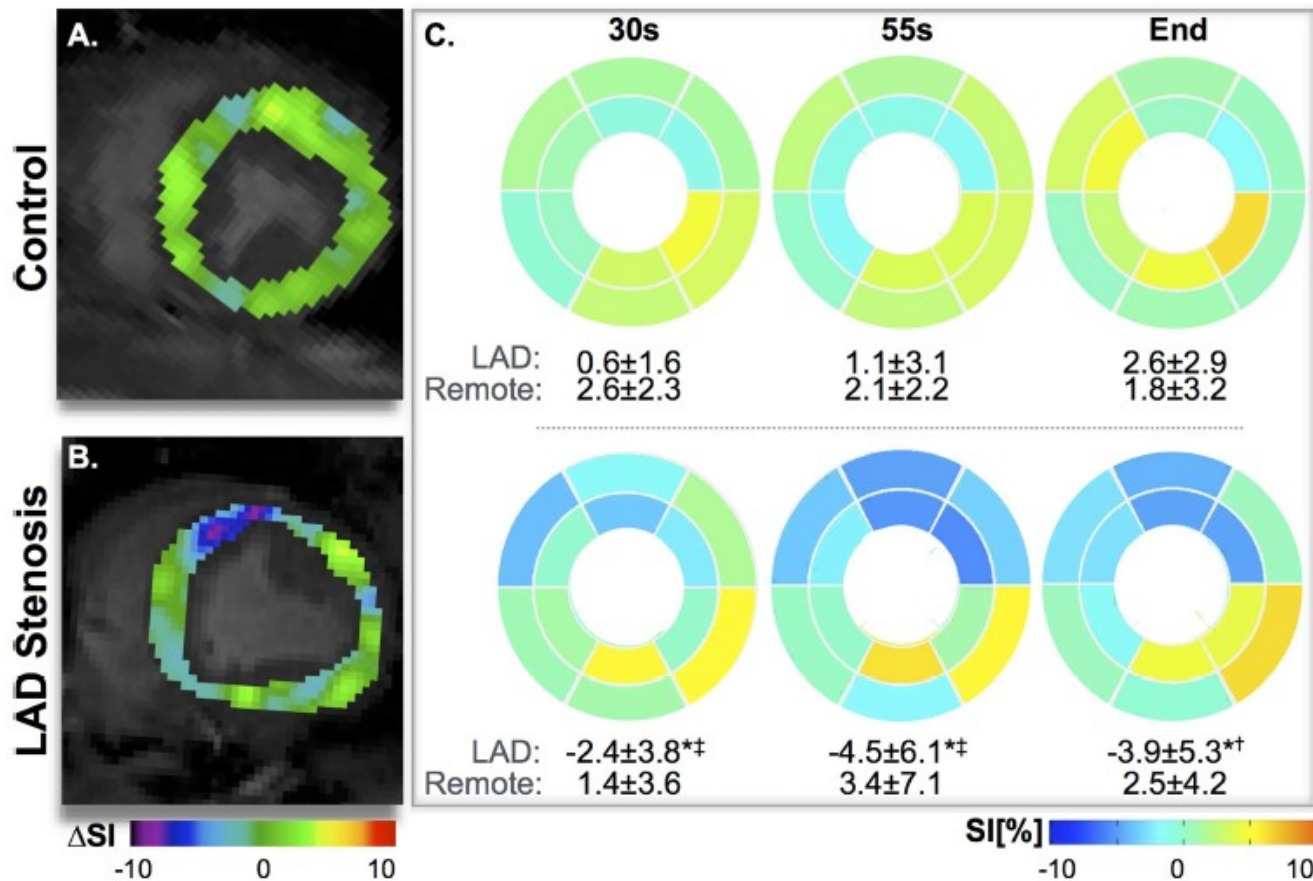


Fig 4. Segmental changes of myocardial oxygenation during the HVBH. Subtraction images (smoothed using a 6mm Gaussian filter) demonstrate that at the 30s, SI increased homogeneously in the control animal (A), while there was a decrease in the territory of the stenosed LAD (B). The mean response for each segment from all animals similarly shows that in control animals (top row, $n = 8$), $\Delta SI[\%]$ is consistently larger for all segments, whereas for the stenosis animals (bottom row, $n = 10$) in the LAD regions a significant decrease is already observed at 30s, and this continues throughout the breath-hold. ($*p < 0.05$ between LAD and remote territory within the group, $\dagger p < 0.05$, $< 0.05 \dagger p < 0.01$ for the difference in LAD response between groups).

doi:10.1371/journal.pone.0164524.g004



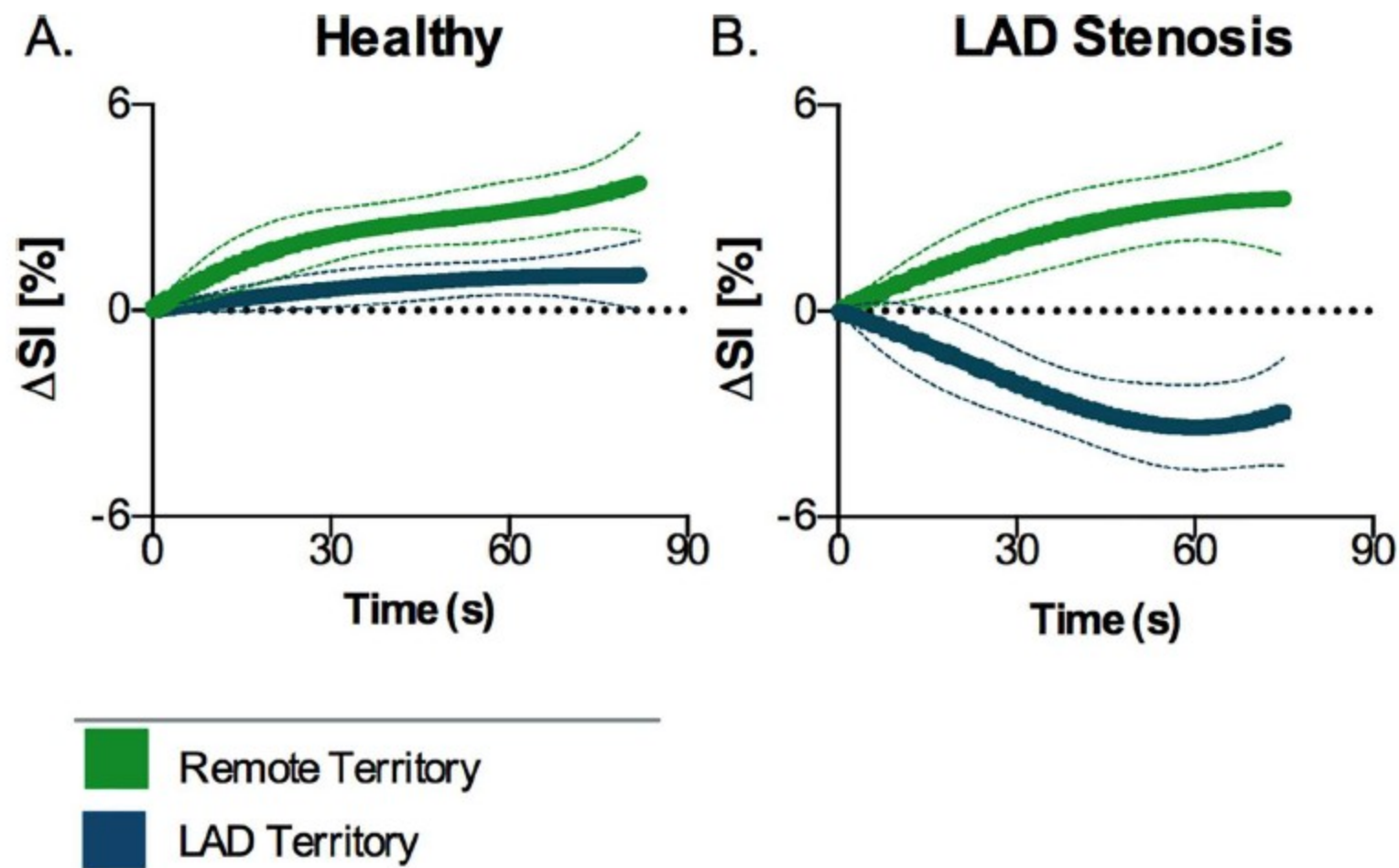


Fig 5. Myocardial oxygenation response curve during the HVBH. Signal intensity increases globally during the HVBH in control animals (A), yet the animals with a stenosis (B) show a significant decrease in the LAD territory (blue), while the remote region (green) remains above baseline with a similar characteristic of the control animals.

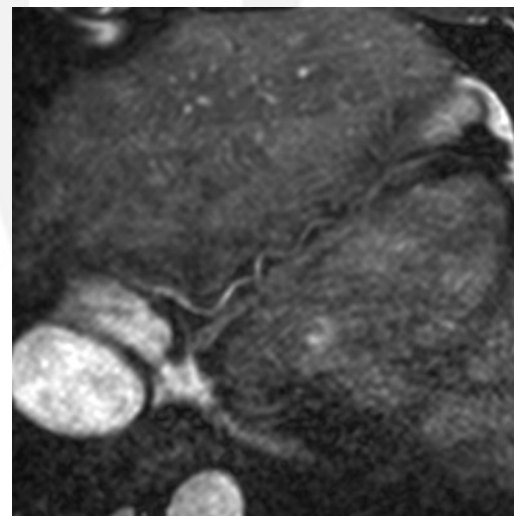
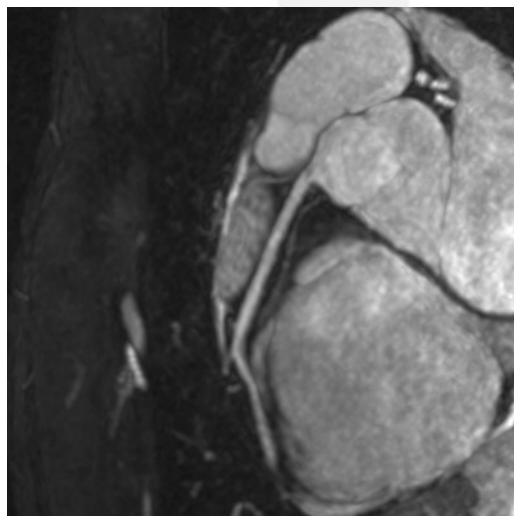
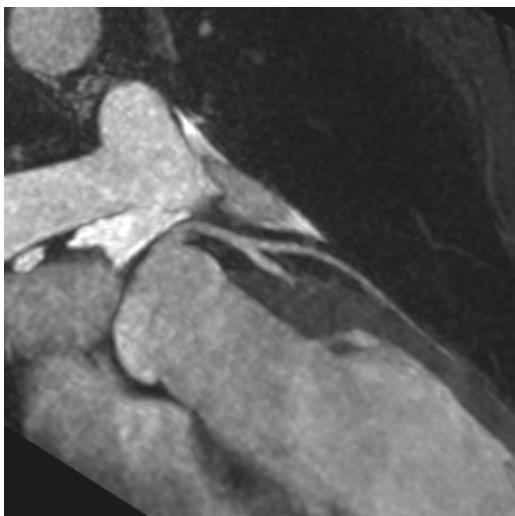
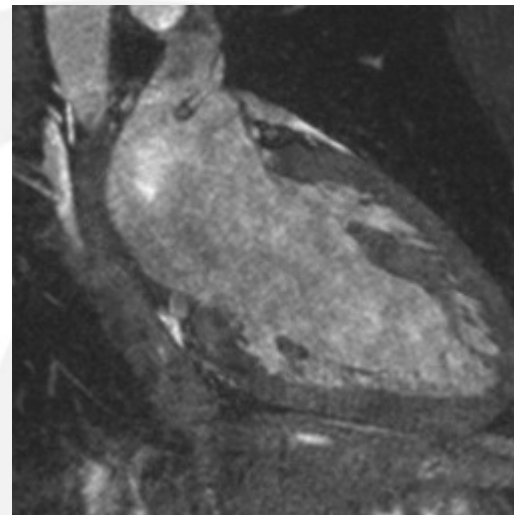
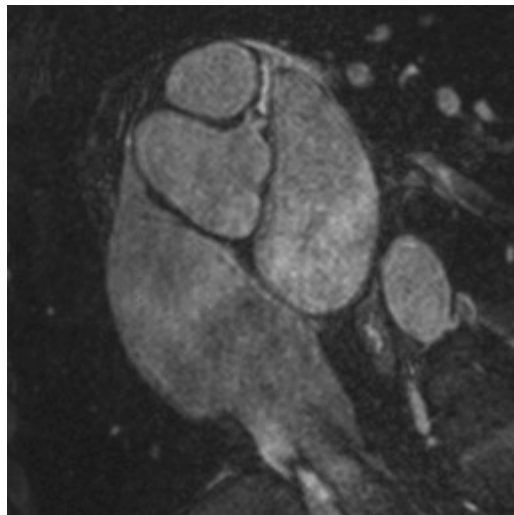
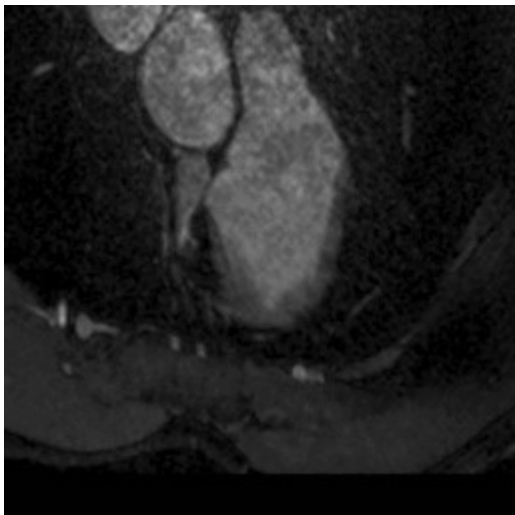
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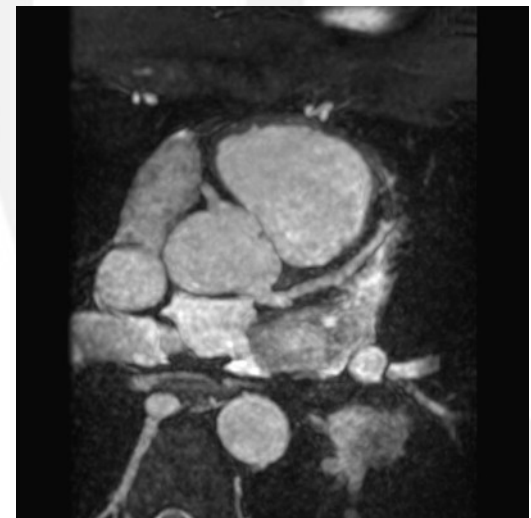
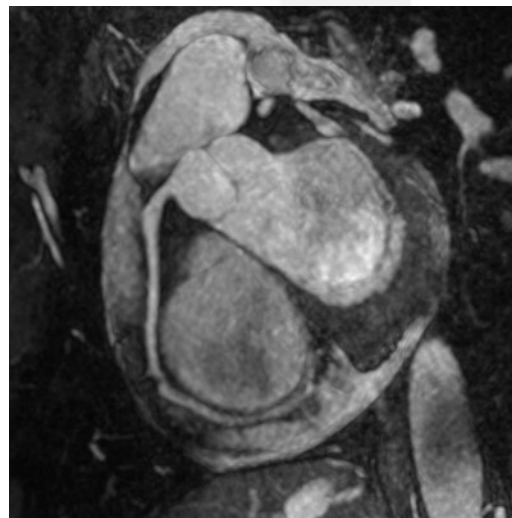
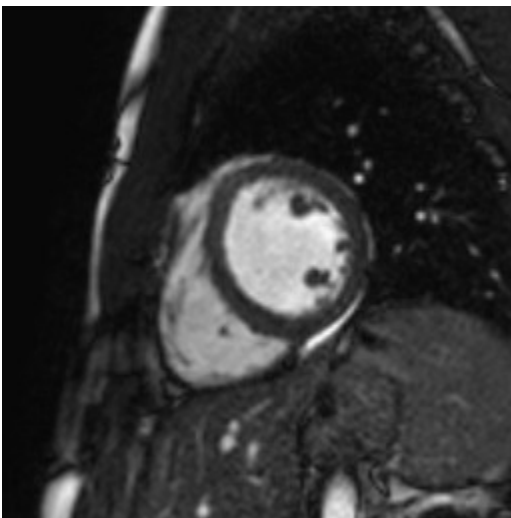
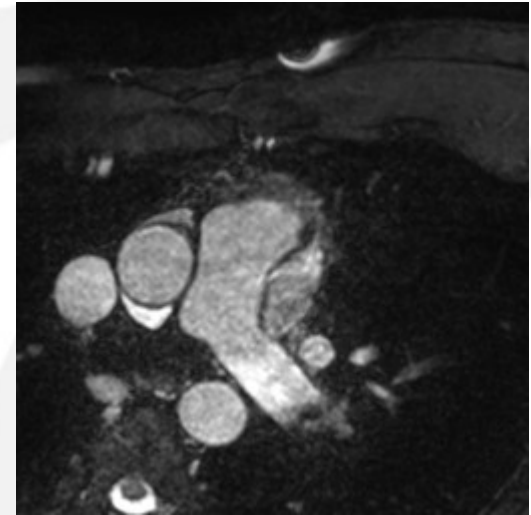
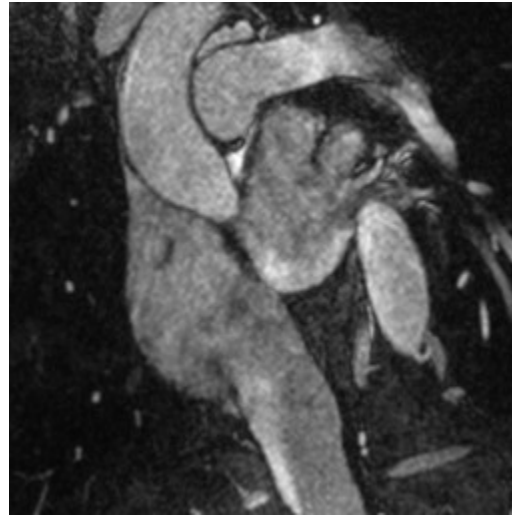
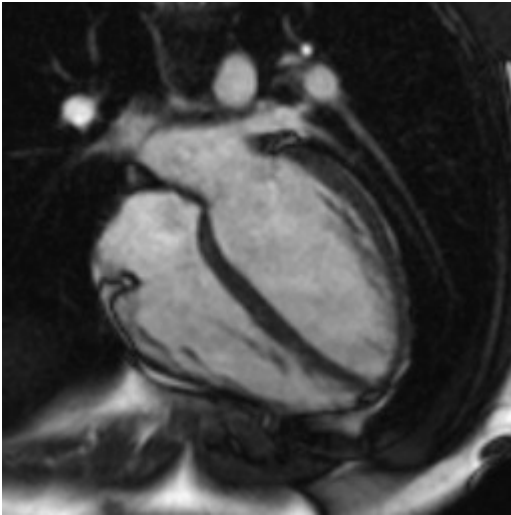
Kawasaki betegség



Cs: 3D NAV MRCA



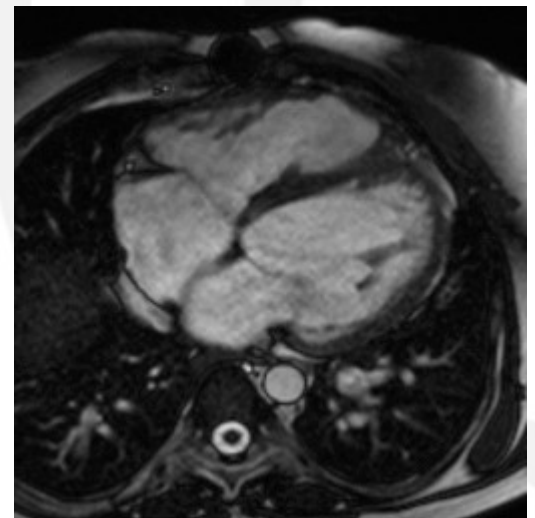
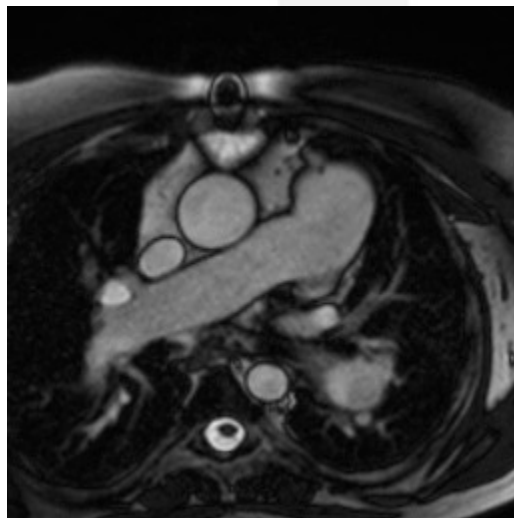
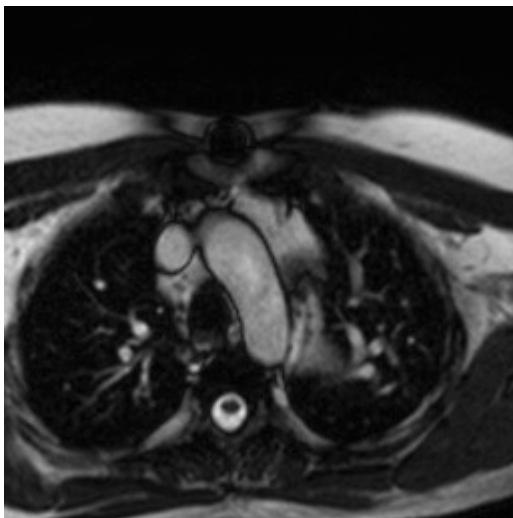
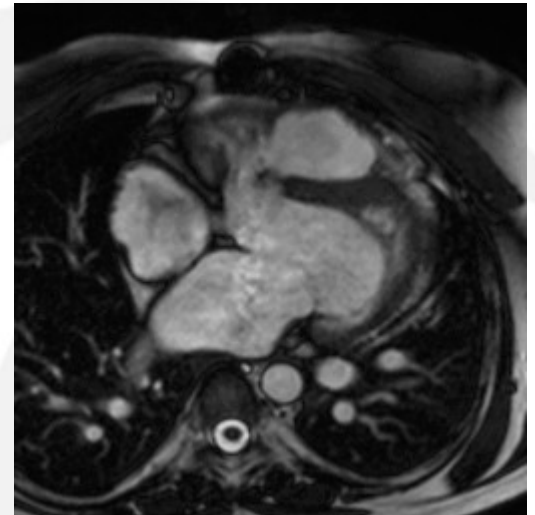
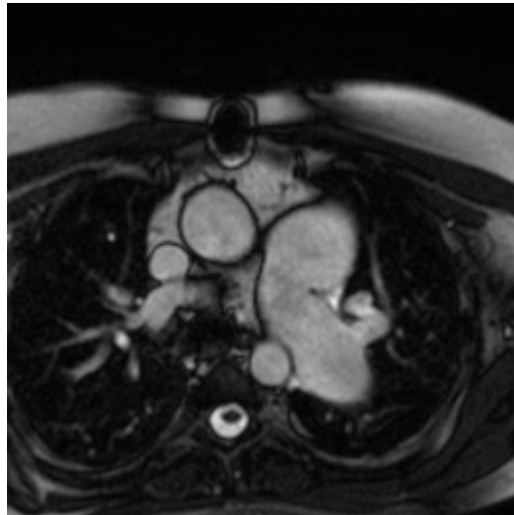
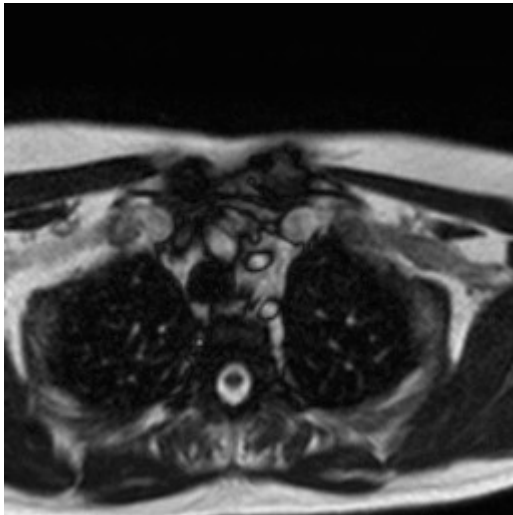
Kawasaki, RCA ectasia, stenosis?



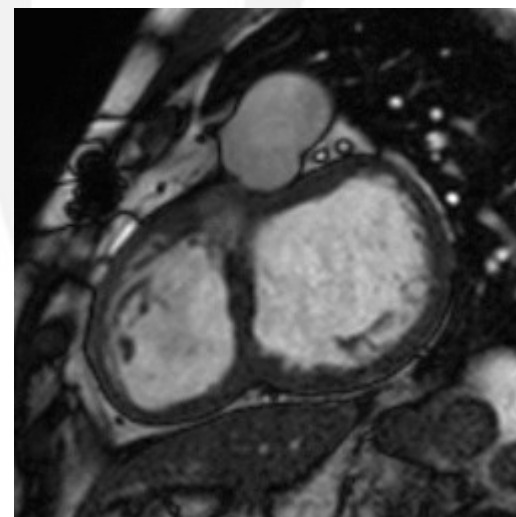
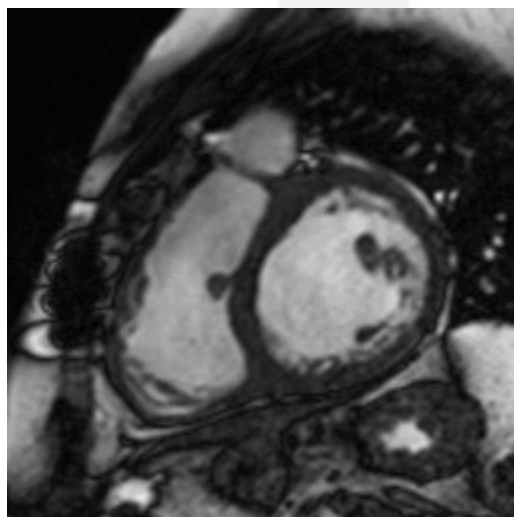
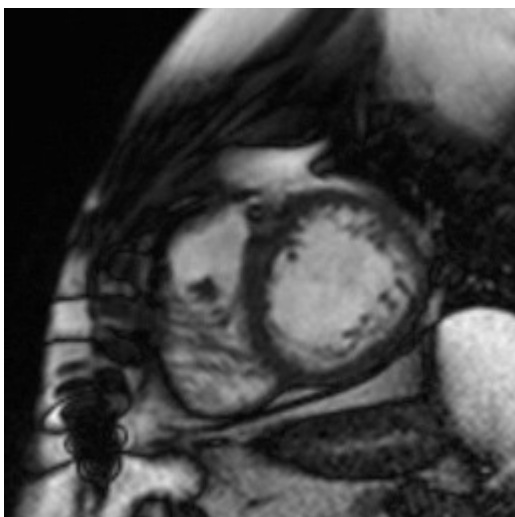
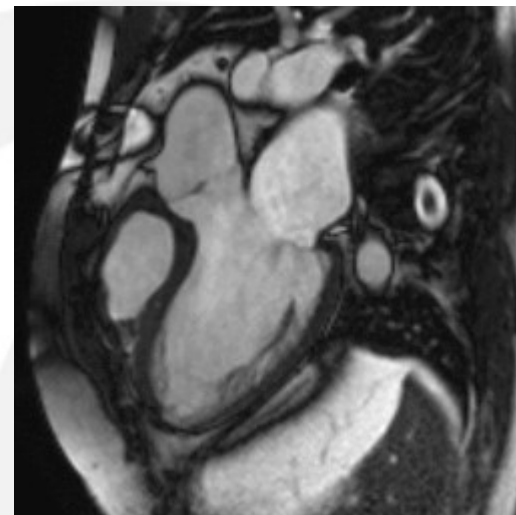
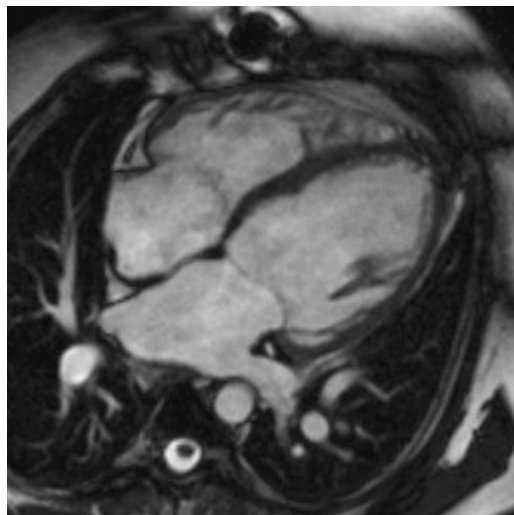
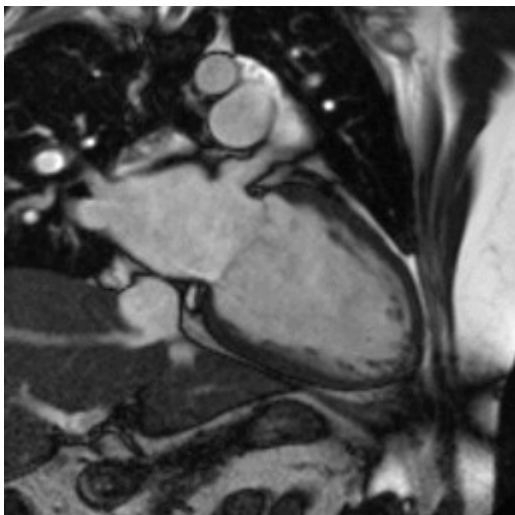
Rekonstruált Fallot tetralógia (TOF or FIV)



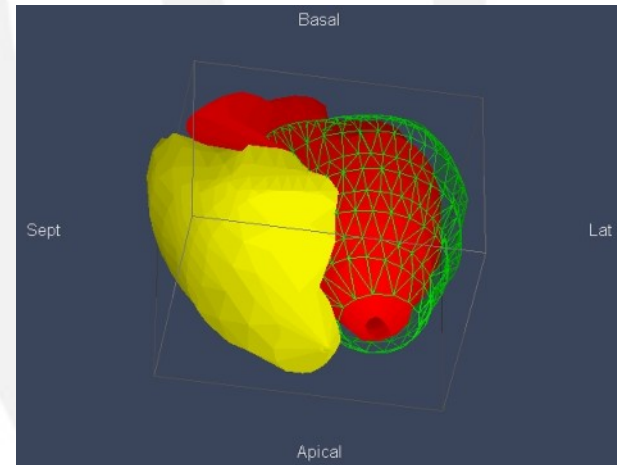
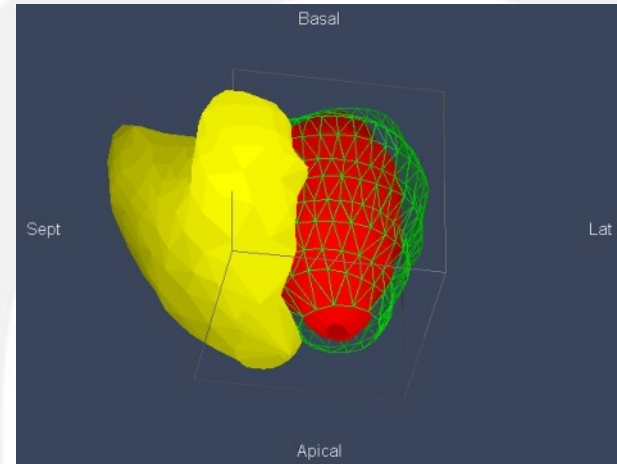
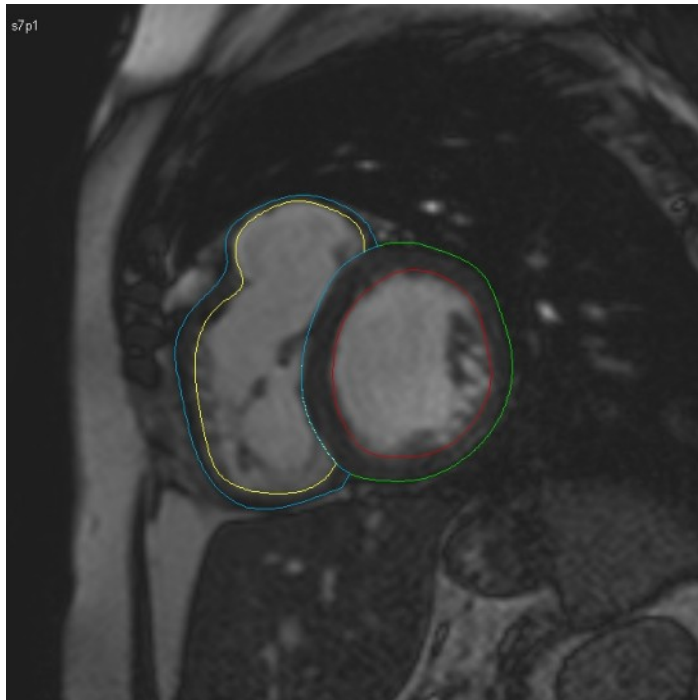
Axialis/transzverz cine stack



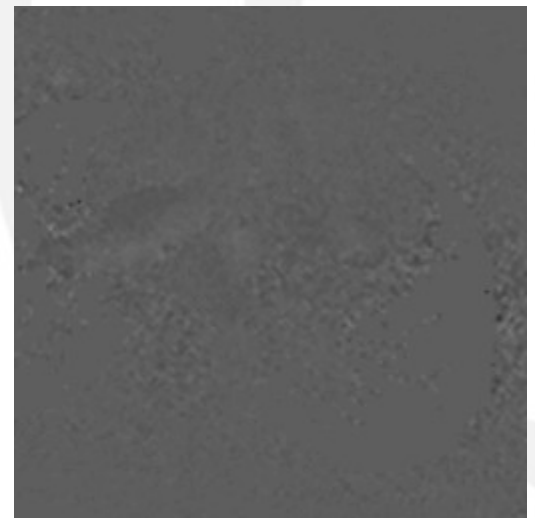
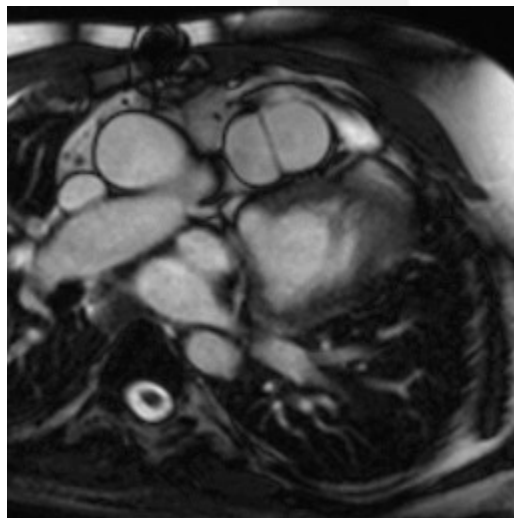
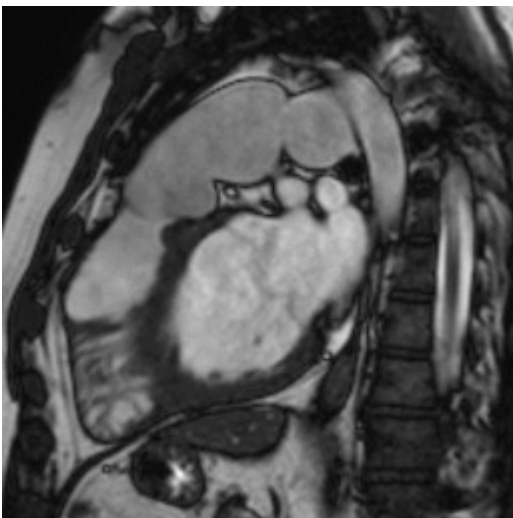
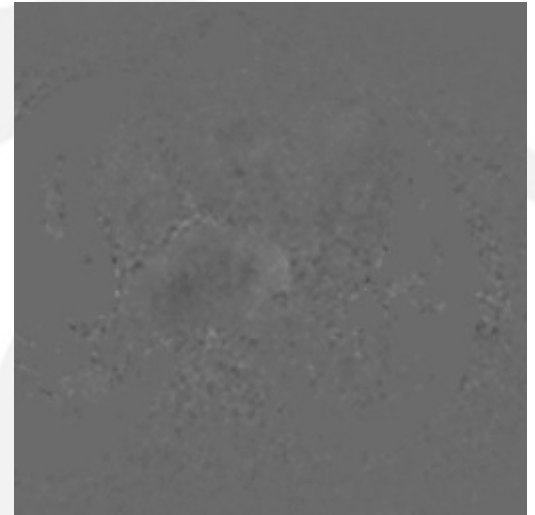
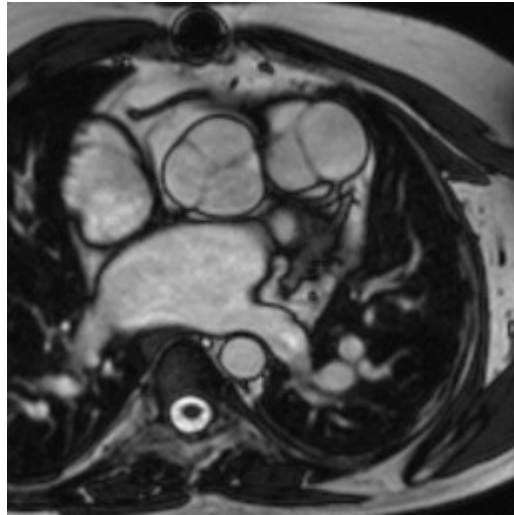
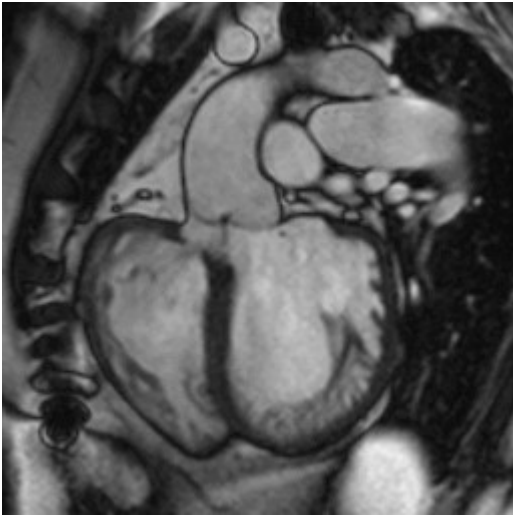
Rövid & hossztengetelyi cine stack



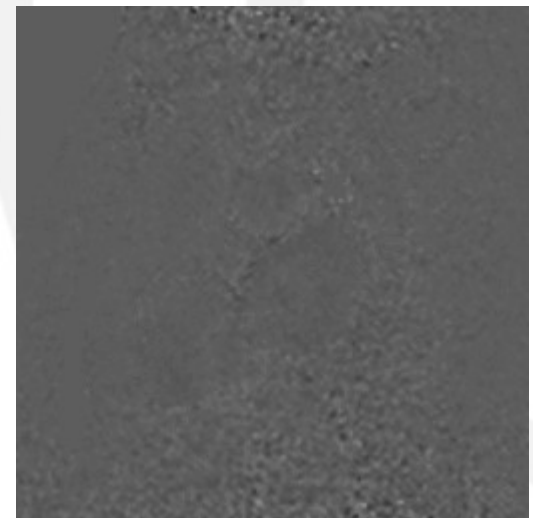
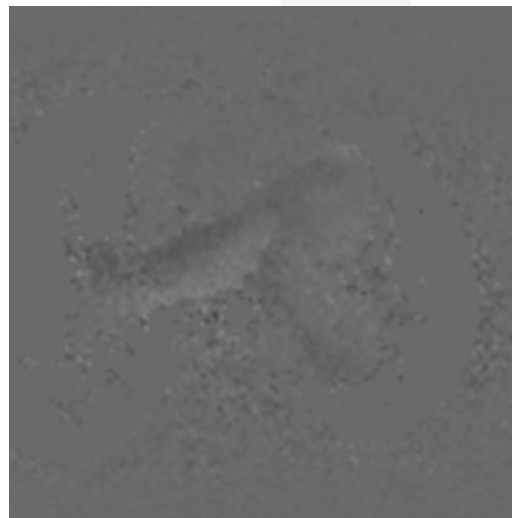
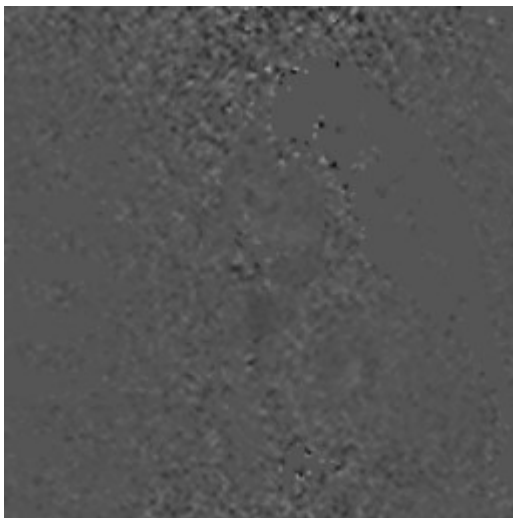
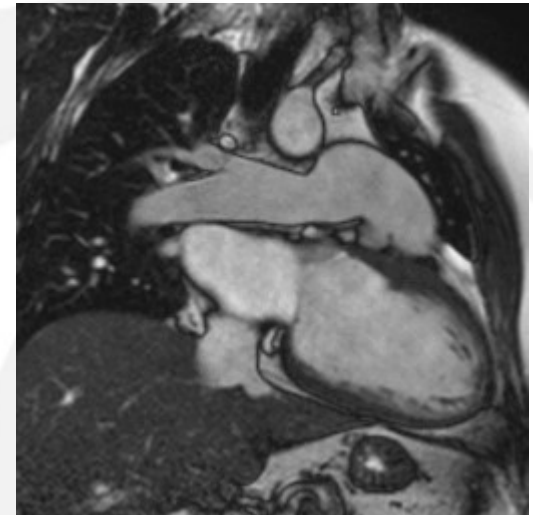
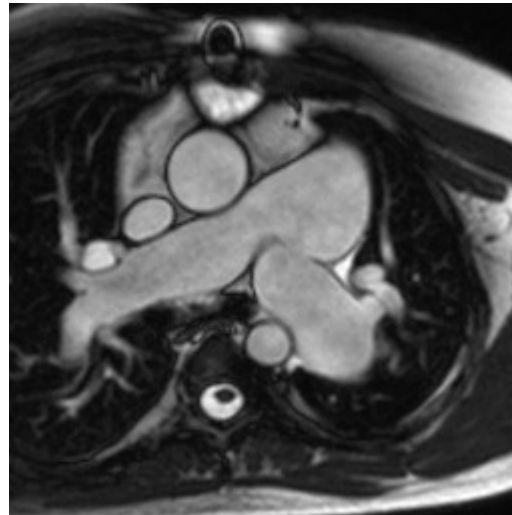
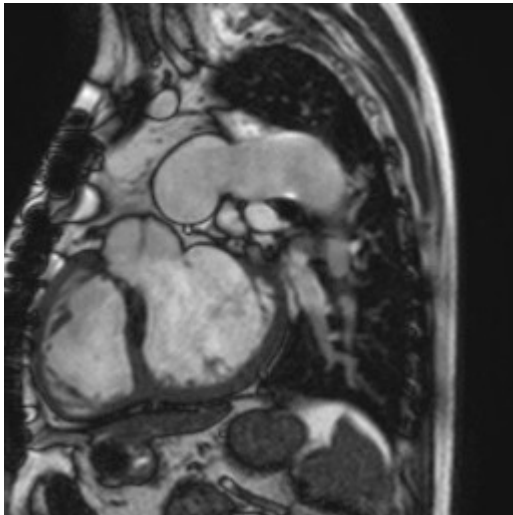
Funkció kiértékelés



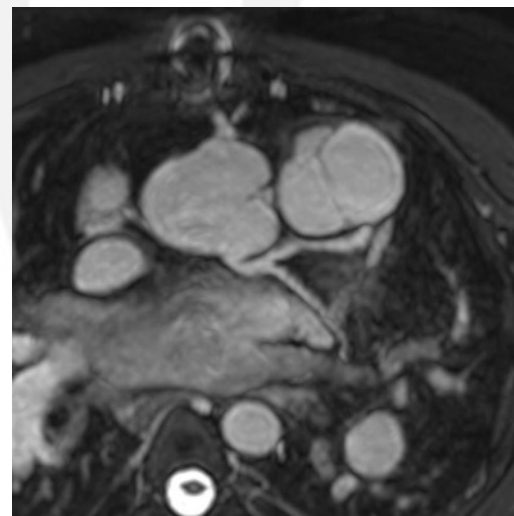
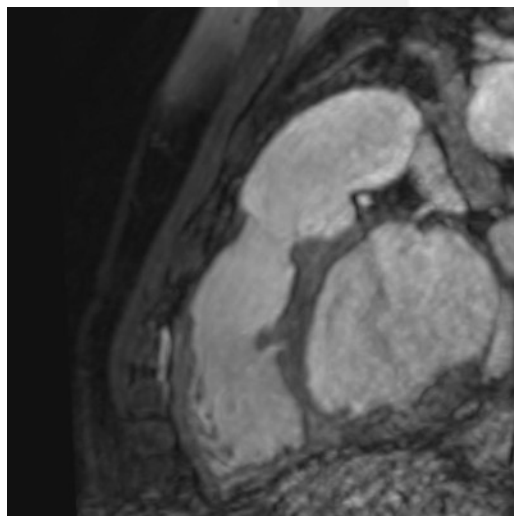
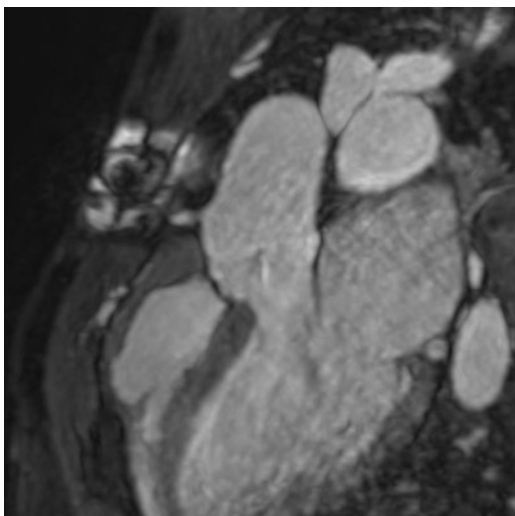
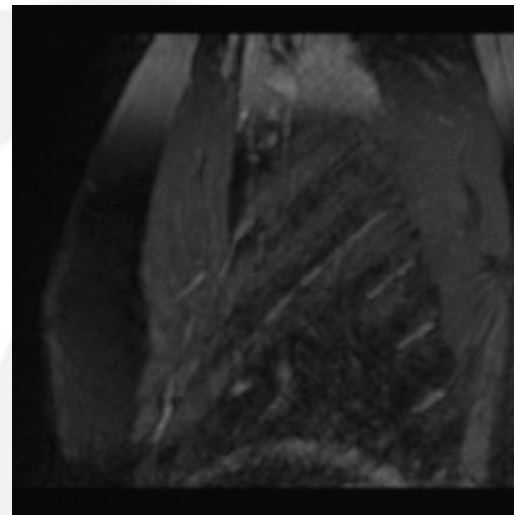
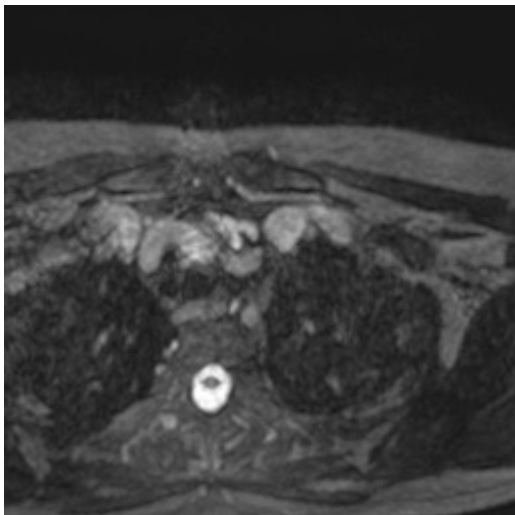
PA 253 16 3, AO 94 2 12, Qp/Qs: 2,27!



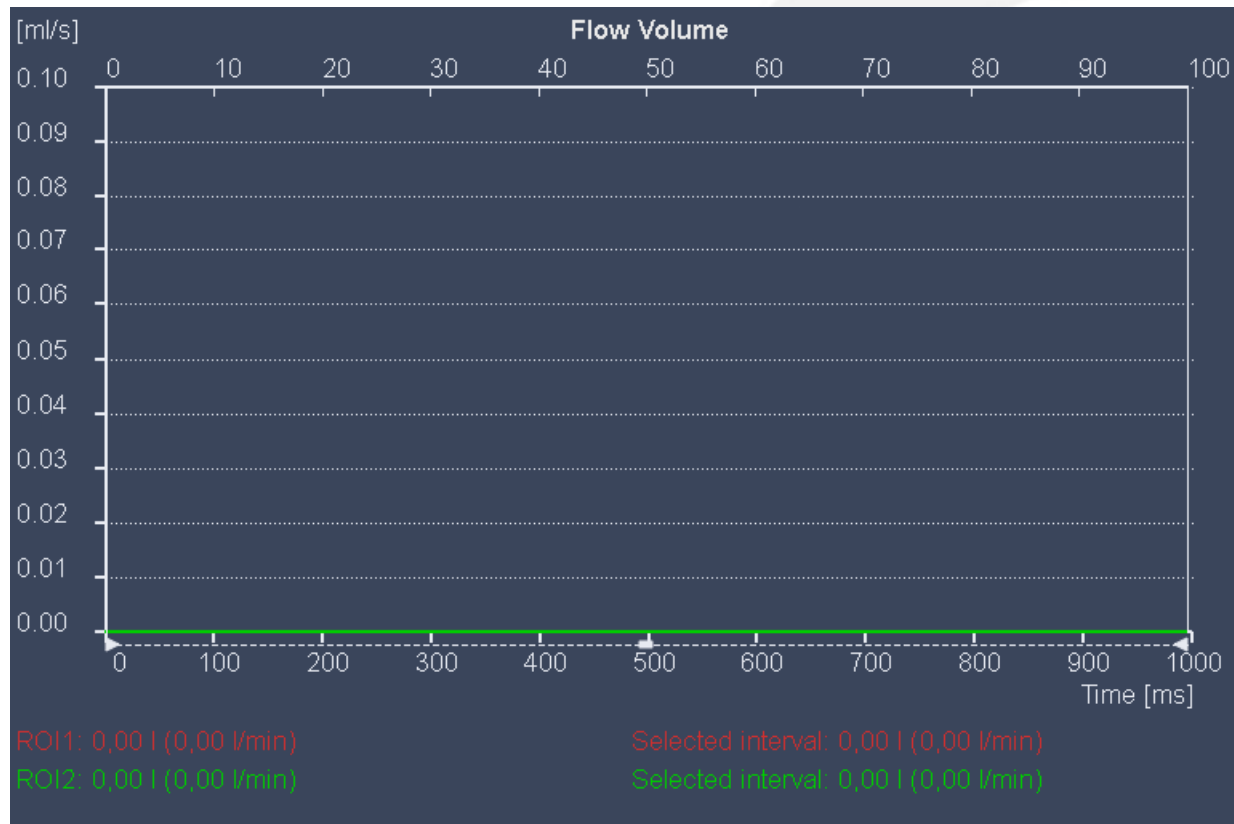
J: 106 2 0, B: 146 9 5, R-L: 54-46%



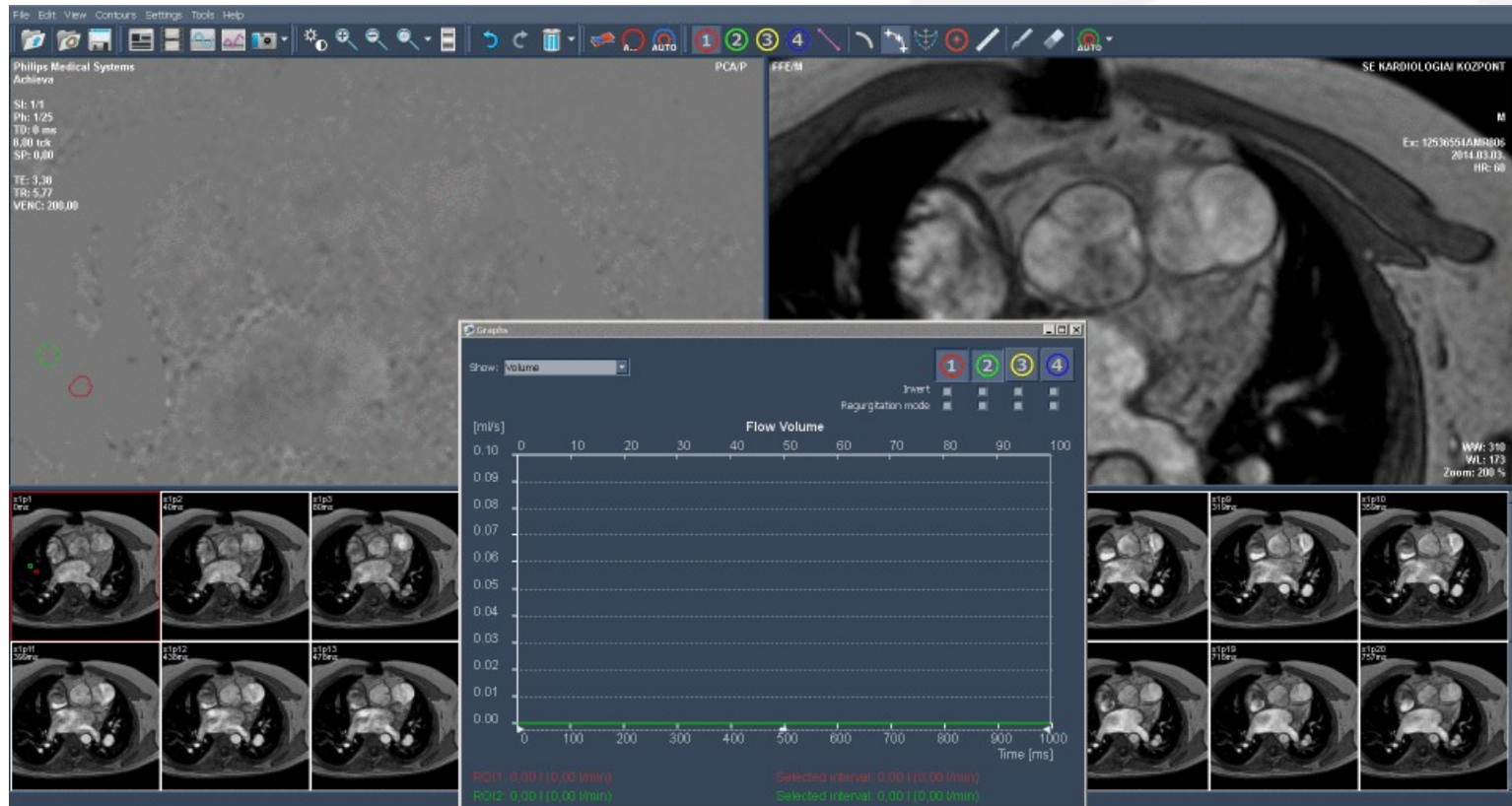
3D NAV MRA



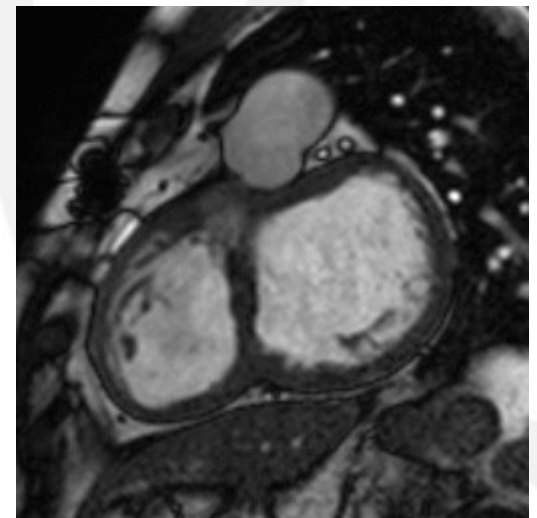
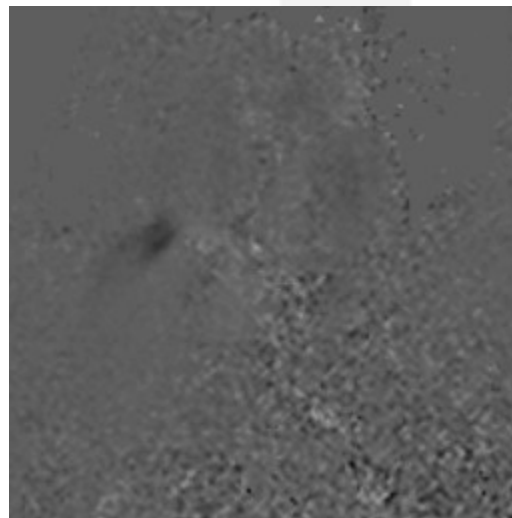
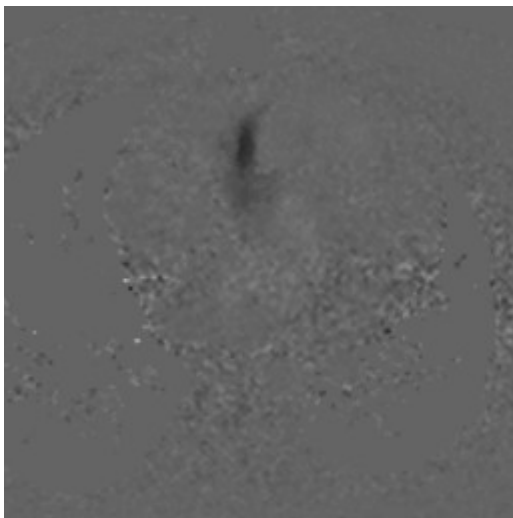
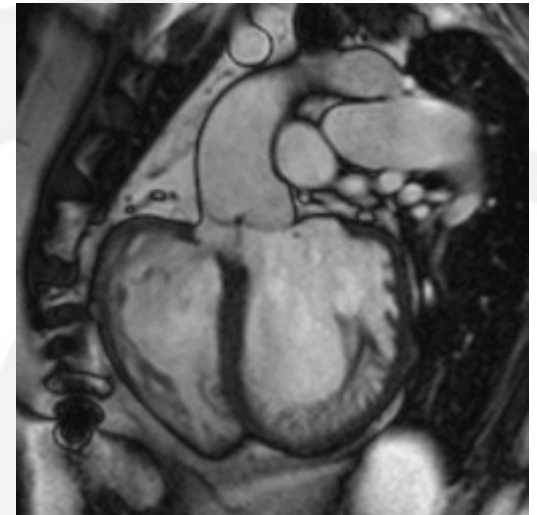
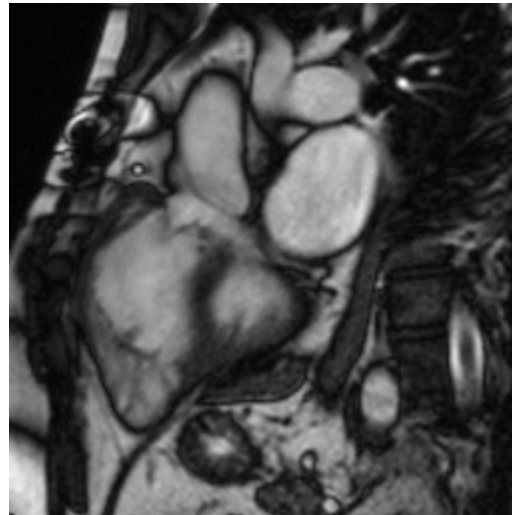
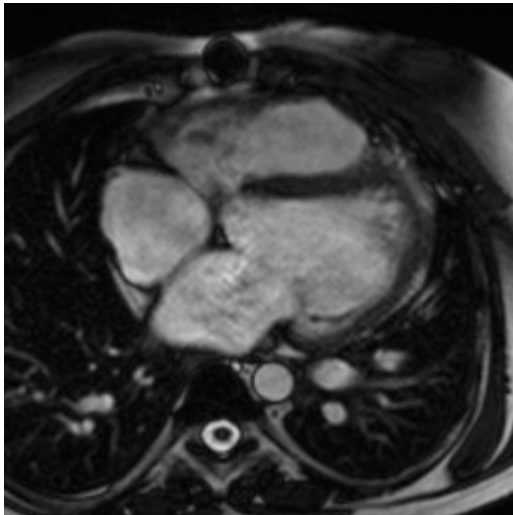
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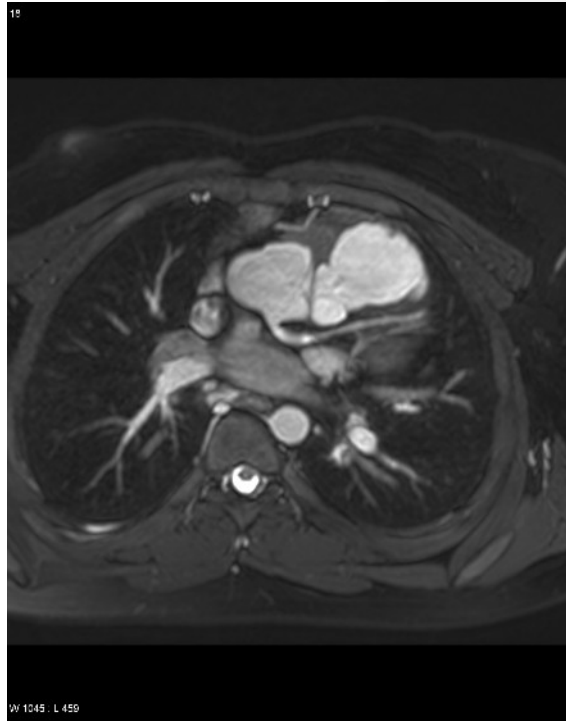
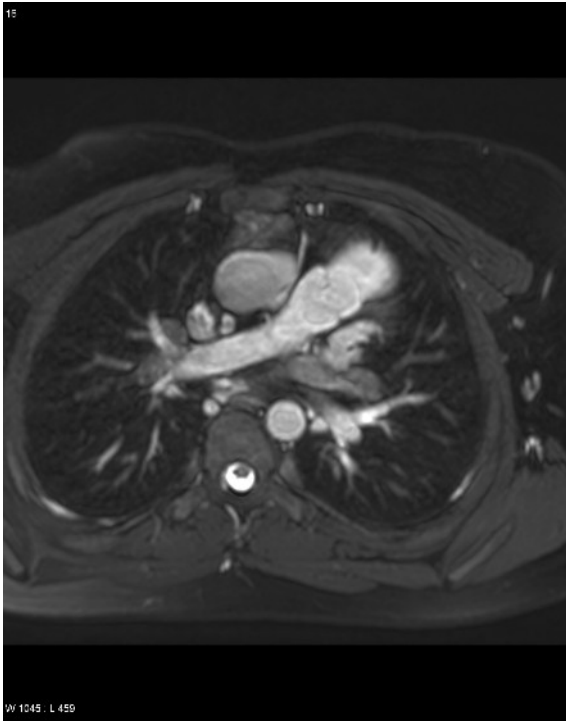
Áramlás kiértékelés



VSD



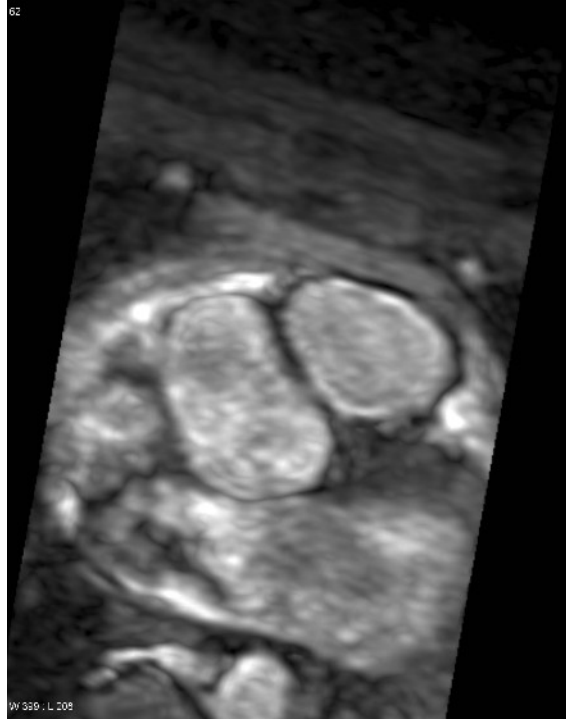
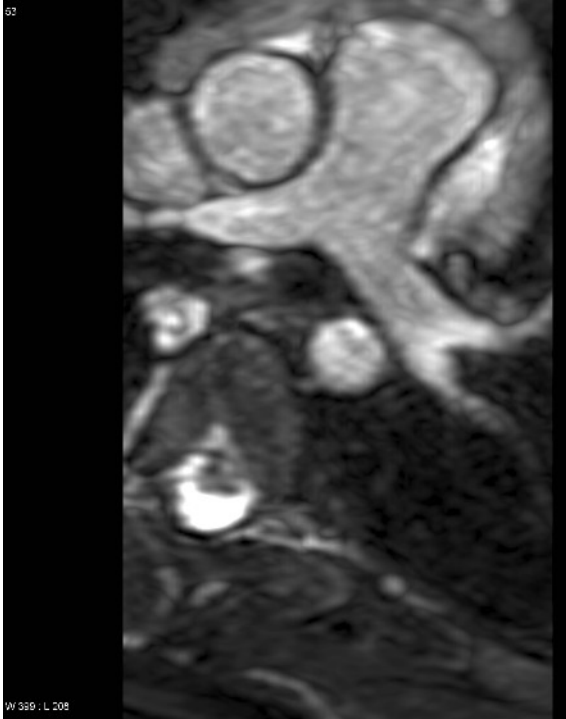
Navigátoros 3D



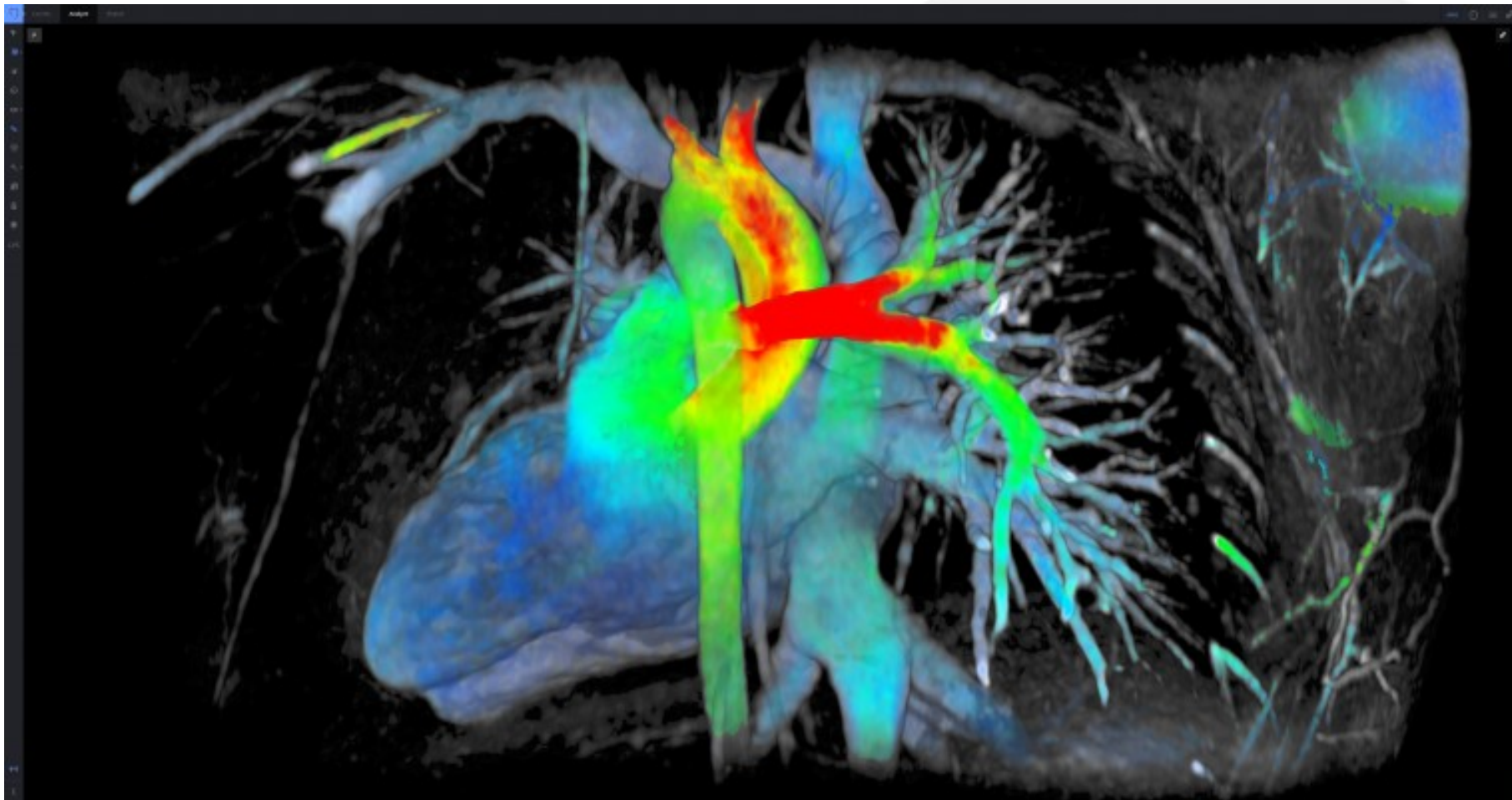
3D navigátoros MRA rekonstrukciók



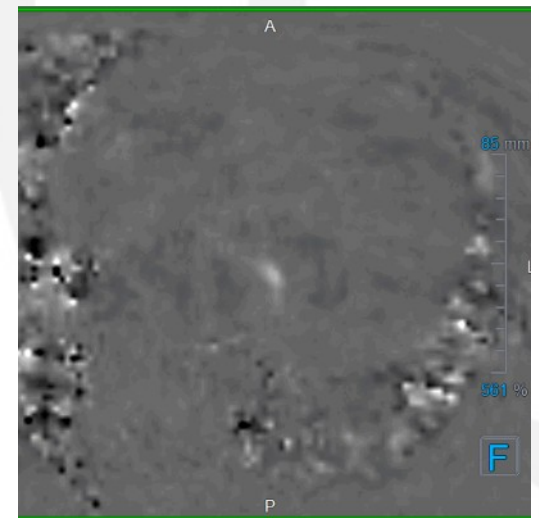
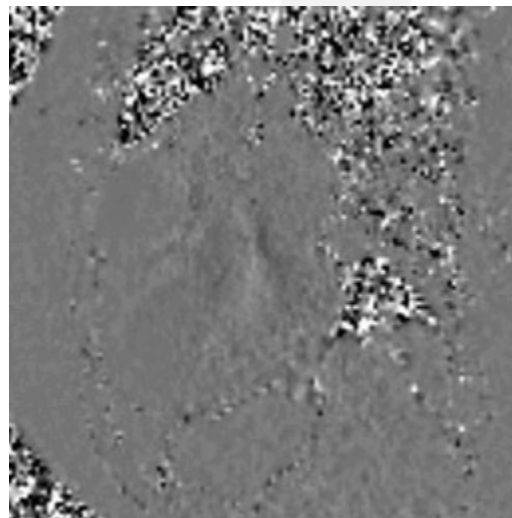
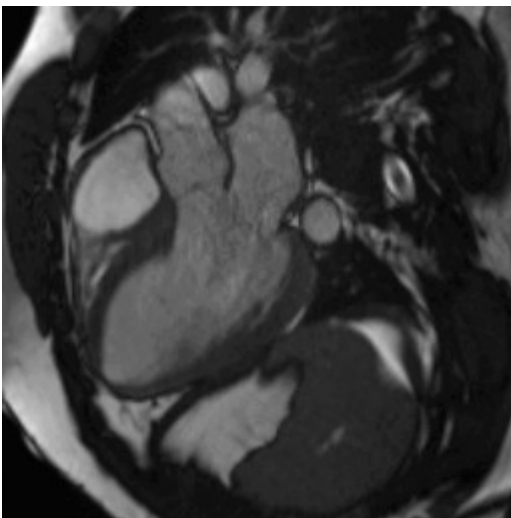
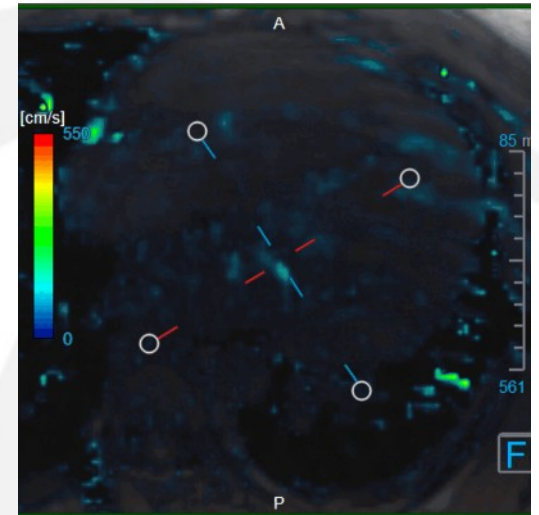
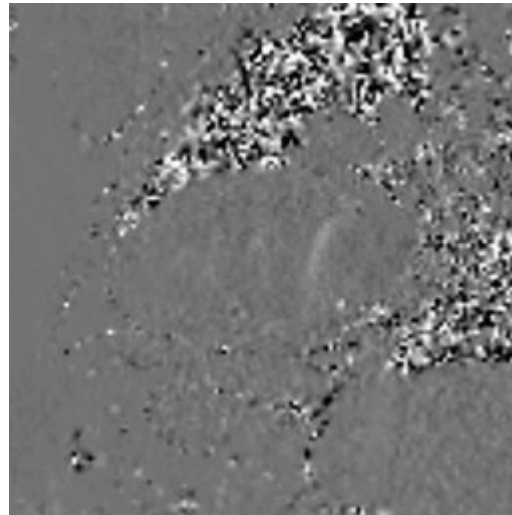
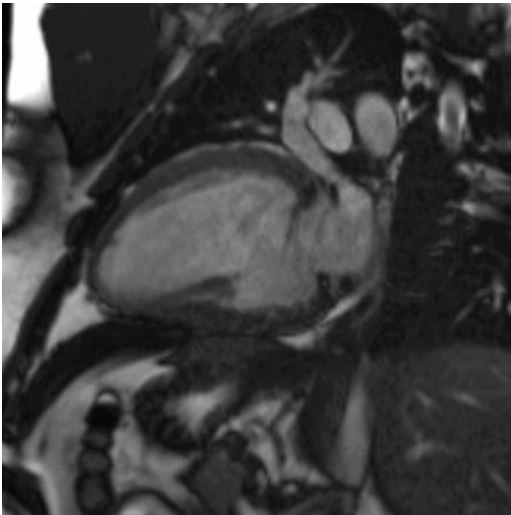
További posztprocesszálas



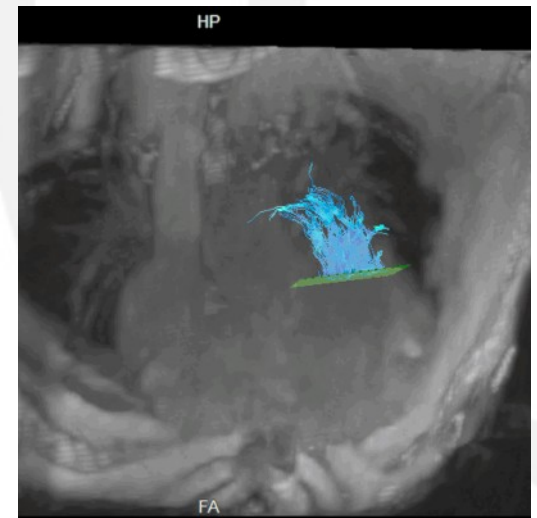
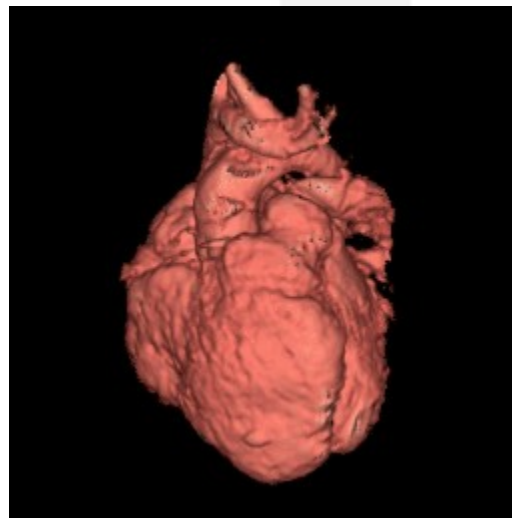
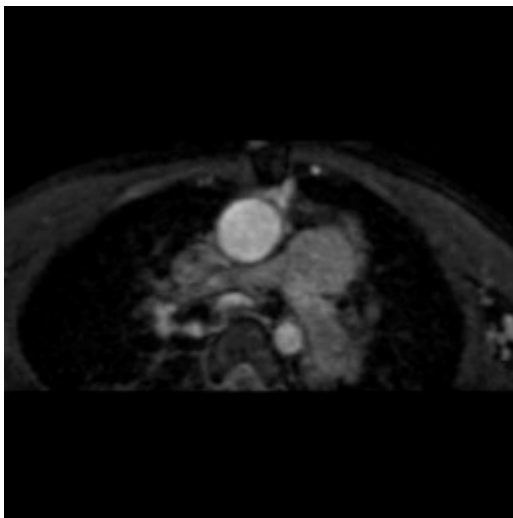
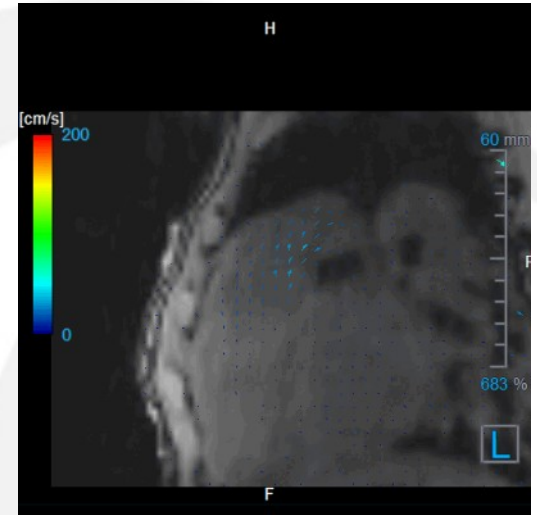
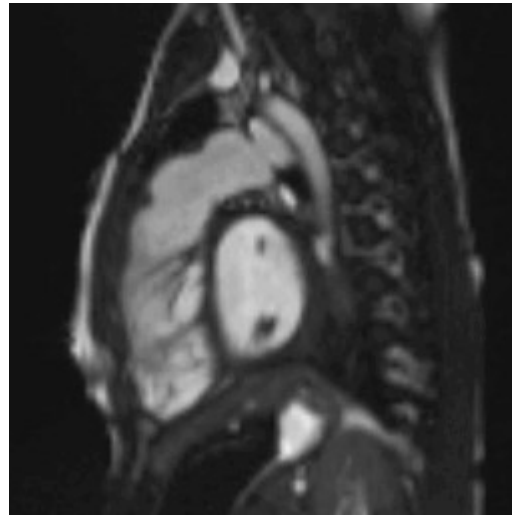
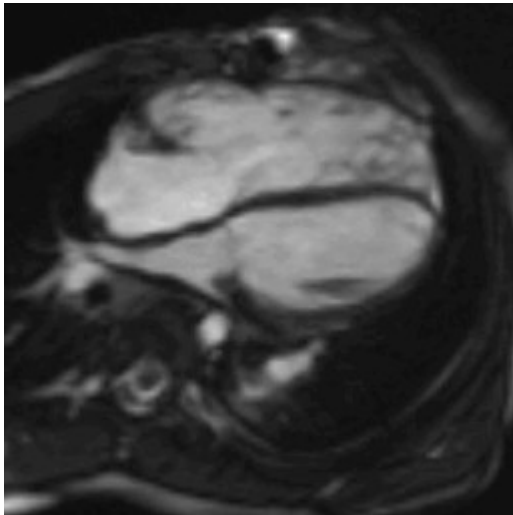
4D flow egyre népszerűbb



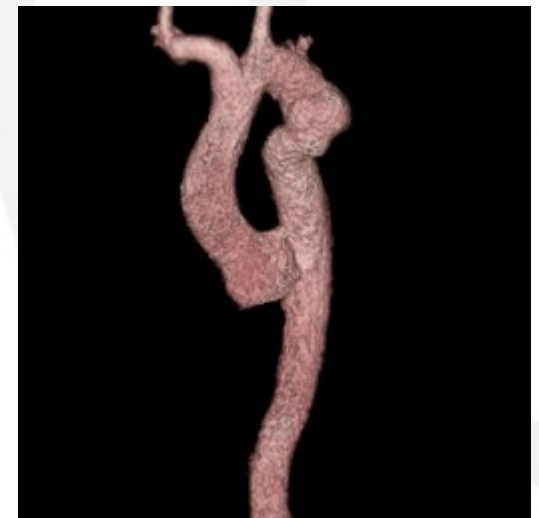
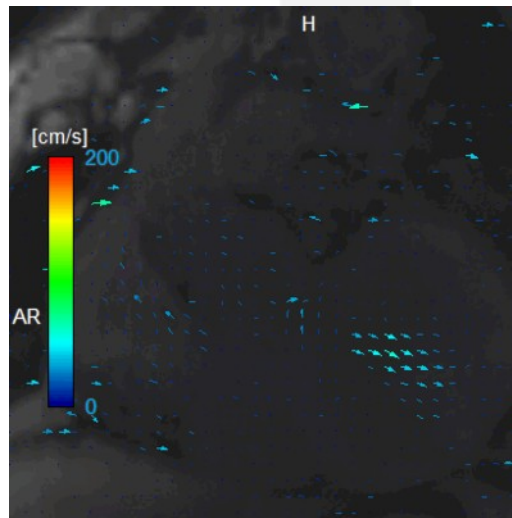
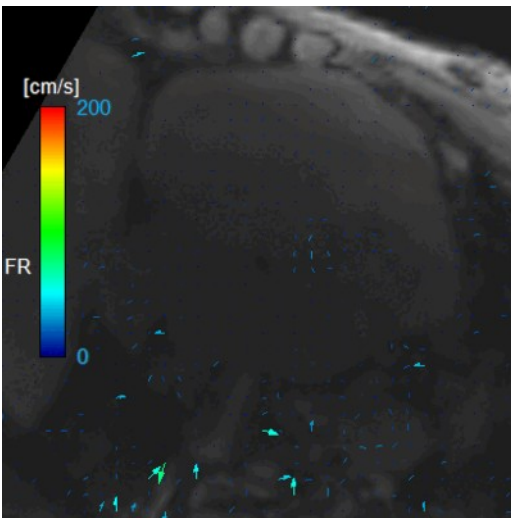
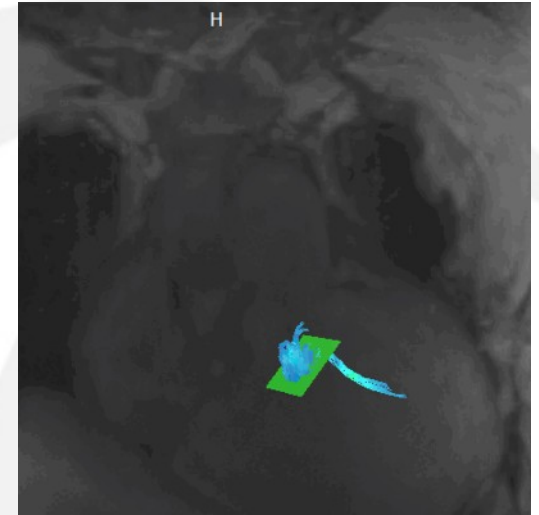
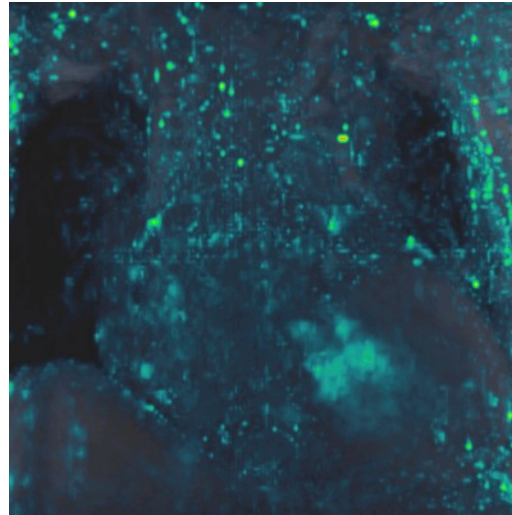
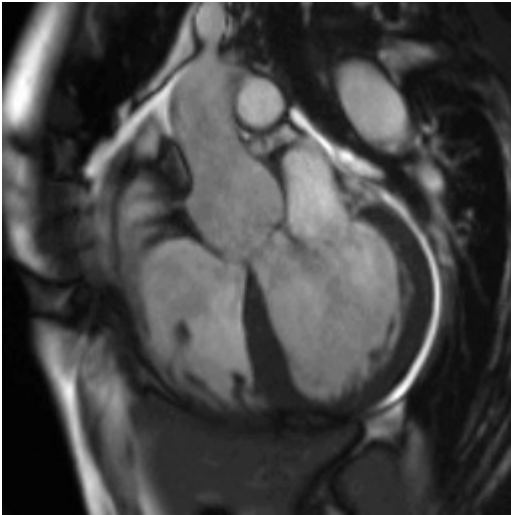
Mitral insuff.: 44%, 468cm/s, 88/38Hgmm



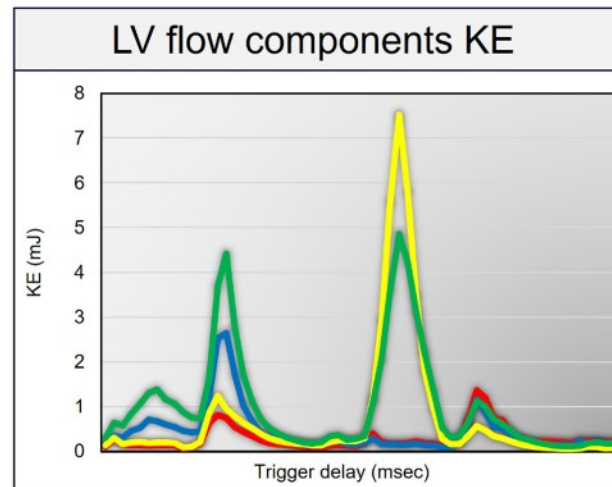
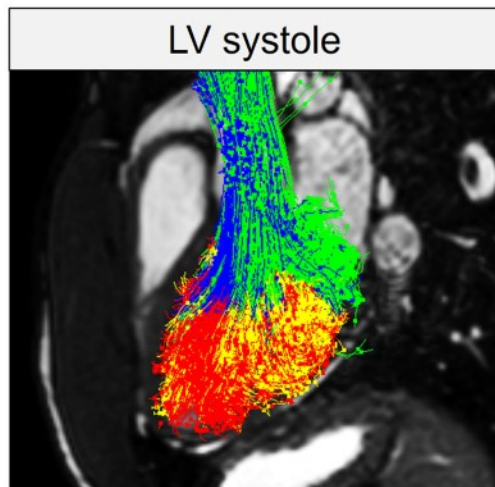
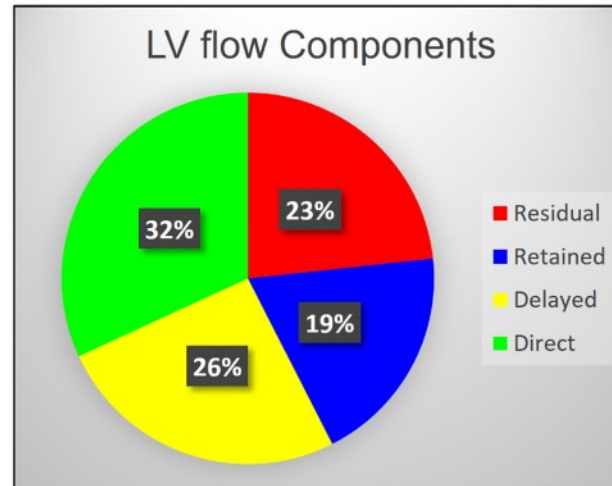
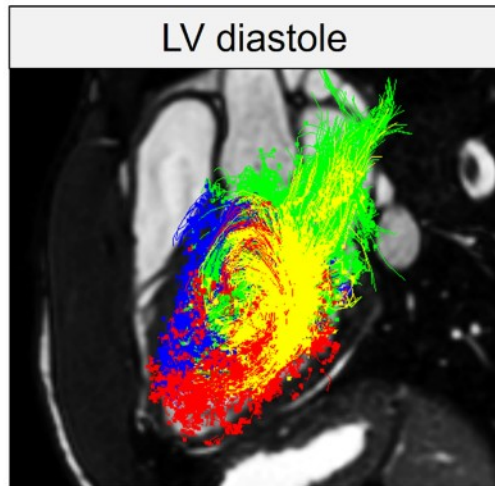
FIV, PA Rf: 64%, iNAV MRA, 4D-Flow

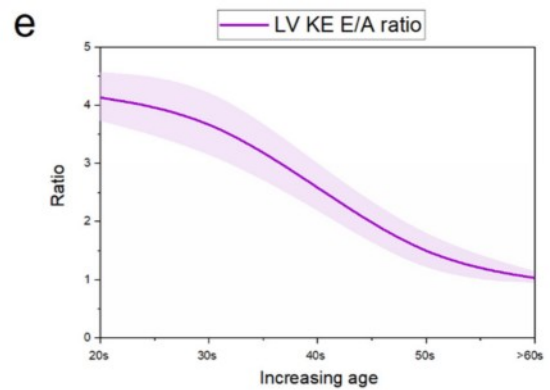
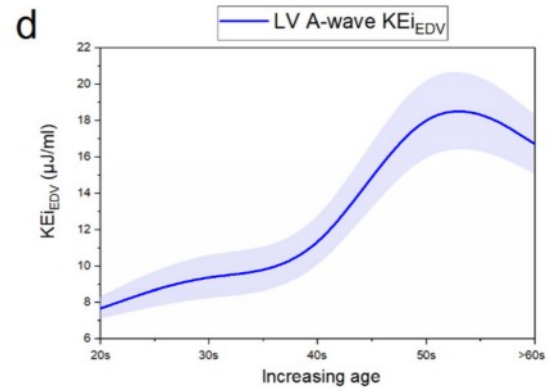
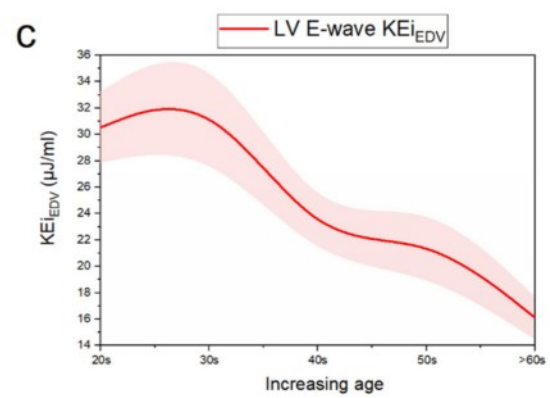
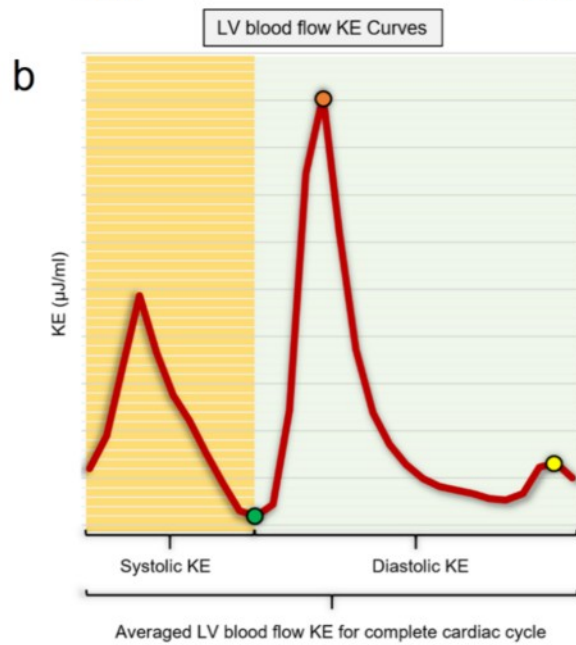
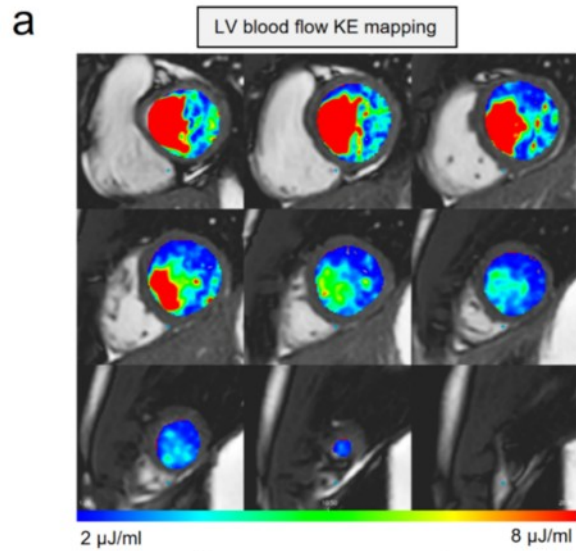


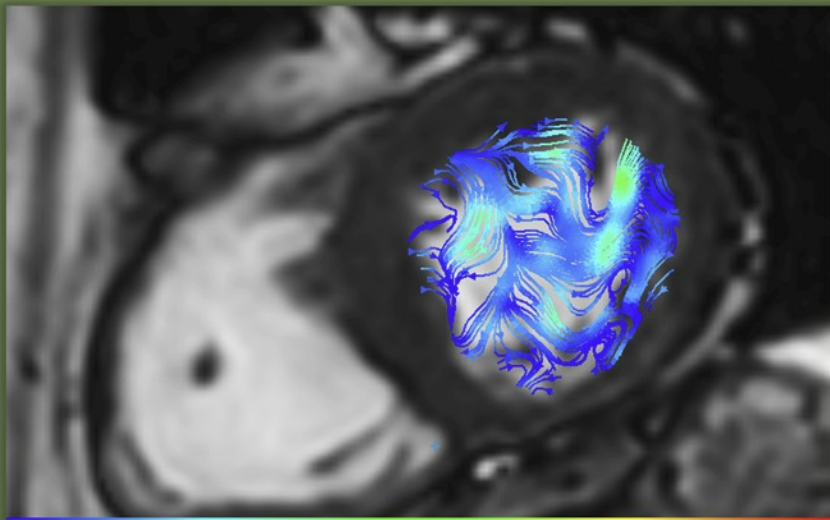
CoA, BAV, AOI, Ebstein-, AO Rf: 49%



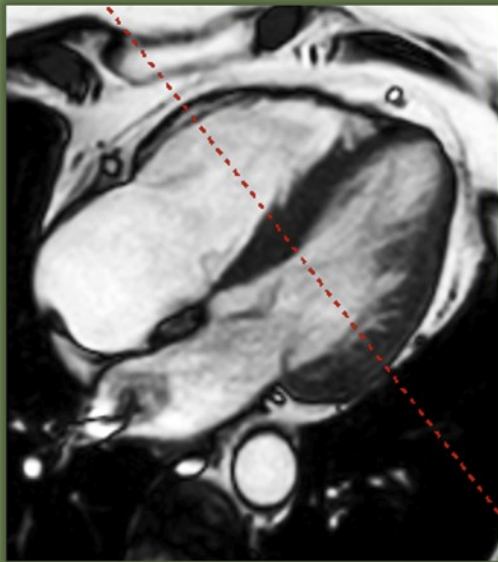
4D-Flow: Kinetic Energy





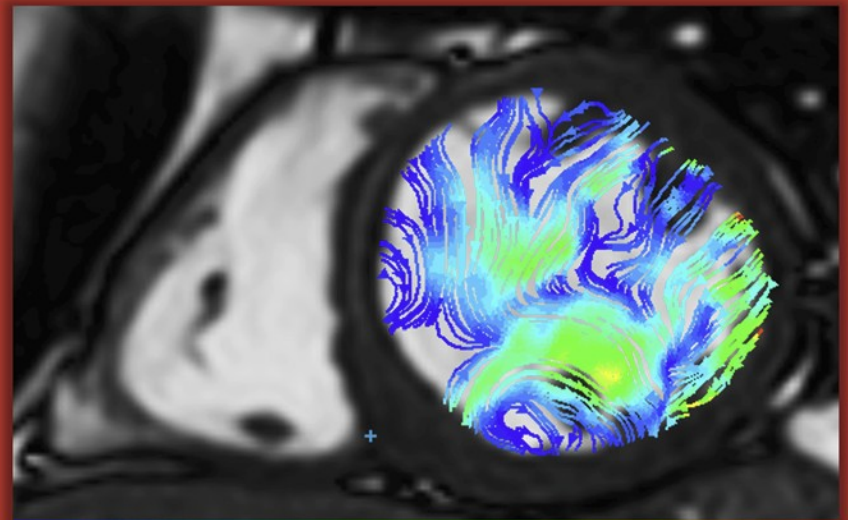


2cm/sec 30cm/sec

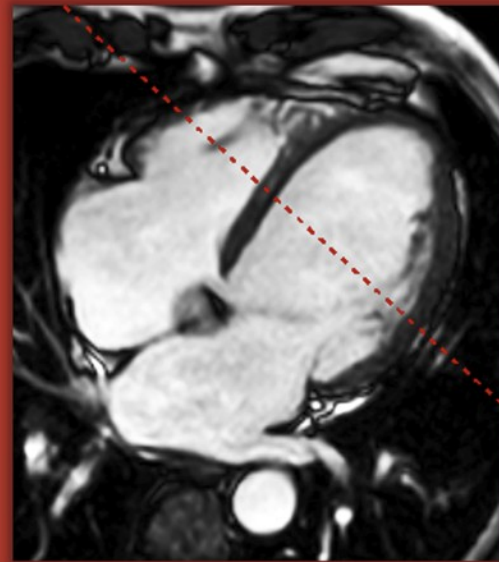


EF=60%
In-plane KE=23%

A



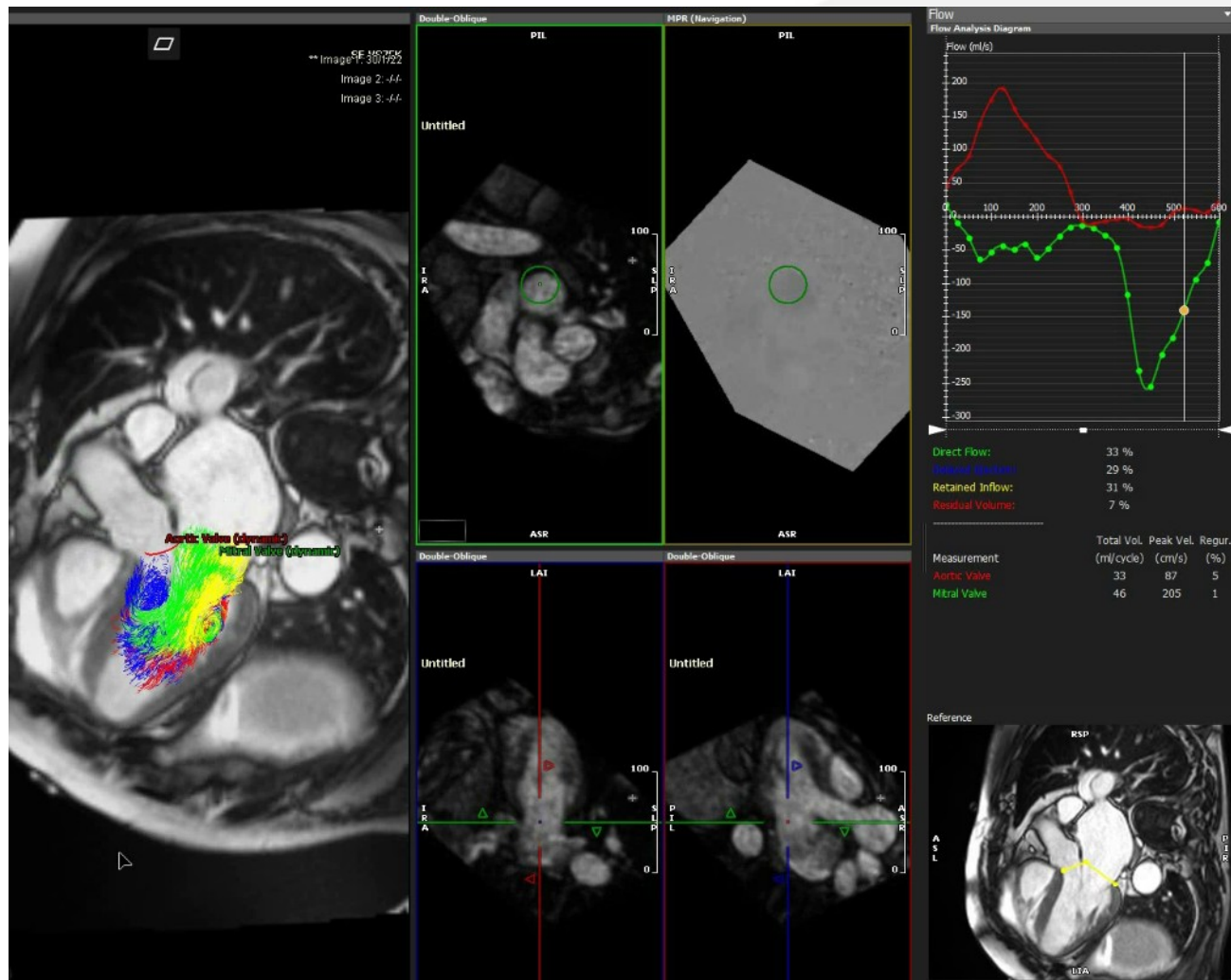
2cm/sec 30cm/sec



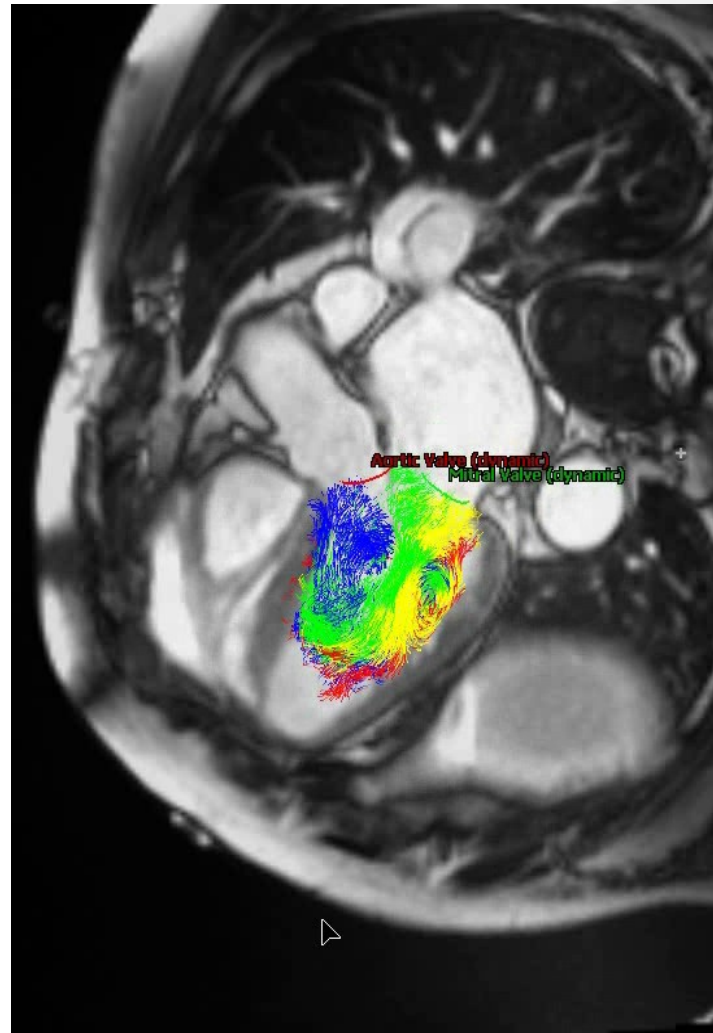
EF=32%
In-plane KE=45%

B

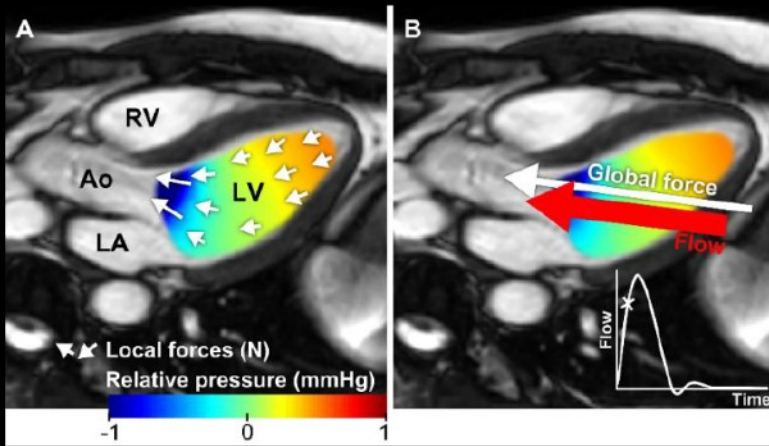
In-house experience



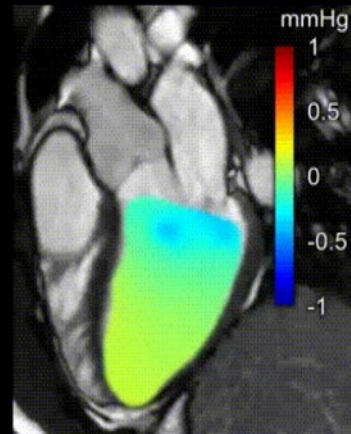
In-house experience



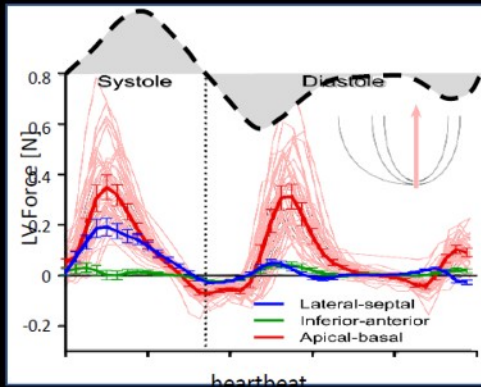
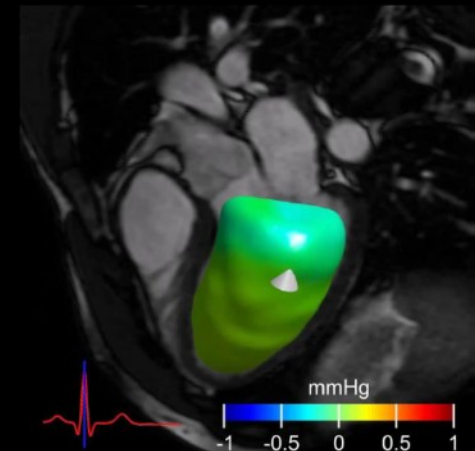
Hemodynamic Forces From 2D - 4D MRI Flow



Arvidsson et al, AJP, 2016



Arvidsson et al. AJP Heart 312(2):H314, 2017



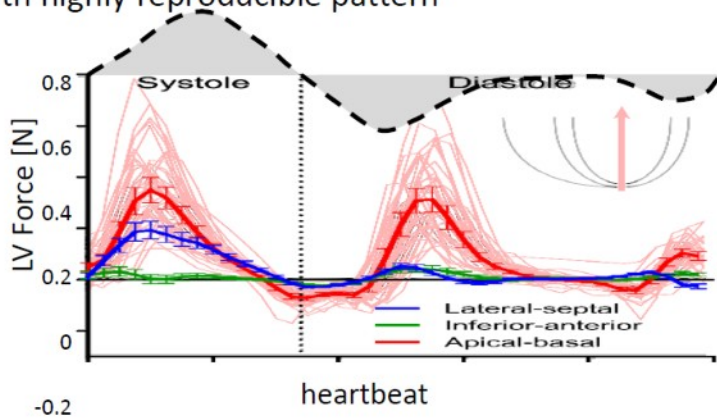
Hemodynamic forces (intra-LV pressure gradients) are normally directed **Base-to-apex** with a highly **reproducible pattern** with little variability among subjects

What Hemodynamic Forces tell us (Observations)

CONFIRMATIONS BY 4D MR FLOW

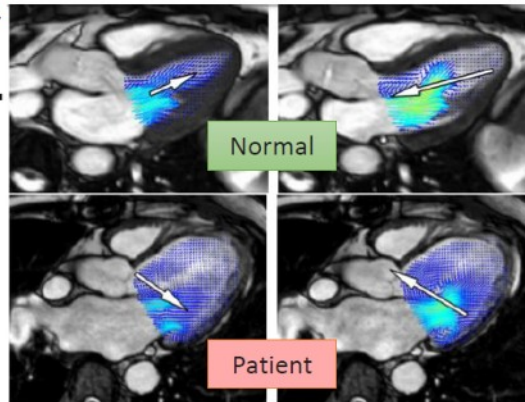
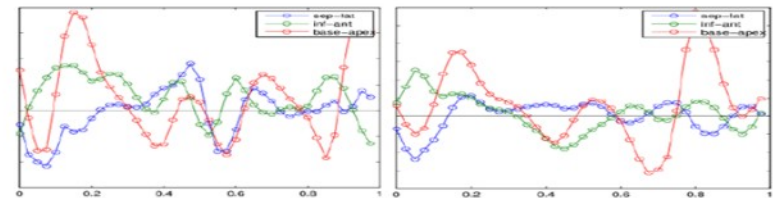
NORMAL SUBJECTS

Hemodynamic forces are directed *Base-to-apex*
With highly reproducible pattern



PATHOLOGICAL SUBJECTS

Appearance of significant transversal components, alteration of timings, with high variability among subjects



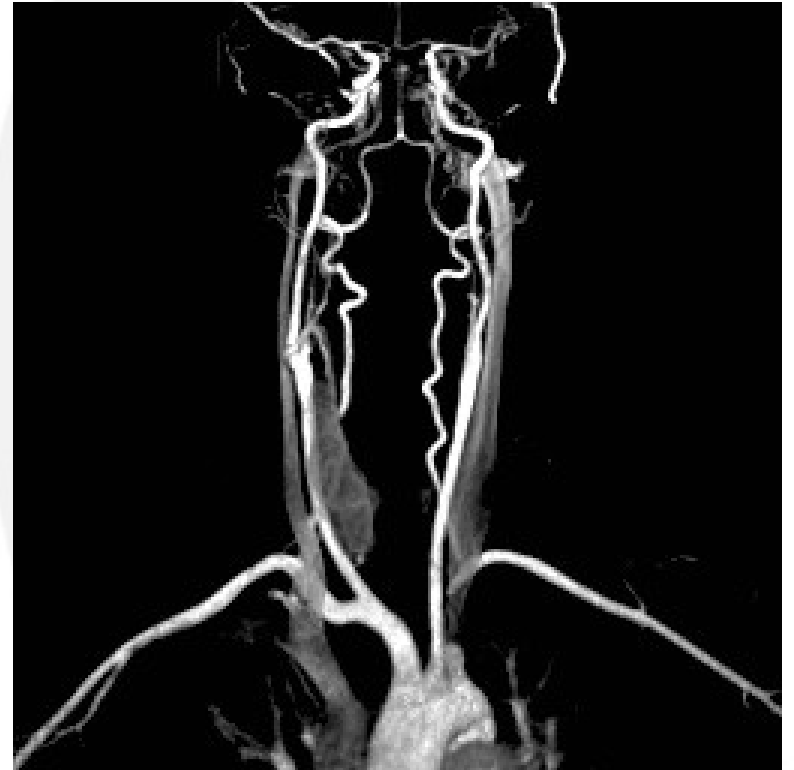
- Ardivsson et al. 2016
- Toger et al. 2018

aps American Physiological Society
AMERICAN JOURNAL of PHYSIOLOGY
Heart and Circulatory
Physiology

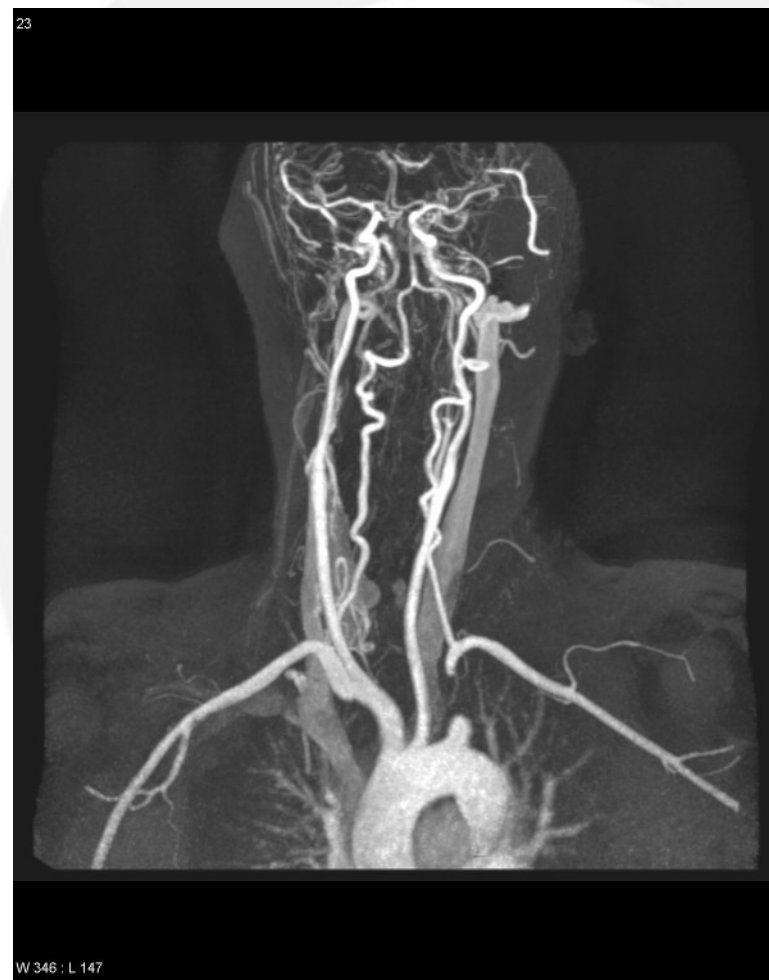
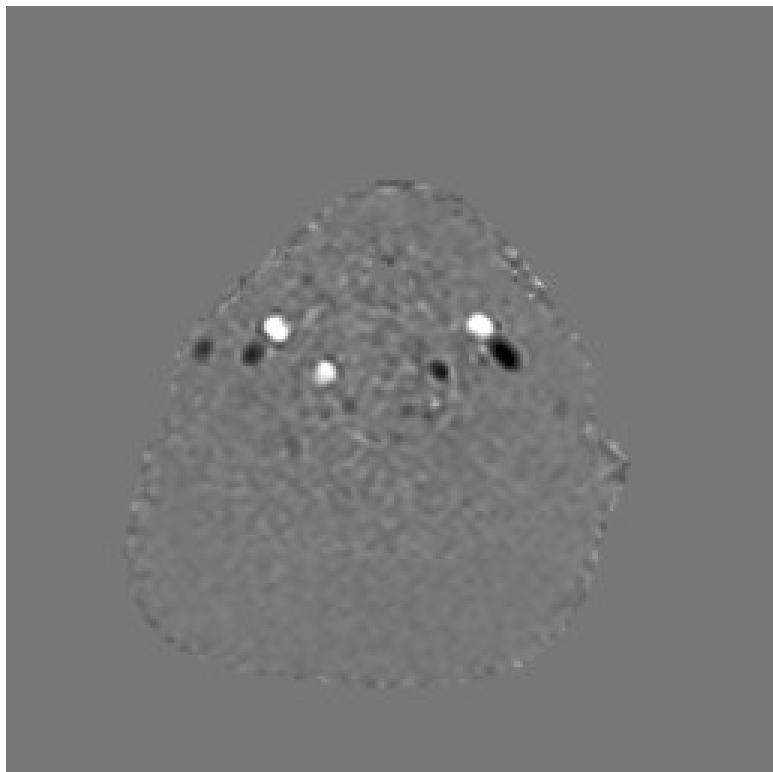
Ardvisson et al. 2016
Eriksson et al. 2017
Ardvisson et al. 2018

aps American Physiological Society
AMERICAN JOURNAL of PHYSIOLOGY
Heart and Circulatory
Physiology
SCIENTIFIC REPORTS
AMERICAN JOURNAL of PHYSIOLOGY
Heart and Circulatory
Physiology

CE-MRA



Áramlás mérés



Nem részletezem

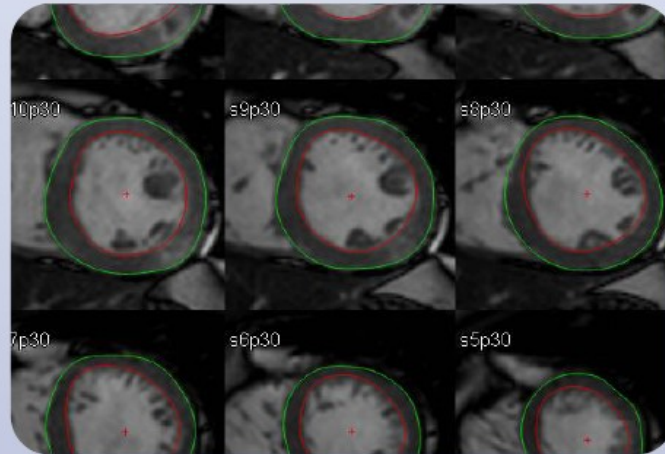


- Tagging

- Top Magn Reson Imag 11(6):359-371 (2000)
- Radiology 214(2):453-466 (2000)
- J Cardiovasc Magn Reson 4(3):341-351 (2002)
- J Magn Reson Imag 24(6):1432-1438 (2006)
- J Magn Reson Imag 29(1):99-105 (2009)

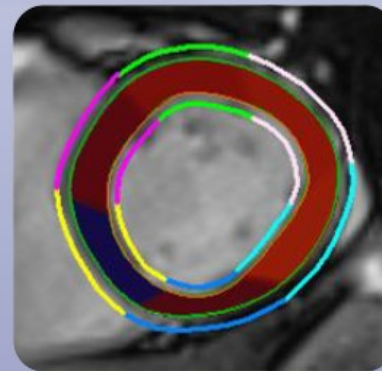
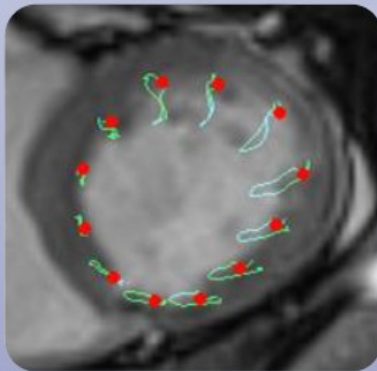


Medis QStrain



Works on SSFP cines
Cutting edge FT-MR
LV, RV and LA

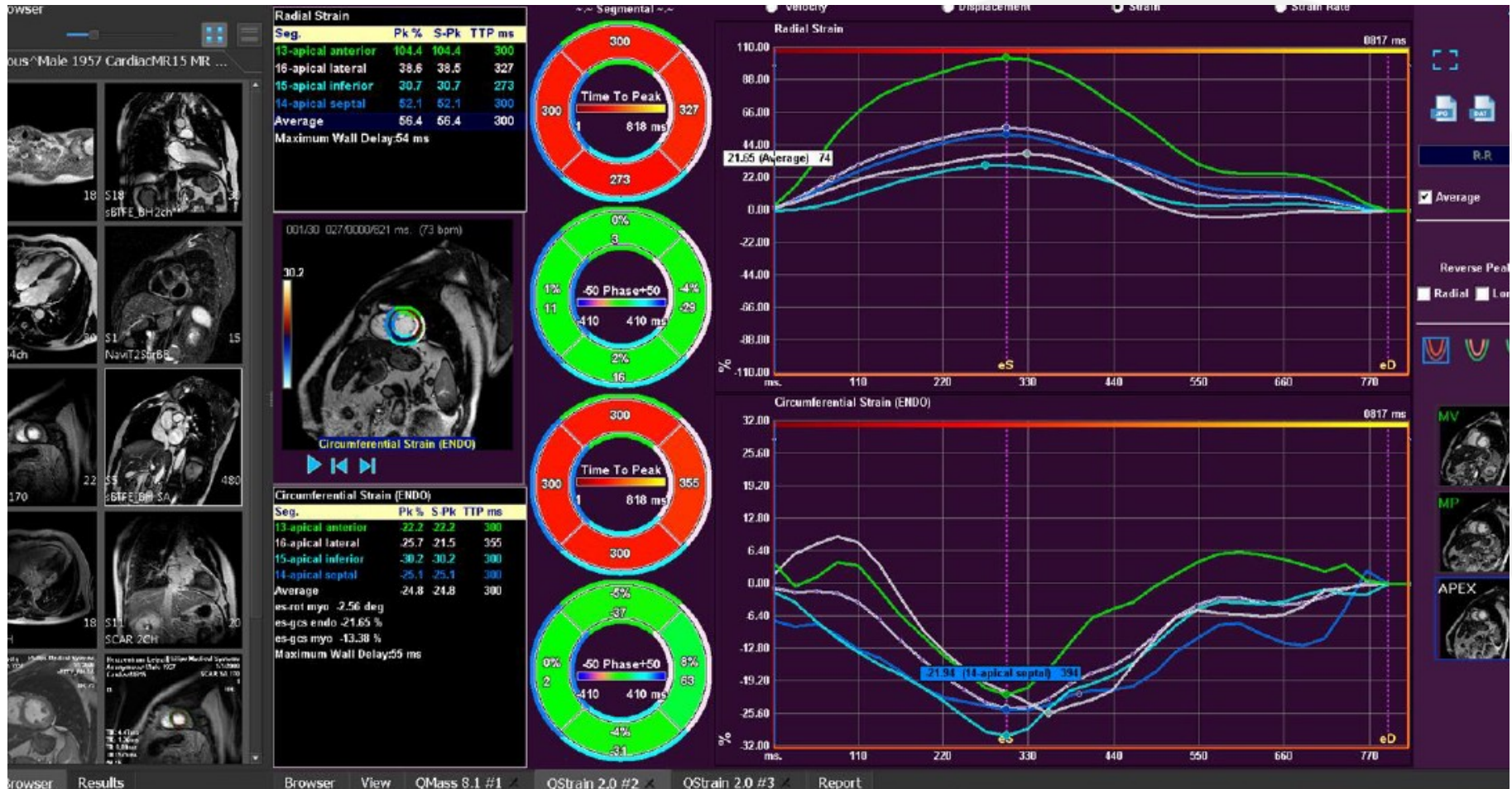
...When you have access to cutting edge, Feature Tracking MR algorithms...



....to obtain a wealth of information with your existing data...

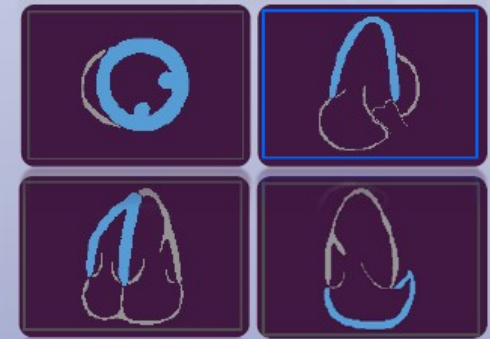
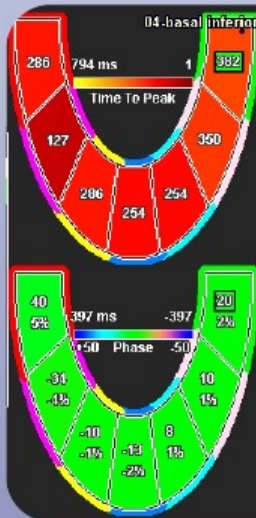
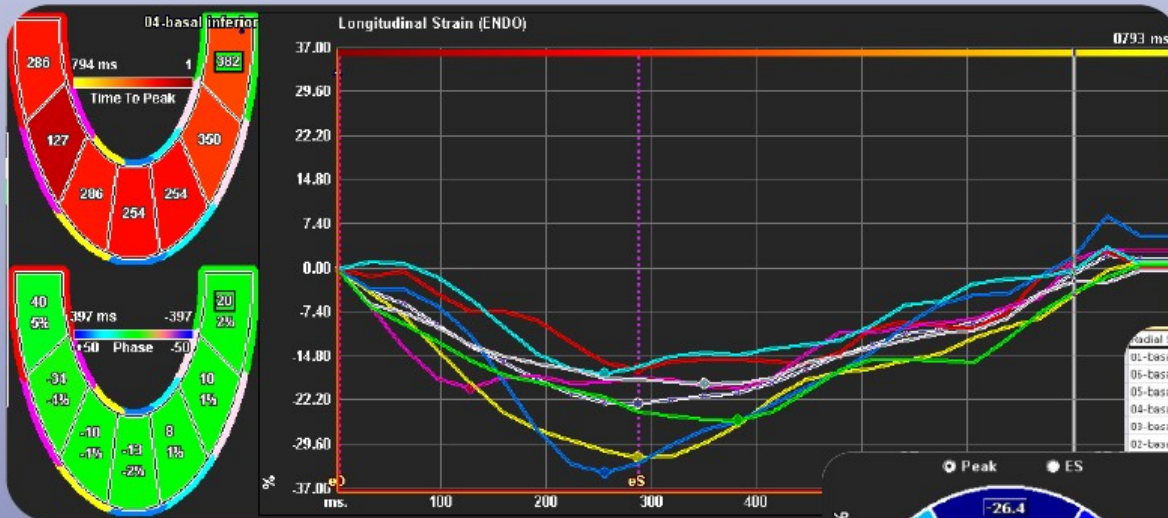


Medis QStrain



Medis QStrain

Left Atrium as well.

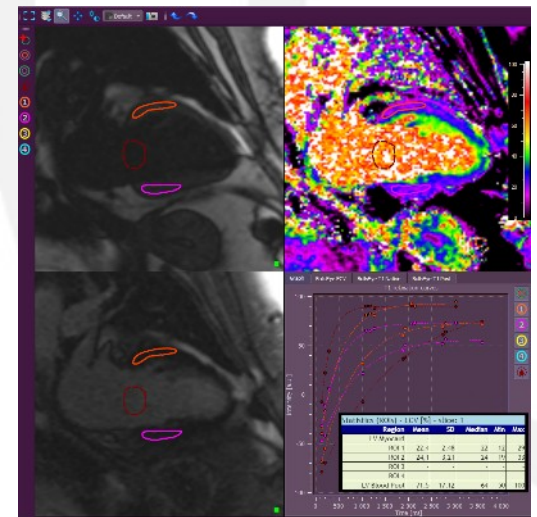
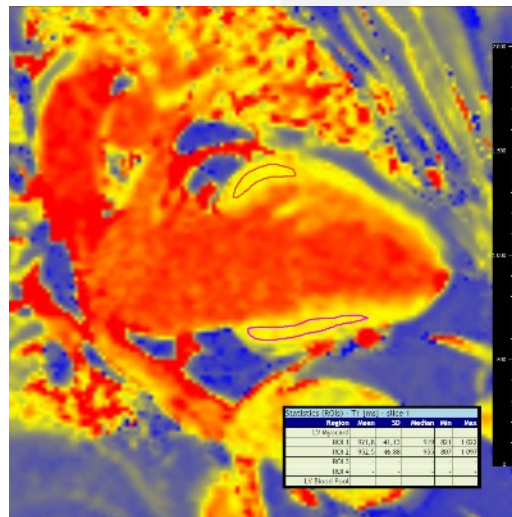
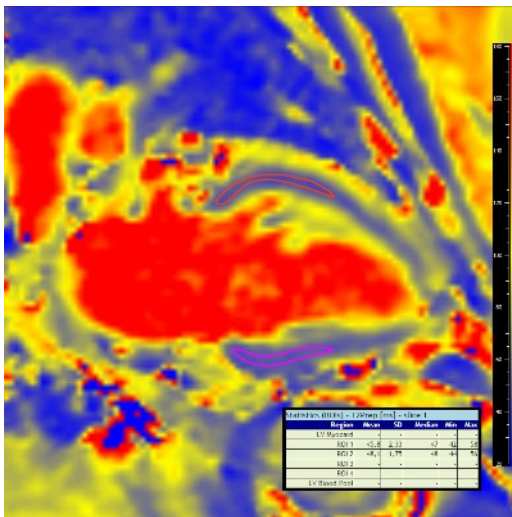
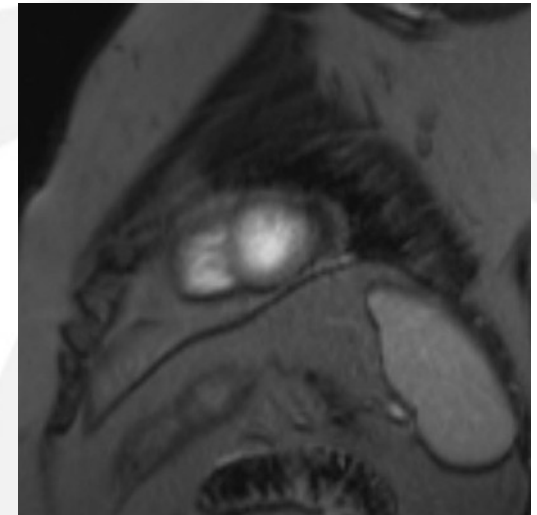
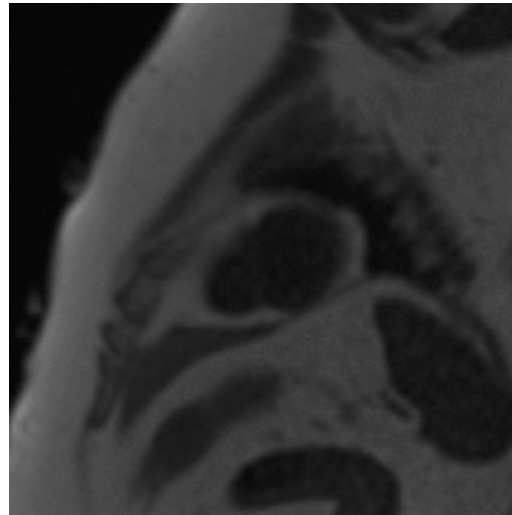
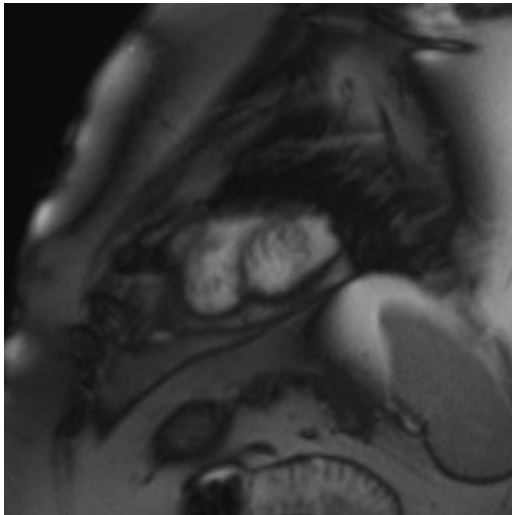


Radial Strain	01	02	03	04	05	06	07	08	09	10
01-basal anterior	-1.082	-0.258	3.005	8.64	25.115	21.743	28.894	36.582	32.7	
05-basal lateral	0.945	3.643	7.553	12.71	18.544	25.603	31.926	37.919	43.66	
05-basal posterior	-3.3	-5.523	-5.773	-2.851	2.588	8.653	14.72	19.57	23.4	
04-basal inferior	-0.264	0.975	1.95	7.081	9.797	9.67	3.004	8.397	8.15	
01-basal septal	0.589	1.149	1.14	0.104	-2.106	-4.47	-5.789	-6.244	-6.40	
02-basal anteroapical	-1.461	-1.77	-1.913	-2.111	-2.137	-2.054	-1.923	-1.646	-2.32	
	-0.762	-0.297	1.334	3.894	6.883	9.751	11.317	14.596	16.54	
	1.551	3.121	4.688	6.449	9.1	12.213	15.306	17.856	20.00	

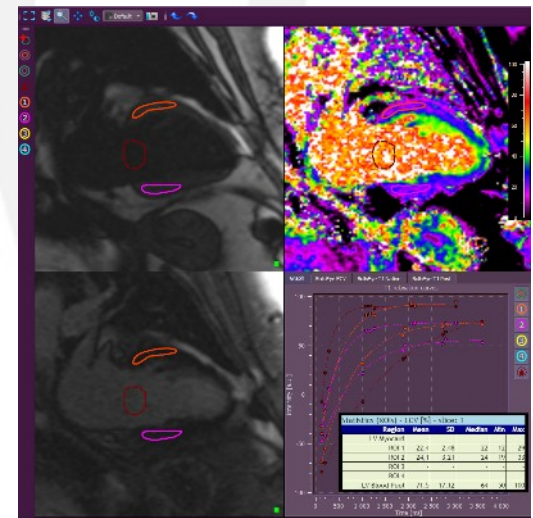
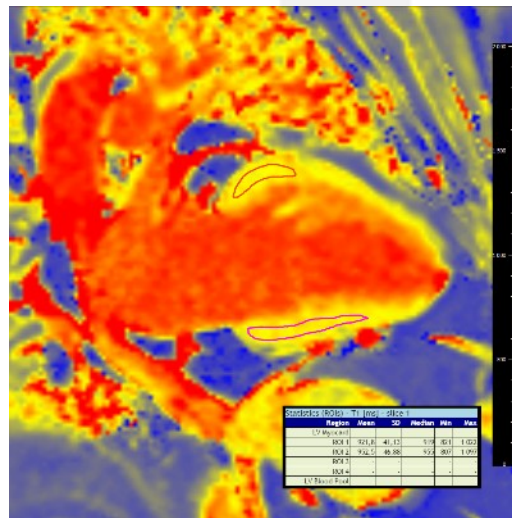
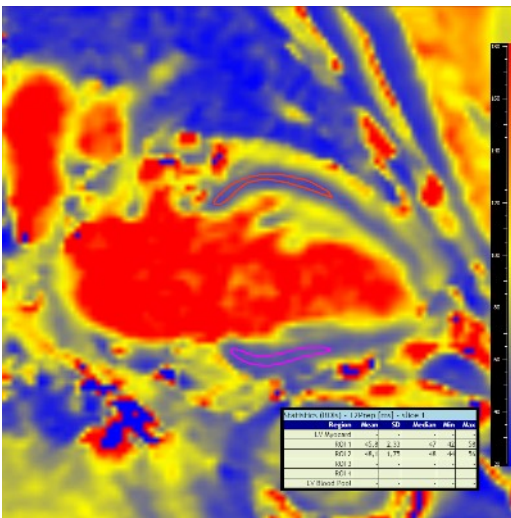
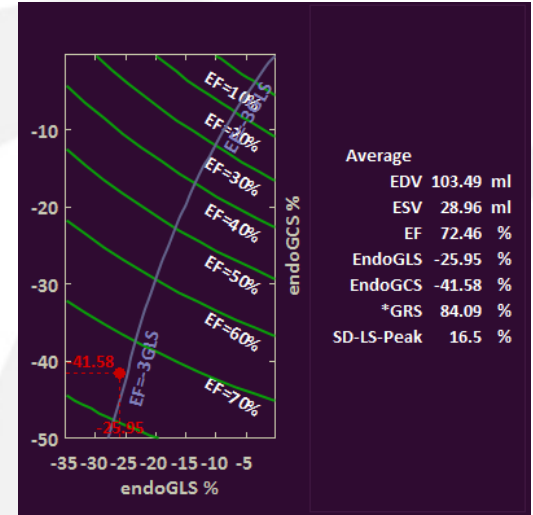
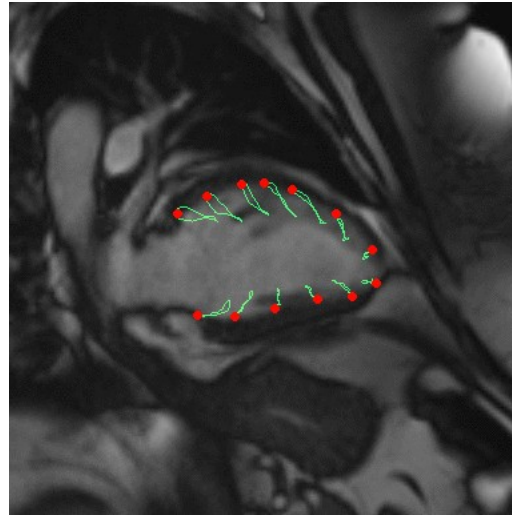
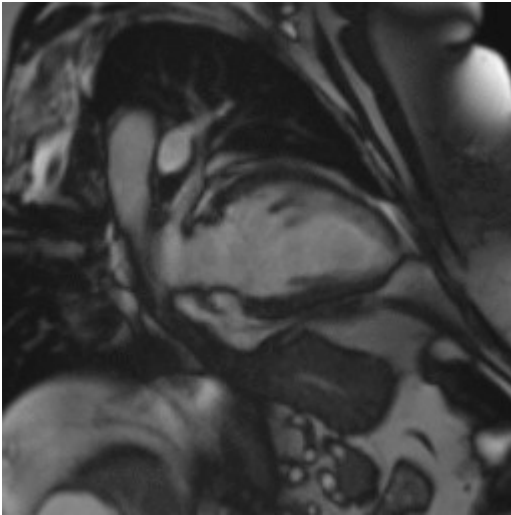


Radial Strain (MYO)	01	02	03	04	05	06	07	08	09	10
01-basal anterior	-1.501	-0.067	-7.704	-11.307	-16.162	-18.010	-21.276	-25.165	-26.25	
05-basal lateral	1.341	1.61	2.285	-1.612	-6.888	-11.107	-13.916	-16.494	-18.35	
05-basal posterior	-1.961	-9.554	-5.01	-9.504	-9.526	-9.556	-11.144	-11.561	-14.0	
04-basal inferior	1.355	1.22	2.185	0.75	-0.197	-0.714	-1.557	-4.744	-6.45	
01-basal septal	-2.033	1.313	-1.115	-3.122	-5.458	-8.263	-11.636	-13.791	-15.05	
02-basal anteroapical	2.95	0.549	-0.002	-4.329	-5.671	-6.861	-7.485	-8.292	-10.76	
	-0.081	-0.023	-1.36	-4.865	-7.267	-9.403	-11.498	-13.675	-15.16	
	1.985	4.813	4.879	4.675	5.295	5.965	6.607	6.931	6.76	

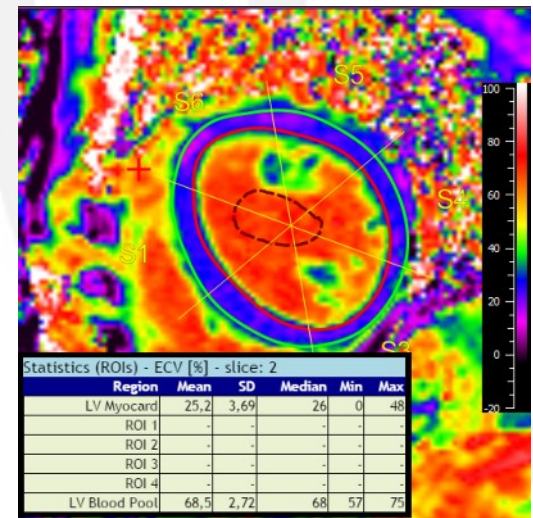
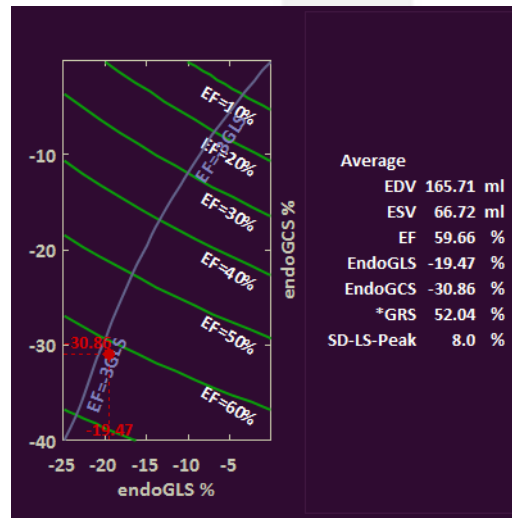
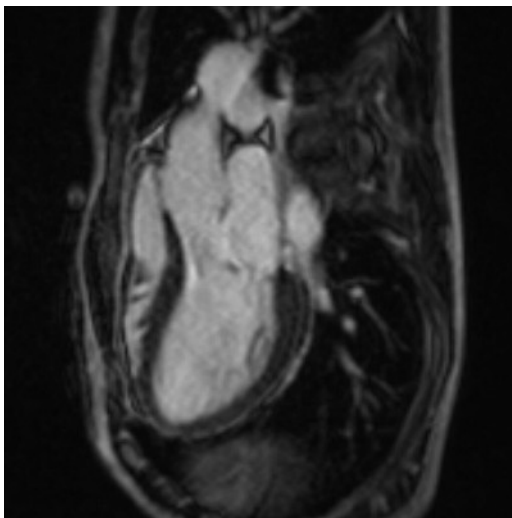
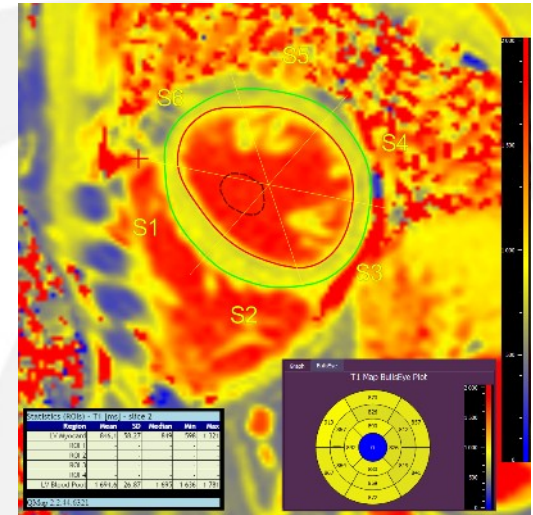
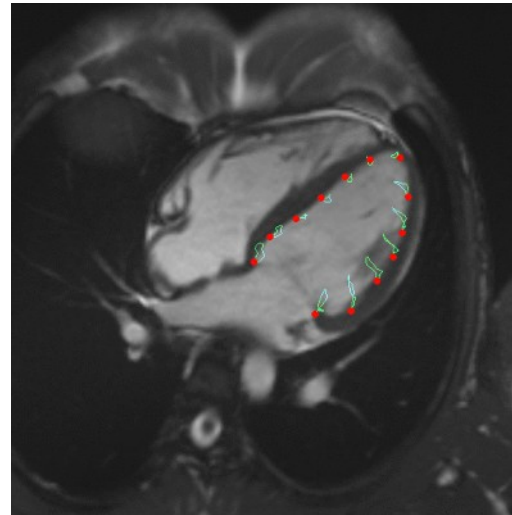
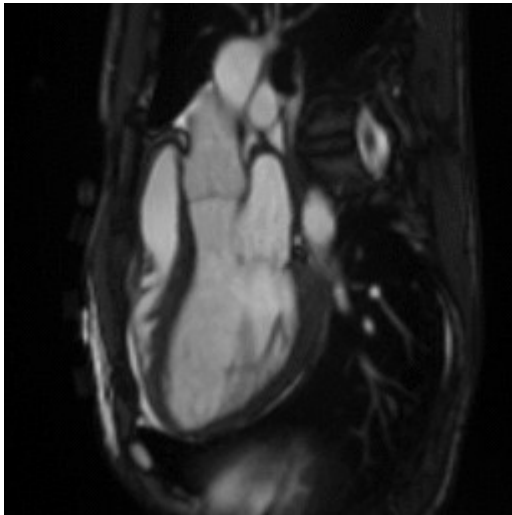
MM: thrombus-, GLS -26%, T2 45ms



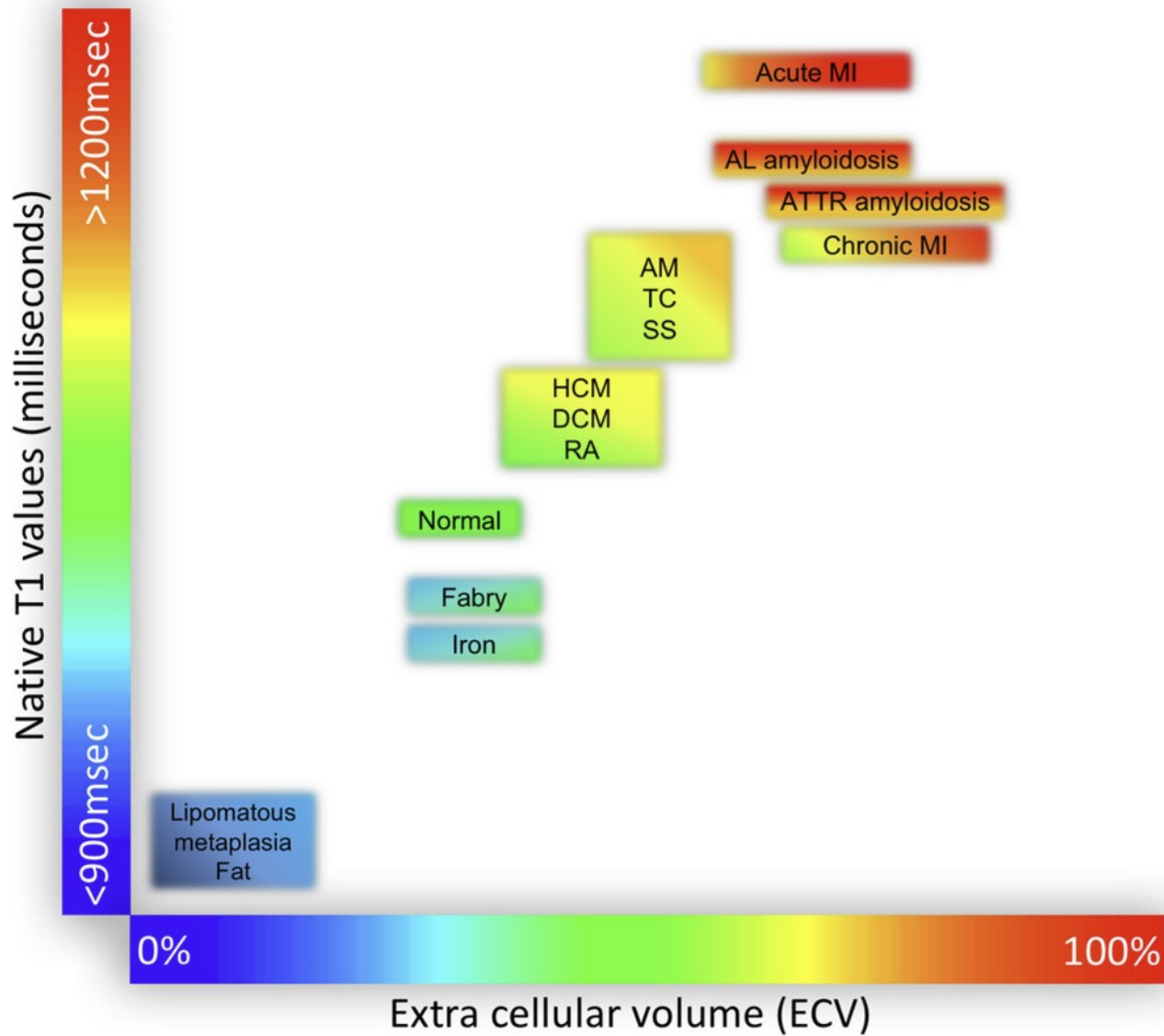
MM: thrombus-, GLS -26%, T2 45ms



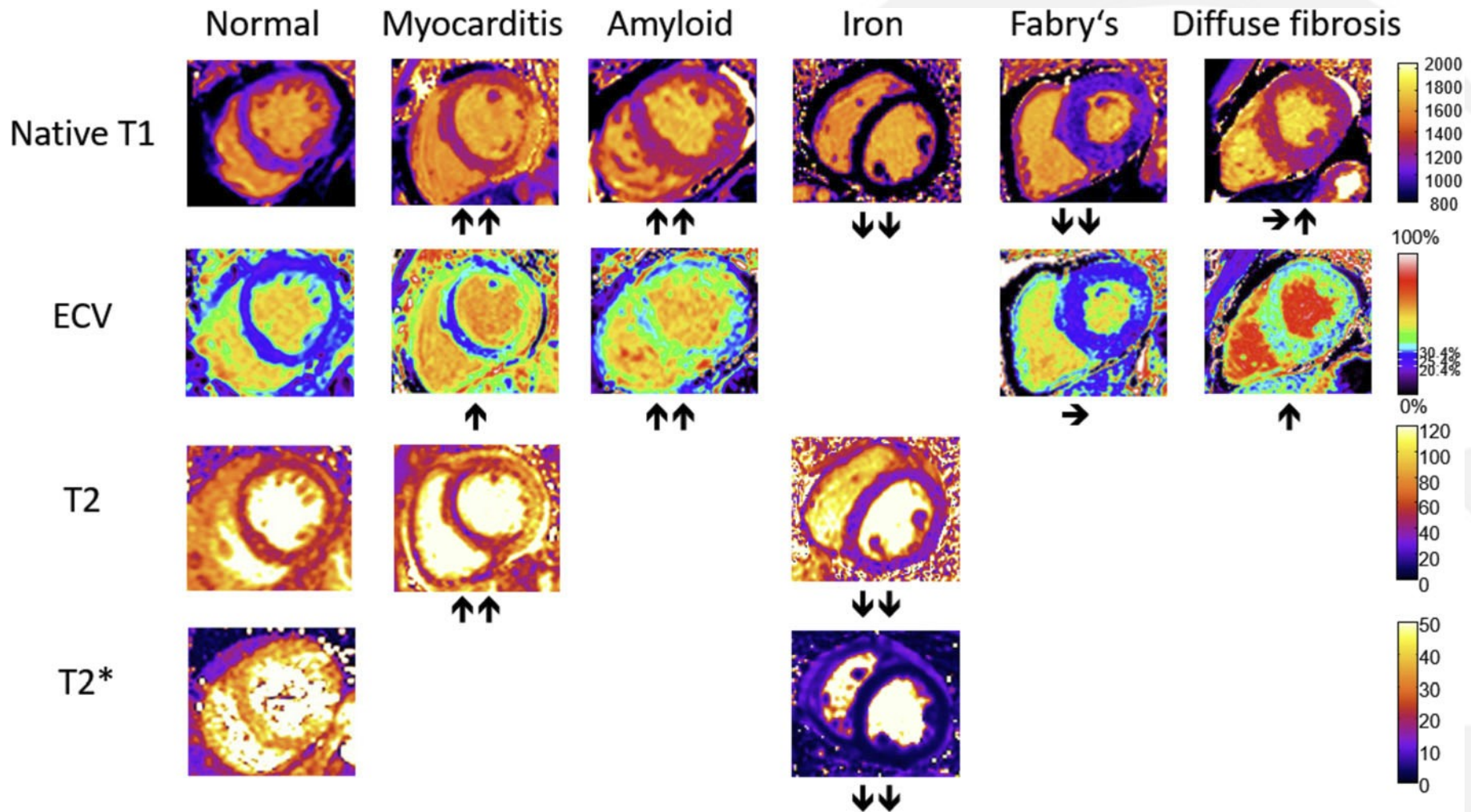
Anderson-Fabry, QStrain, QMap, LGE-



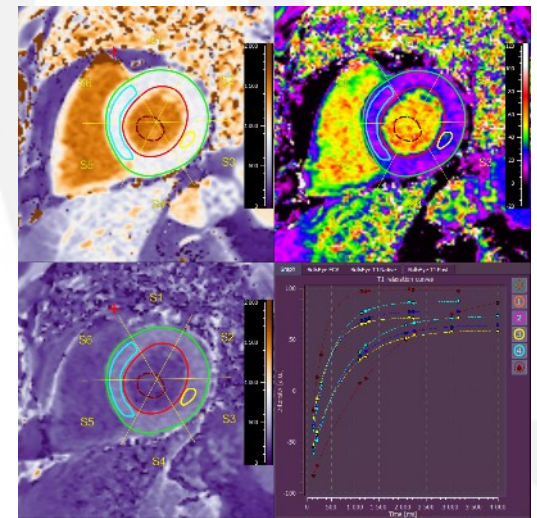
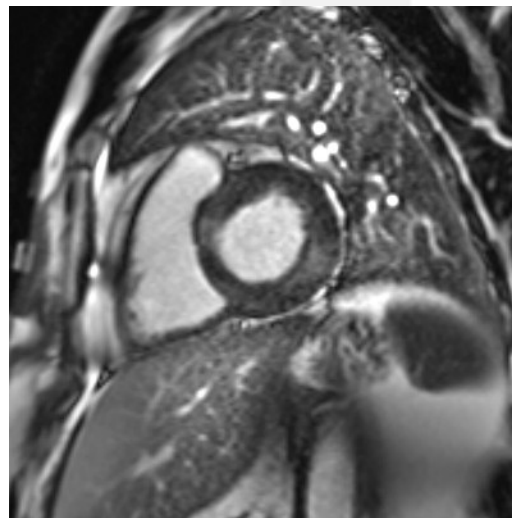
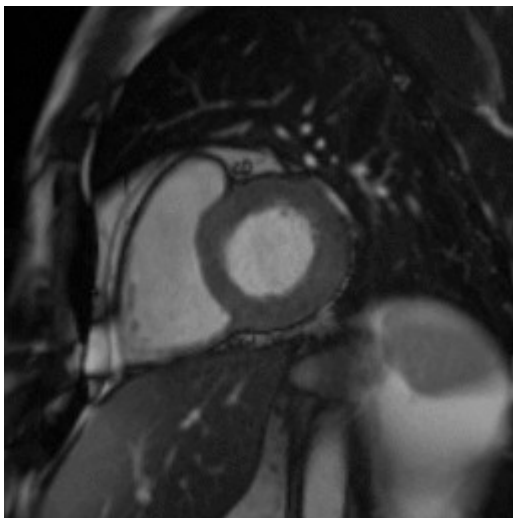
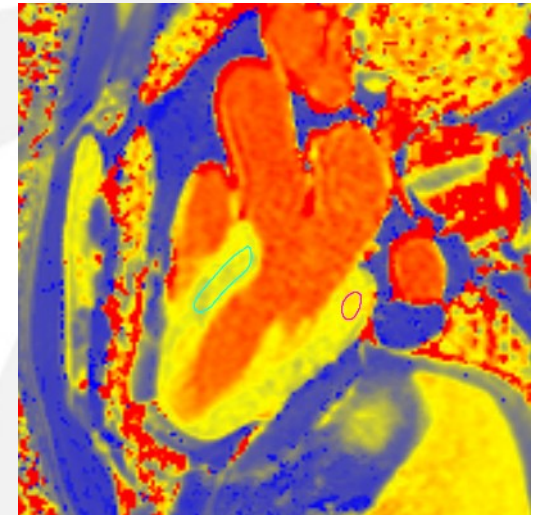
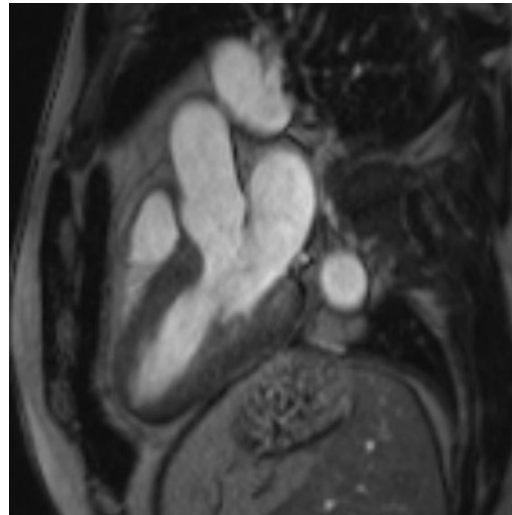
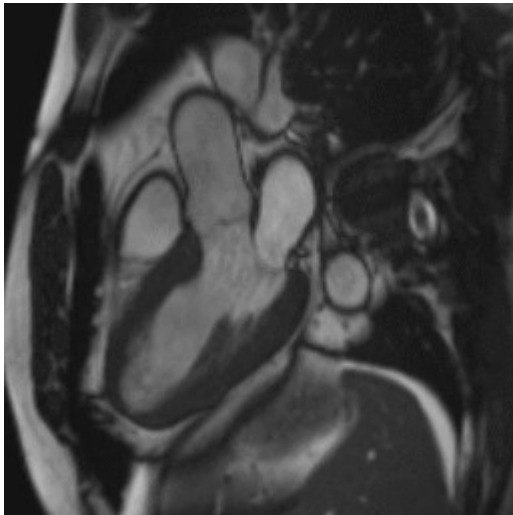
T1 Mapping and ECV in clinical practice



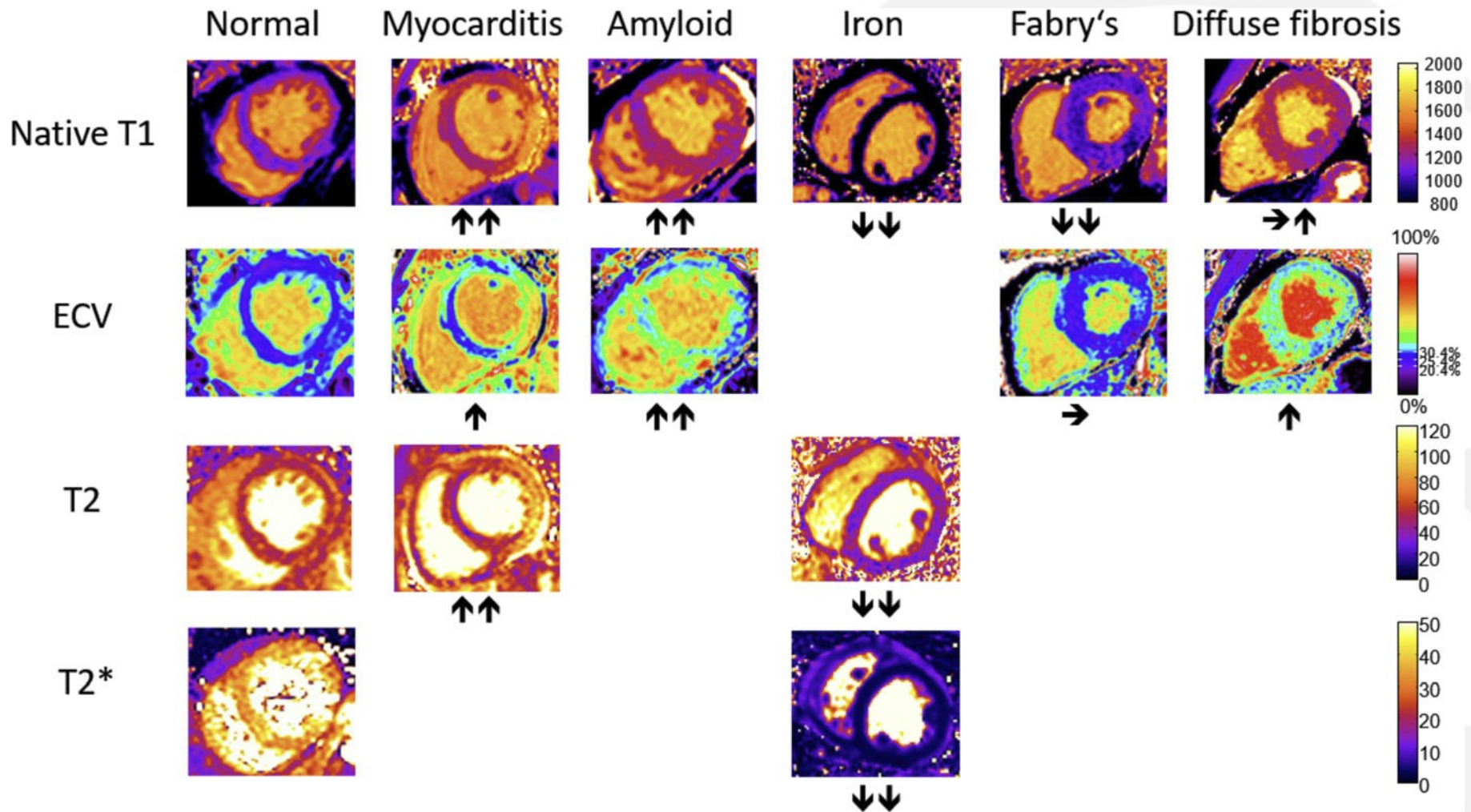
$$ECV = (1 - haematocrit) \frac{\frac{1}{post\ contrast\ T1\ myo} - \frac{1}{native\ T1\ myo}}{\frac{1}{post\ contrast\ T1\ blood} - \frac{1}{native\ T1\ blood}}$$



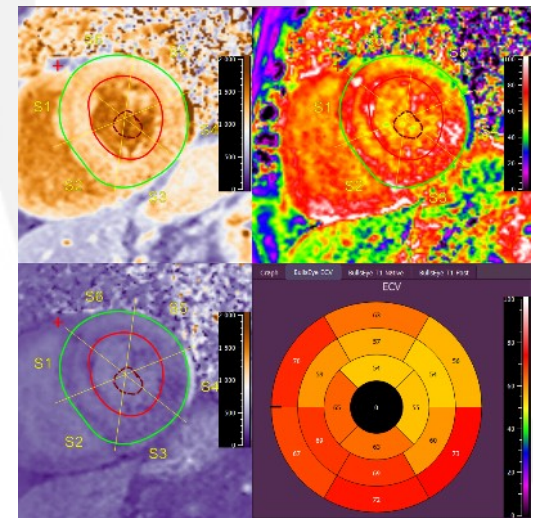
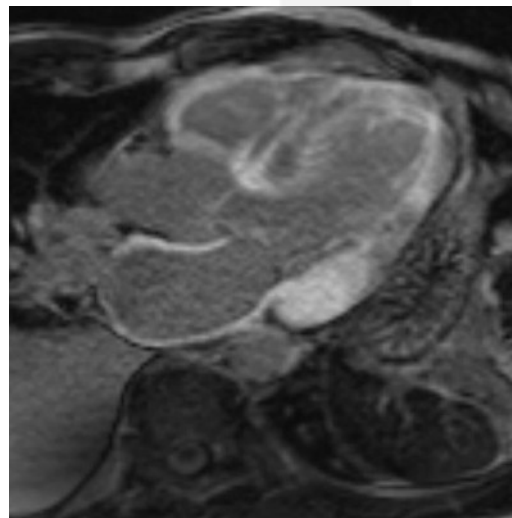
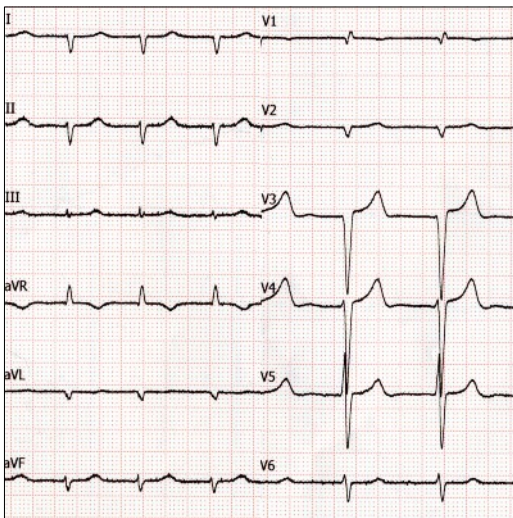
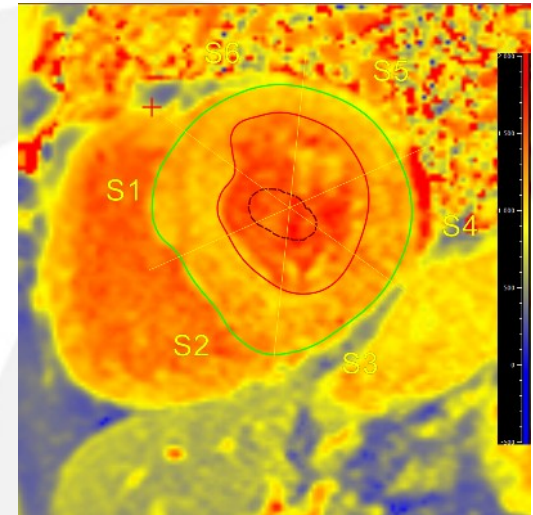
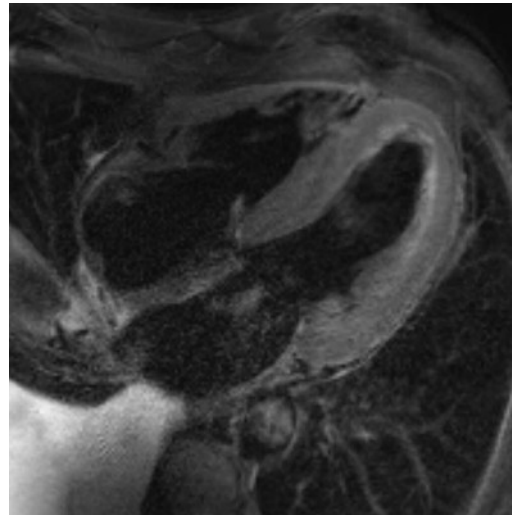
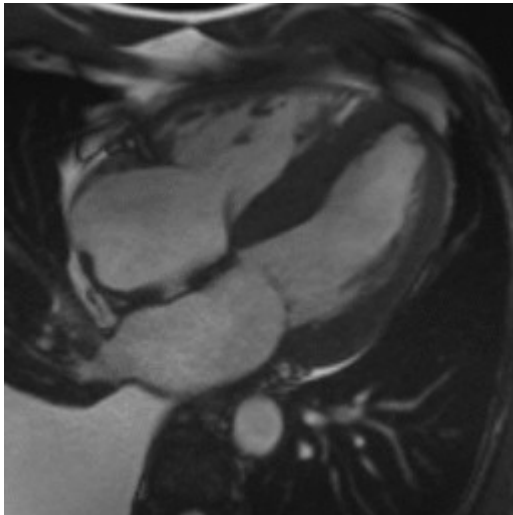
Anderson-Fabry: 828/967 ms, 23/33 %



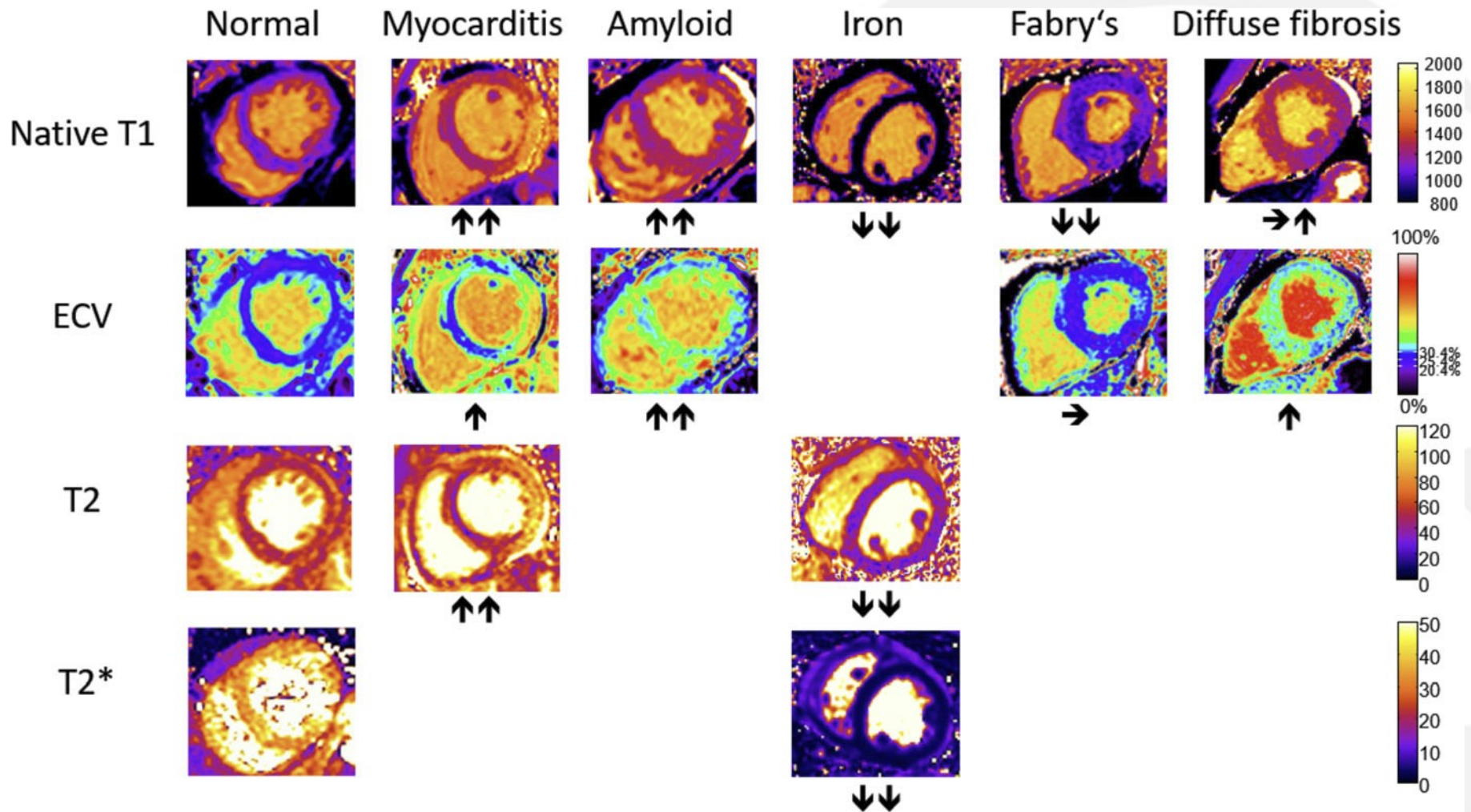
$$ECV = (1 - haematocrit) \frac{\frac{1}{post\ contrast\ T1\ myo} - \frac{1}{native\ T1\ myo}}{\frac{1}{post\ contrast\ T1\ blood} - \frac{1}{native\ T1\ blood}}$$



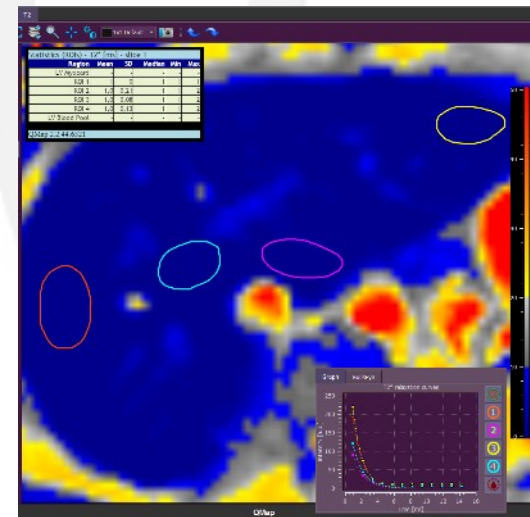
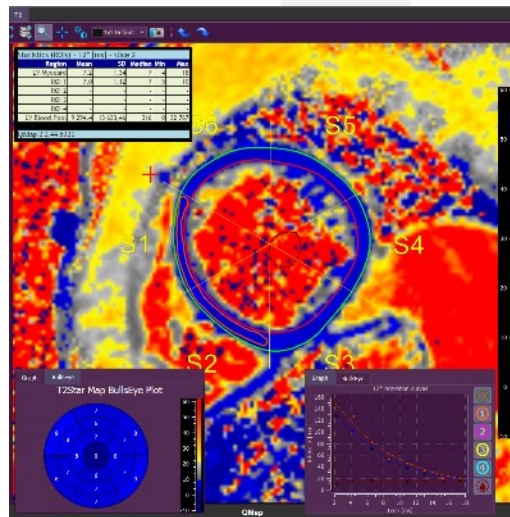
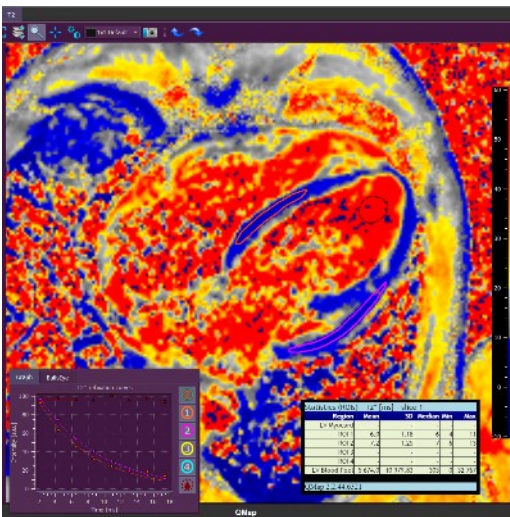
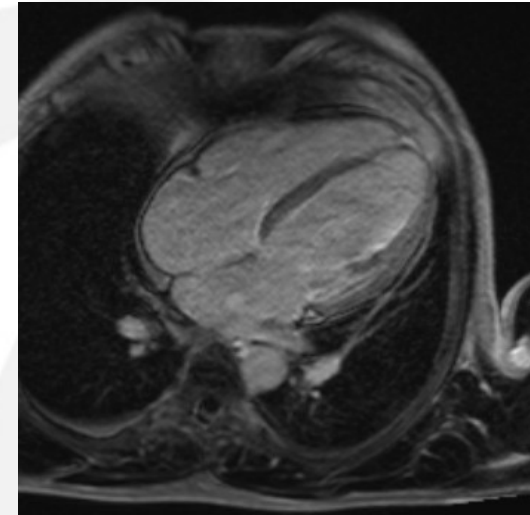
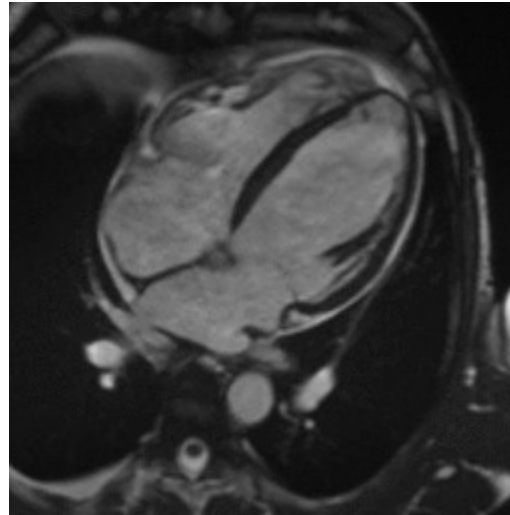
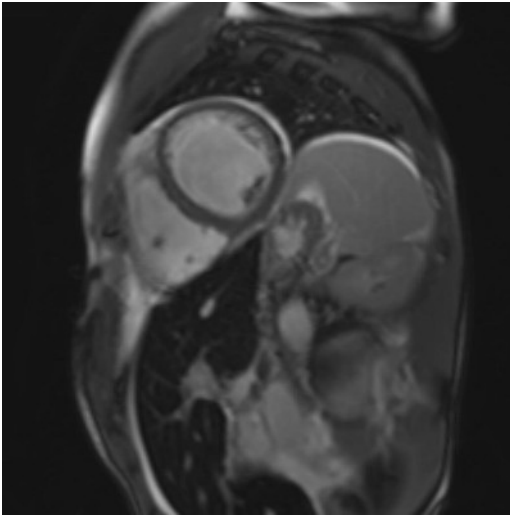
Amyloidosis – T1: 1166ms, ECV: 65%



$$ECV = (1 - haematocrit) \frac{\frac{1}{post\ contrast\ T1\ myo} - \frac{1}{native\ T1\ myo}}{\frac{1}{post\ contrast\ T1\ blood} - \frac{1}{native\ T1\ blood}}$$

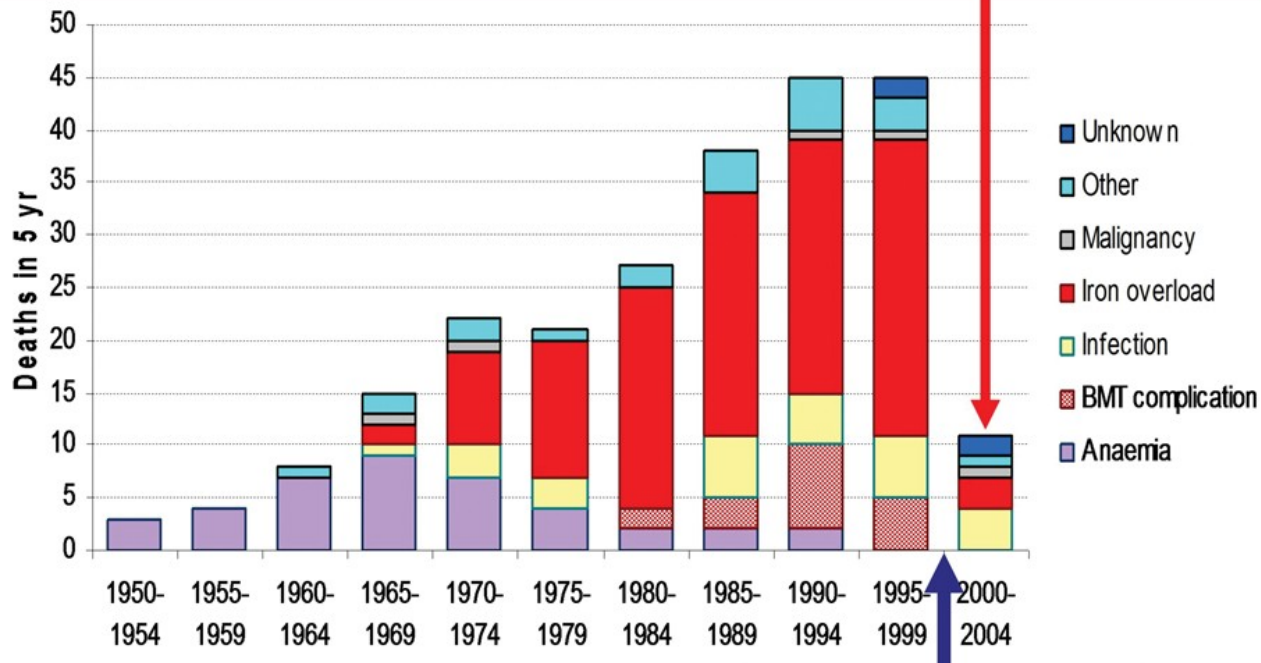


Hemochromatosis: T2* 7ms, liver 1ms



Survival: 71% reduction!

Reduction in cardiac death by 71%



T2* CMR

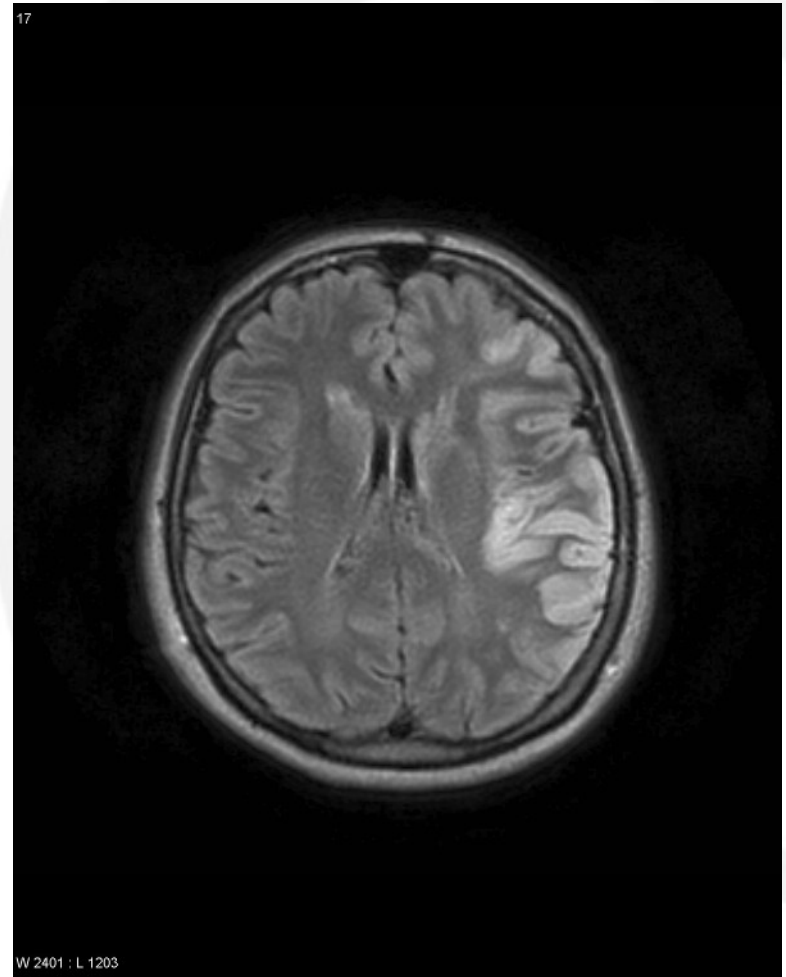
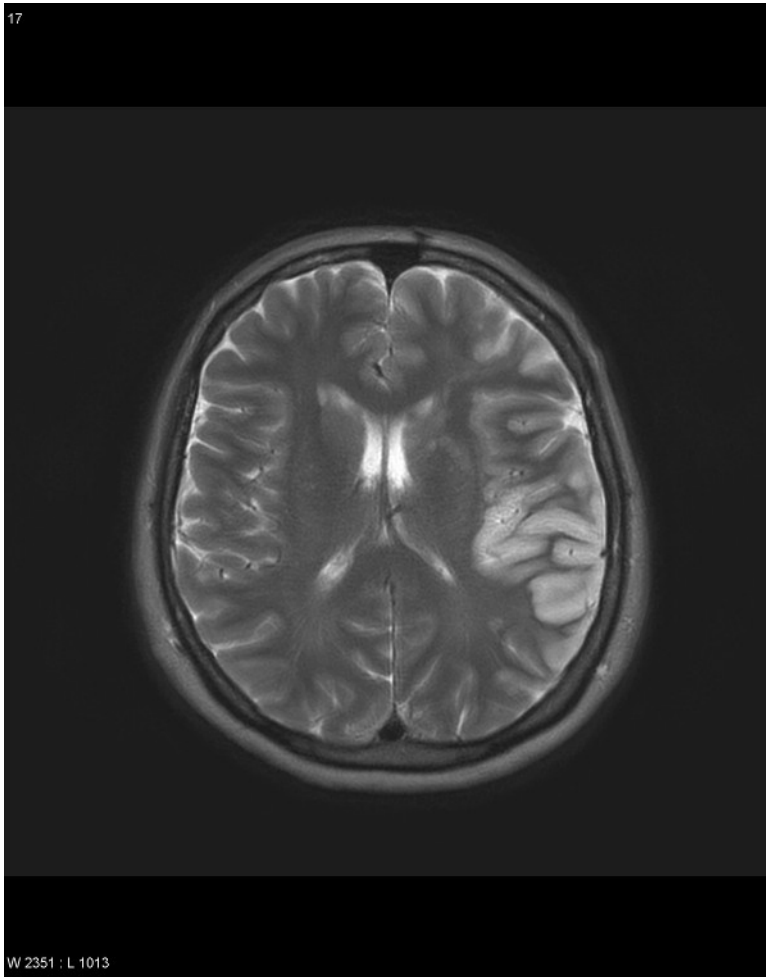
Modell. J Cardiovasc MR 2008: 42

Nem részletezem

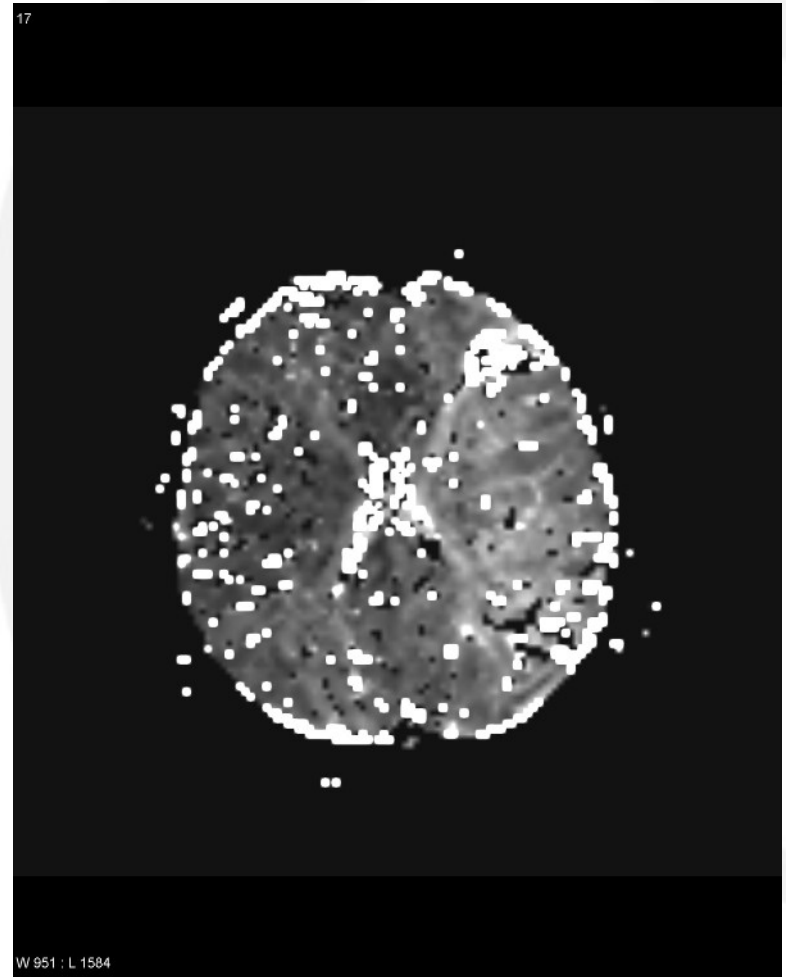
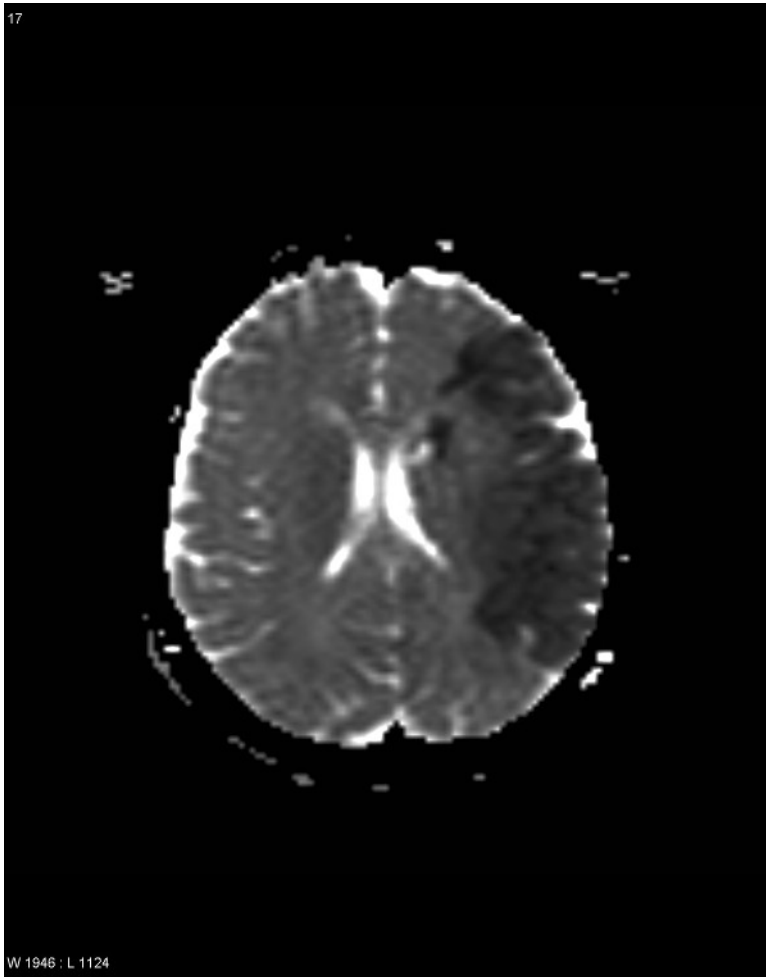
- Mágneses rezonancia spektroszkópia
 - ^1H , ^{31}P , ^{23}Na , ^{13}C
 - MAGMA 11(1-2):44-46 (2000)
 - Heart Lung Circ 12(1):25-30 (2003)
 - Nat Clin Pract Cardiovasc Med 5:S49 (2008)



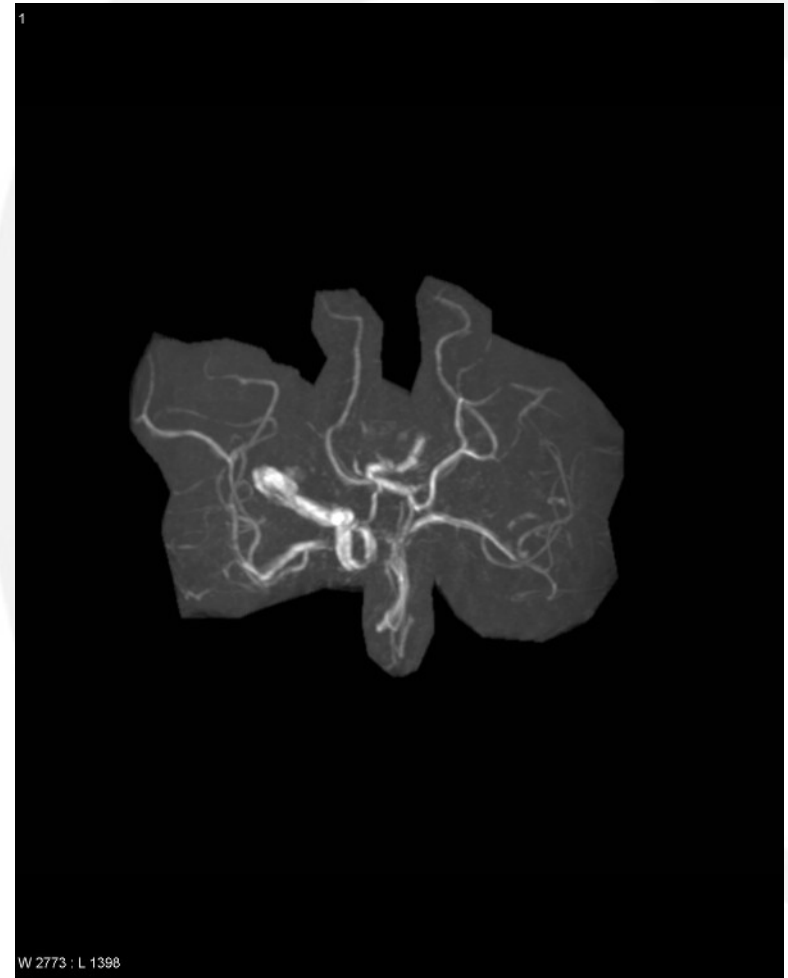
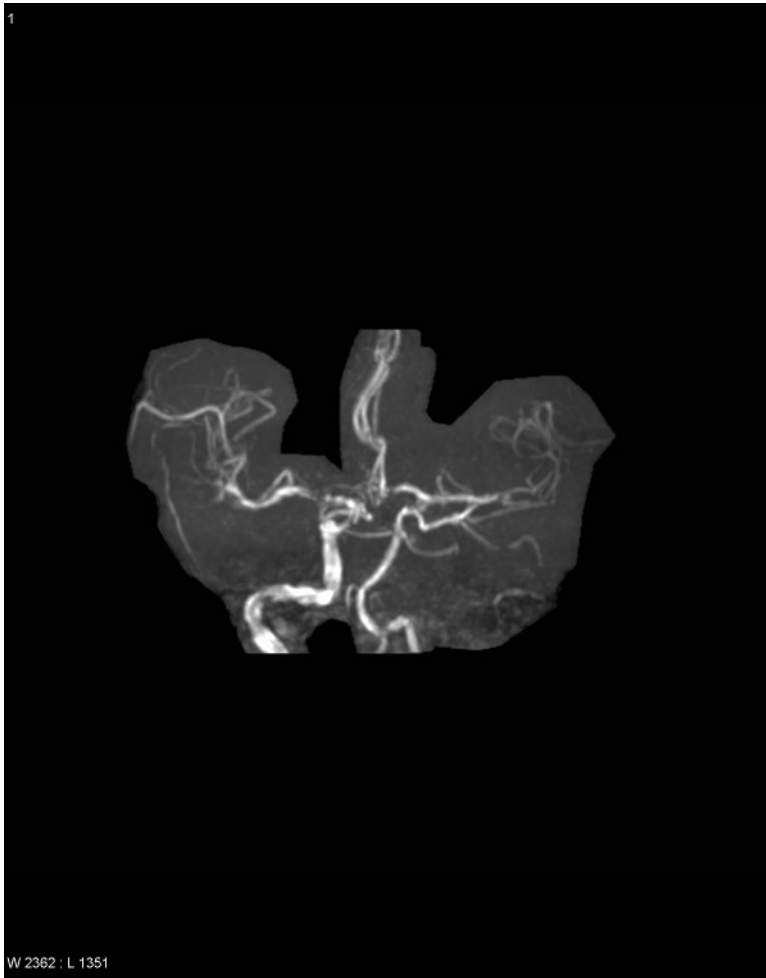
T2w és FLAIR



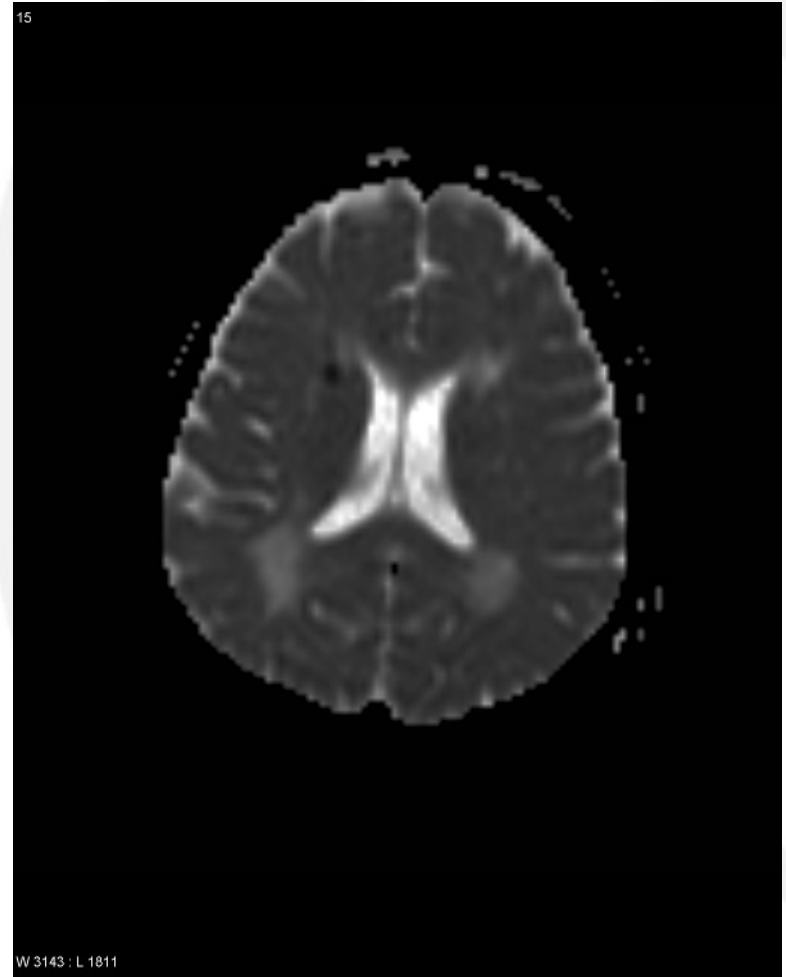
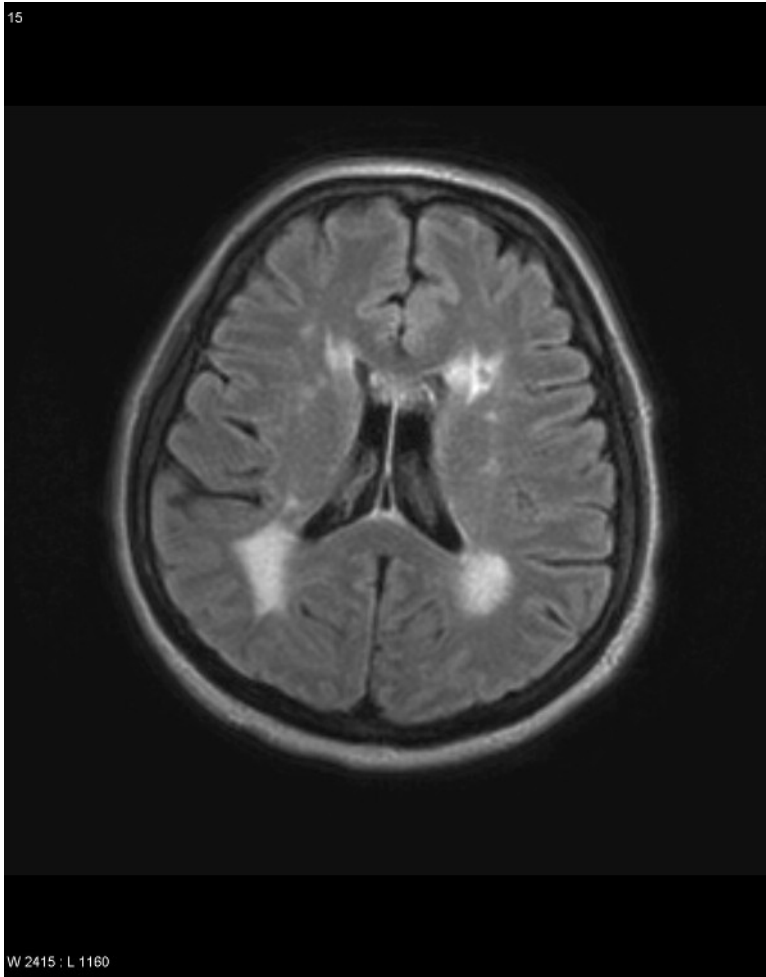
ADC és MTT



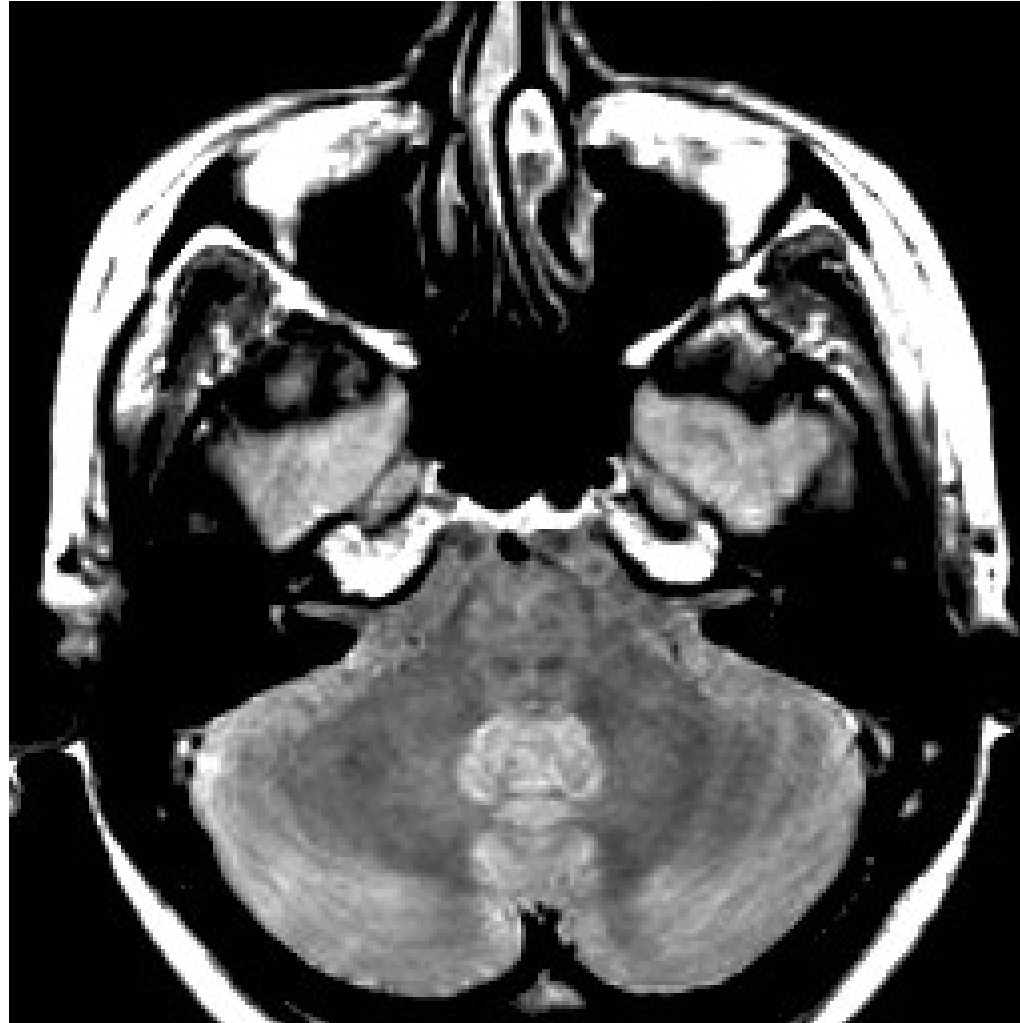
TOF MRA



Lézió: FLAIR és ADC



Védőszent



Ajánlott linkek és irodalom

- Prof Kovács J Sándor
 - <http://www.kardiologia.hu/symposium/73-21334.php>
 - <http://cbl1.wustl.edu>
- MR fizika:
 - Magnetic Resonance Imaging
 - Vlaardingerbroek, ISBN: 3540436812
- Szív MR:
 - Clinical Cardiac MRI
 - Taylor, ISBN: 3540262172



Köszönet

- Merkely Béla
- Simor Tamás
- Hüttl Kálmán
- Vágó Hajnalka
- Balázs György
- Beutalók – GOKI

