SISTEMA SANITARIO REGIONALE
AZIENDA OSPEDALIERO-UNIVERSITARIA
SANT'ANDREA

Cardio-TC/RM
WEBINAR FAD

Dal 16 maggio 2024 all'11 Luglio 2024

SAPIENZA
UNIVERSITÀ DI ROMA

Il **Corso Webinar CardioTC e CardioRM** del Sant'Andrea 2024 è un corso di Cardio TC (Tomografia Computerizzata) e Cardio RM (Risonanza Magnetica) progettato per fornire ai discenti una comprensione approfondita delle due principali tecniche di imaging cardiaco utilizzate nella pratica clinica moderna.
Questo corso mira a fornire una panoramica completa dei principi di base, delle applicazioni cliniche e delle sfide associate all'uso della TC e della RM nel contesto della valutazione cardiaca. Il corso inizia con una discussione delle tecniche di acquisizione della Cardio TC, compreso l'uso dei mezzi di contrasto e i protocolli come il "Triple-rule- out". I discenti impareranno a interpretare le immagini TC per valutare l'anatomia coronarica, identificare caratteristiche delle placche aterosclerotiche e definire stenosi coronariche secondo il sistema CAD-RADS.
Successivamente, il focus si sposta sulla Cardio RM, esplorando le indicazioni per questo tipo di imaging, i protocolli di acquisizione e le sequenze principali utilizzate per valutare la struttura e la funzione cardiaca per diagnosticare patologie cardiache, tra cui infiammazioni miocardiche, cardiomiopatie e malattie da accumulo.

PROGRAMMA

16 Maggio – ore 17.00/18.00
Introduzione al Corso (A. Laghi)
Saluti Direzione Generale AOUSA (D. Donetti)
Tecnica di acquisizione della Cardio TC/Utilizzo del Mdc e Triple-rule-out (D. Caruso)

23 Maggio – ore 17.00/18.00
Anatomia coronarica (L. Pugliese)

30 Maggio – ore 17.00/18.00
Caratteristiche di placca: calcifica, non calcifica, vulnerabile (D. De Santis)

6 Giugno – ore 17.00/18.00
La definizione della stenosi secondo CAD-RADS v.2 (D. De Santis)

13 Giugno – ore 17.00/18.00
Indicazione alla Cardio RM, protocollo di acquisizione e sequenze principali (D. De Santis)

27 Giugno – ore 17.00/18.00
Patologia infiammatoria (miocarditi, pericarditi) (D. De Santis)

4 Luglio – ore 17.00/18.00
Cardiopatia ischemica (L. Pugliese)

11 Luglio – ore 17.00/18.00
Cardiomiopatie (ipertrofica, dilatativa, aritmogena) e patologie da Accumulo (L. Pugliese)

PROVIDER: StudioProgress ID: 652
N° IDENTIFICATIVO AGENAS: ID 412471

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Segreteria Scientifica
Prof. Andrea Laghi – Dott. Damiano Caruso
U.O.C. di Radiologia
AOU Sant'Andrea Sapienza Università di Roma

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Indicazione alla Cardio RM, Protocollo di Acquisizione e Sequenze Principali

Dr. Domenico De Santis, MD
Dept of Medical-Surgical Science and Translational Imaging
Sapienza - University of Rome
domenico.desantis@uniroma1.it

CMR ADVANTAGES

CMR advantages over conventional cardiac imaging

- No ionizing radiation
- Free choice of imaging planes
- Tissue characterization capability
- Qualitative and quantitative evaluation myocardium and blood motion
- Assessment of regional perfusion.

CMR – CLINICAL INDICATIONS

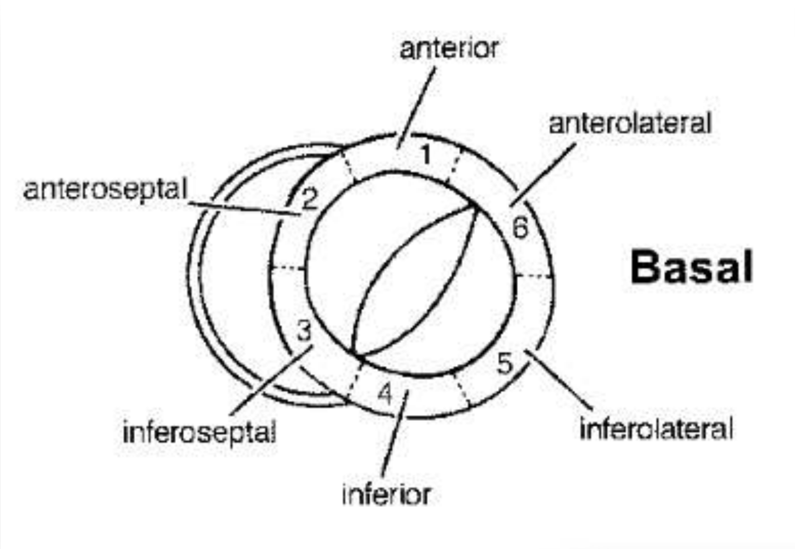
- Assessment of myocardial function following myocardial infarction
- Assessment of myocardial viability/hibernation
- Myocarditis
- Cardiomyopathies
- Congenital heart disease
- Valvular disease
- Pericardial disease
- Myocardial tumor
- Clinical research

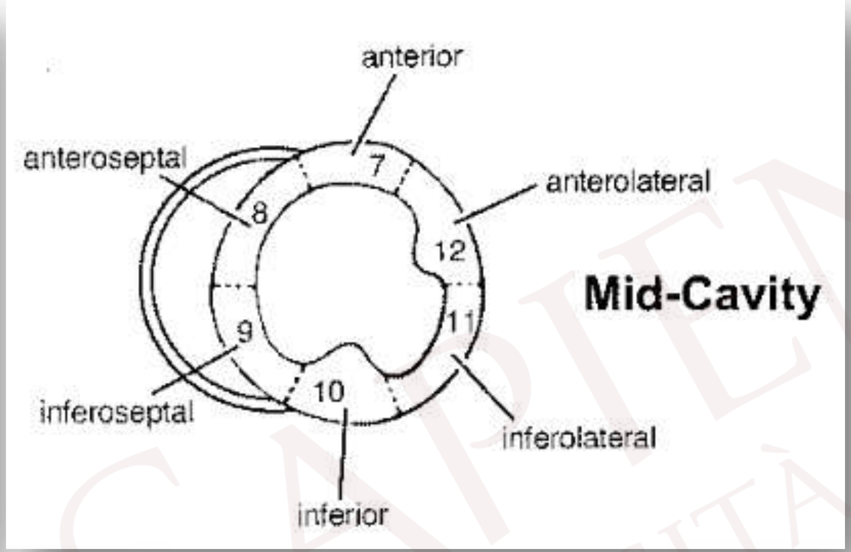
Disadvantages of CMR

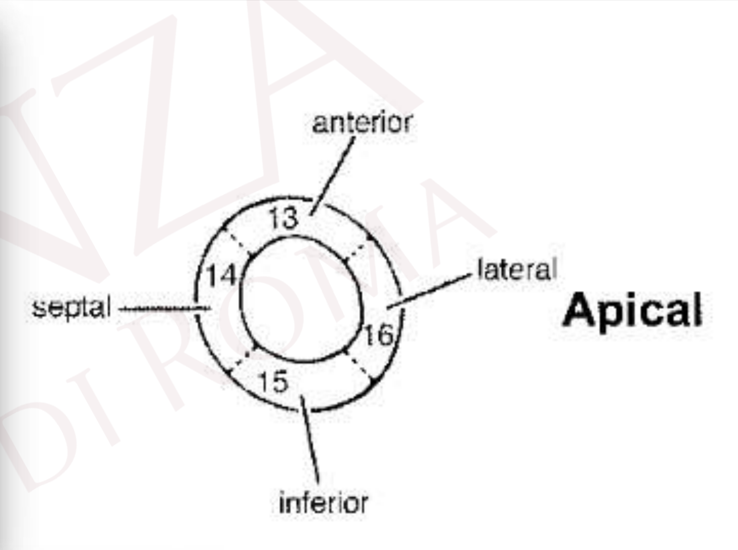
- Time
- Pts collaboration
- MR-safe ICDs
- highly irregular rhythms
- Gd injection if GFR < 30ml/min.

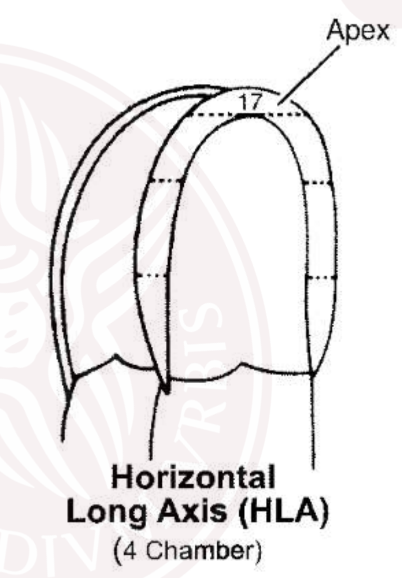
https://www.escardio.org/Journals/E-Journal-of-Cardiology-Practice/Volume-6/Clinical-Utilities-of-cardiac-MRI

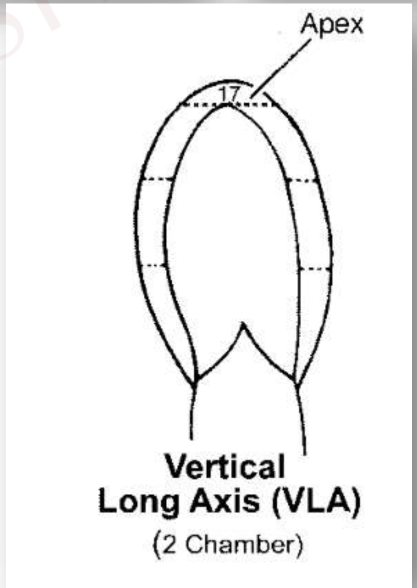
STANDARDIZED NOMENCLATURE











Cerqueira MD et al. Circulation. 2002 Jan 29;105(4):539-42. doi: 10.1161/hc0402.102975

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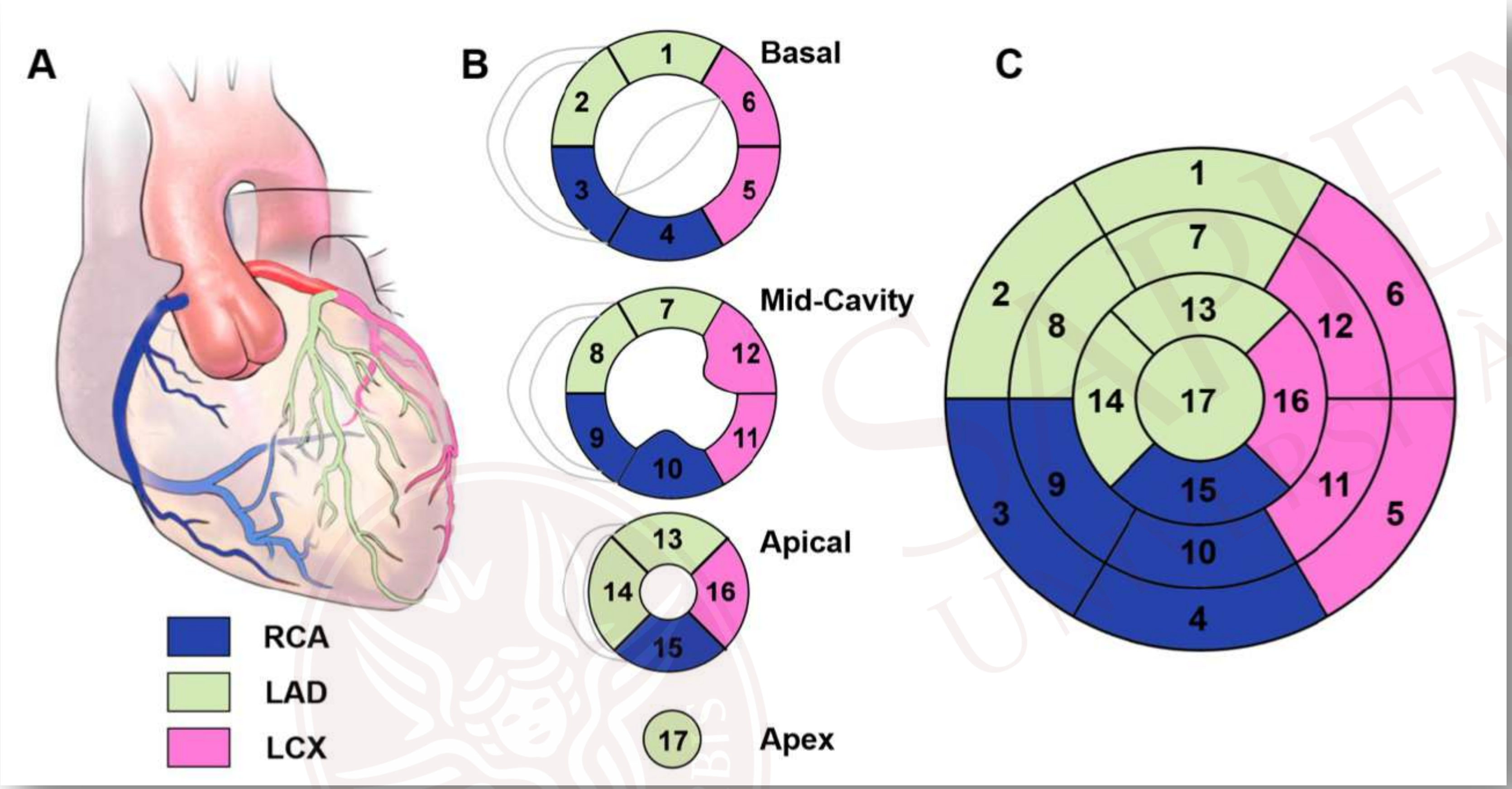
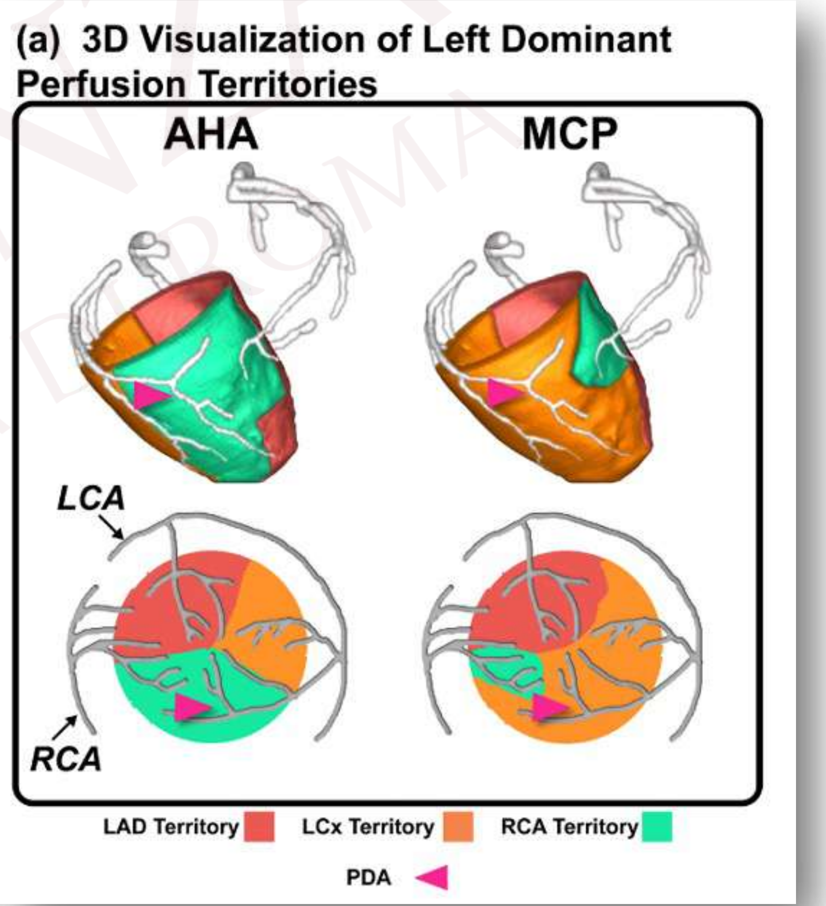


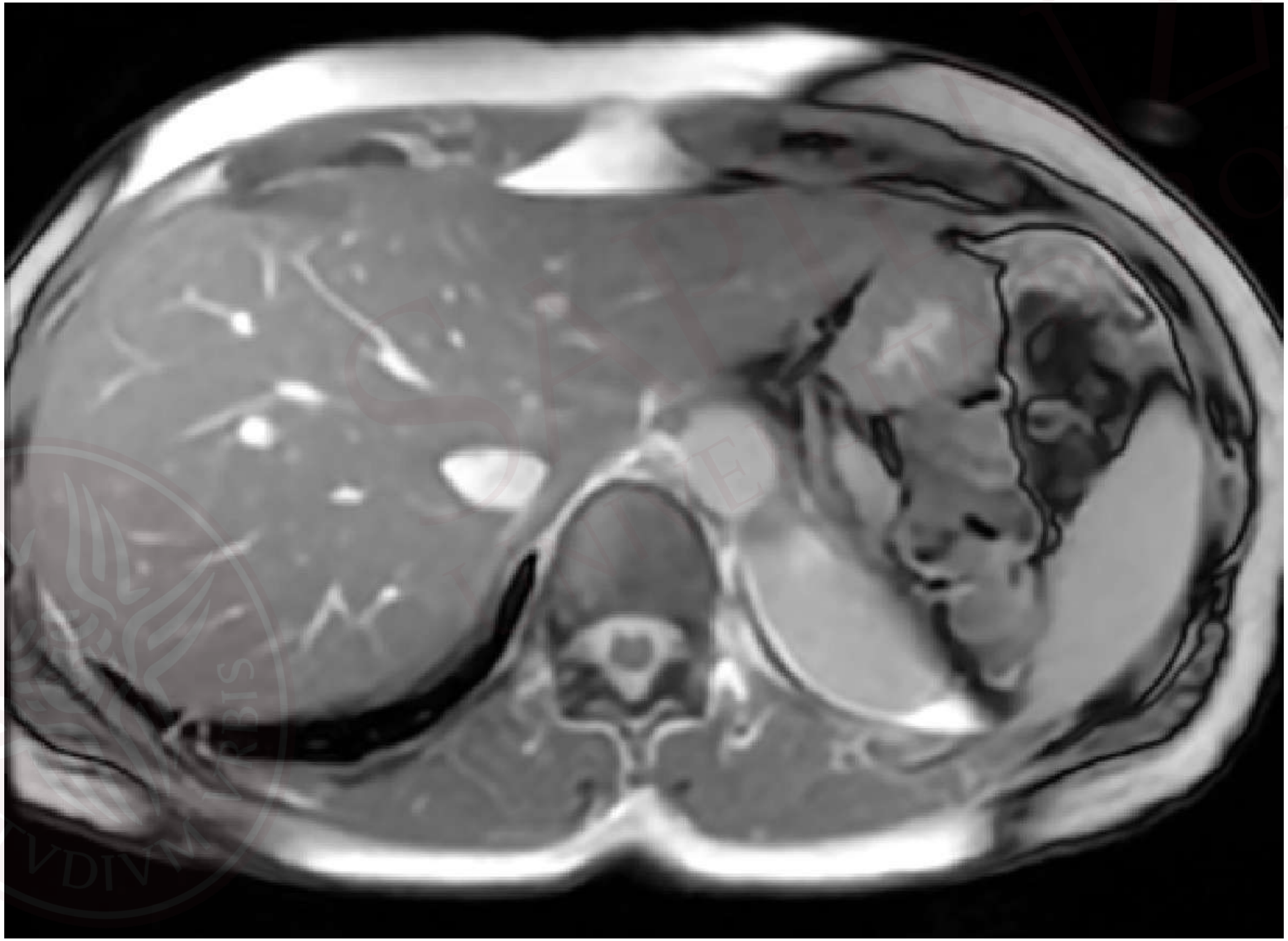


Velasco Jimeno C. (2019). Advanced Imaging Techniques for Cardiovascular Research. 10.13140/RG.2.2.19233.84321

Malkasian S et al. Eur Radiol. 2020 Jun;30(6):3334-3345. doi: 10.1007/s00330-020-06697-w

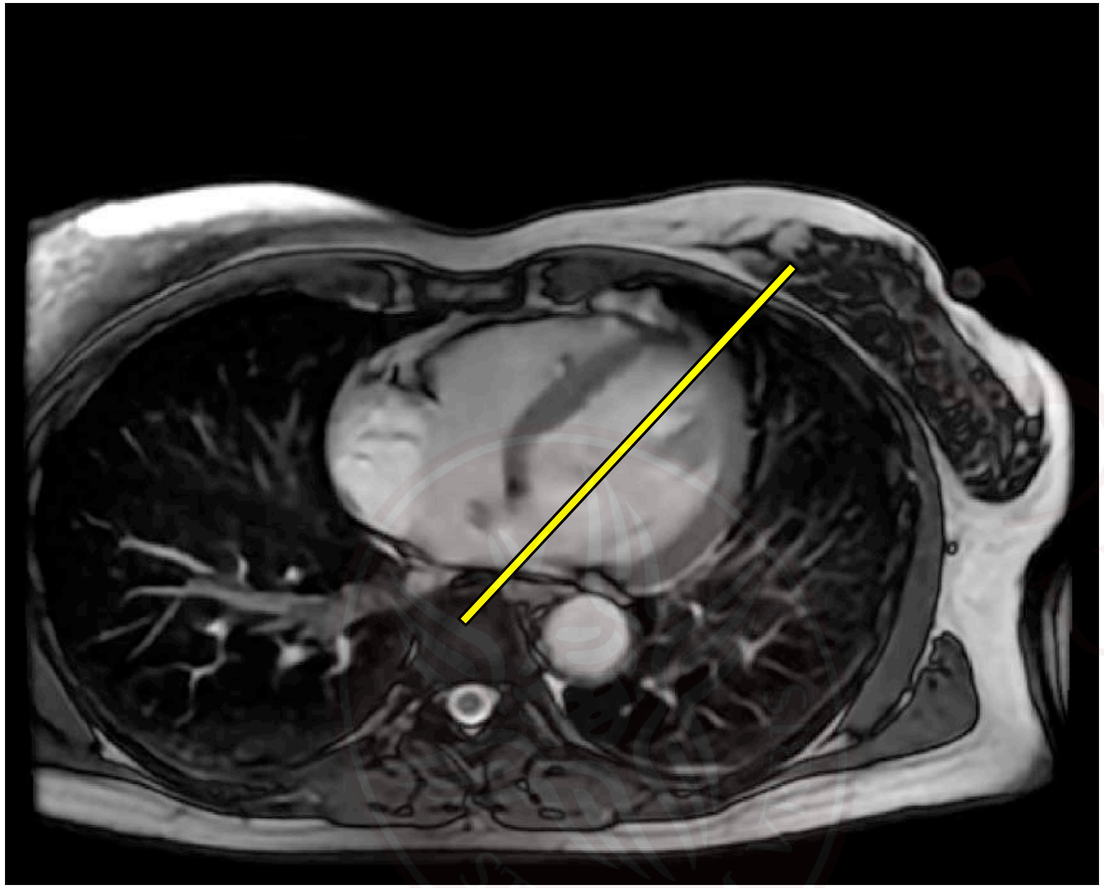
SCOUT

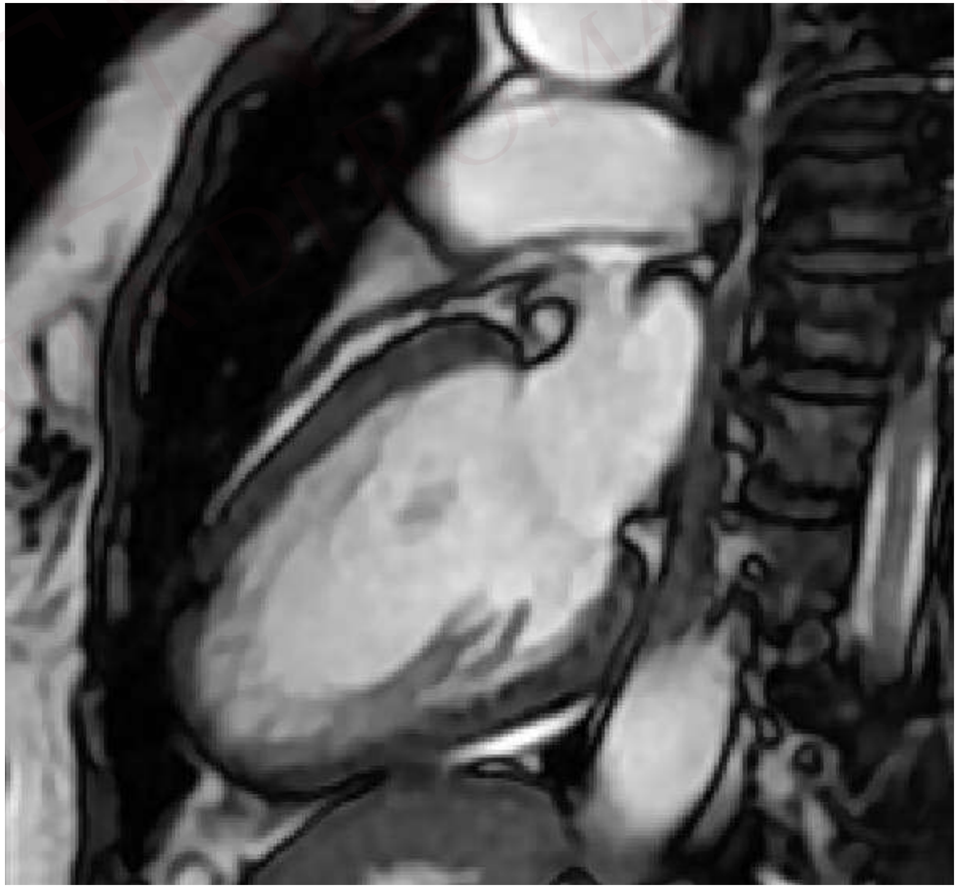
Axial of bSSFP or FSE images through the chest



NEAR 2-CHAMBER LONG AXIS SCOUT

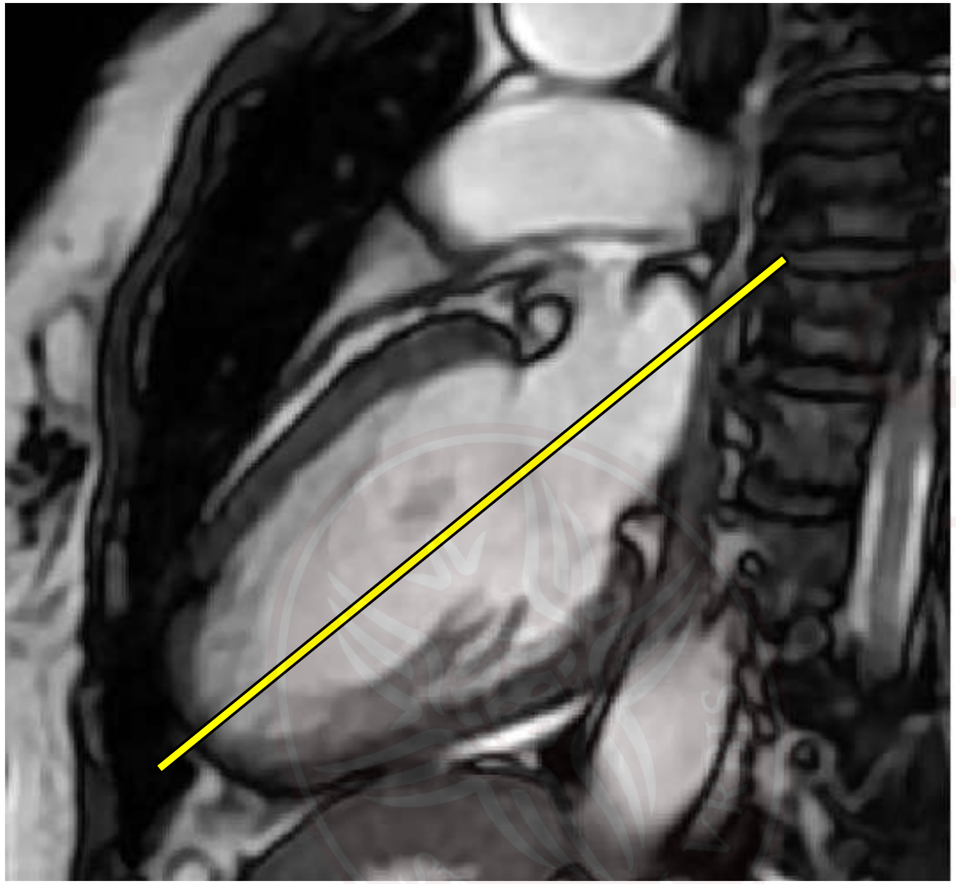
Aligned through the apex and center of the mitral valve

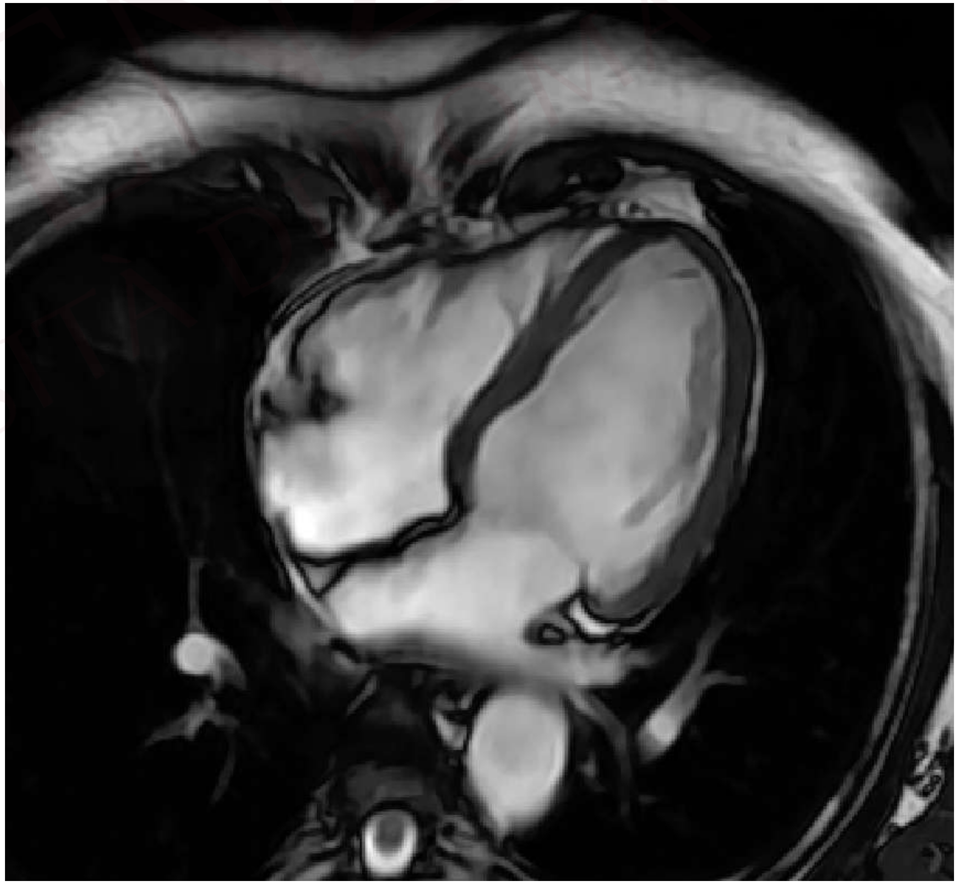




NEAR 4-CHAMBER LONG AXIS SCOUT

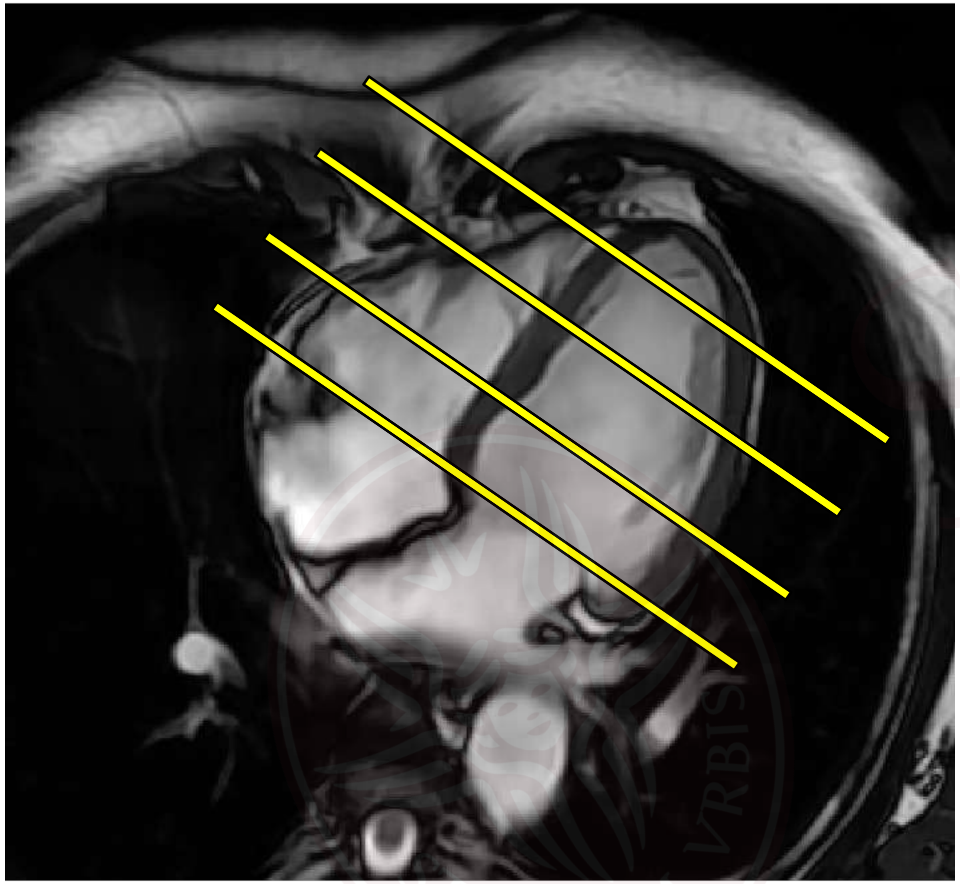
Aligned through the apex and center of the mitral valve

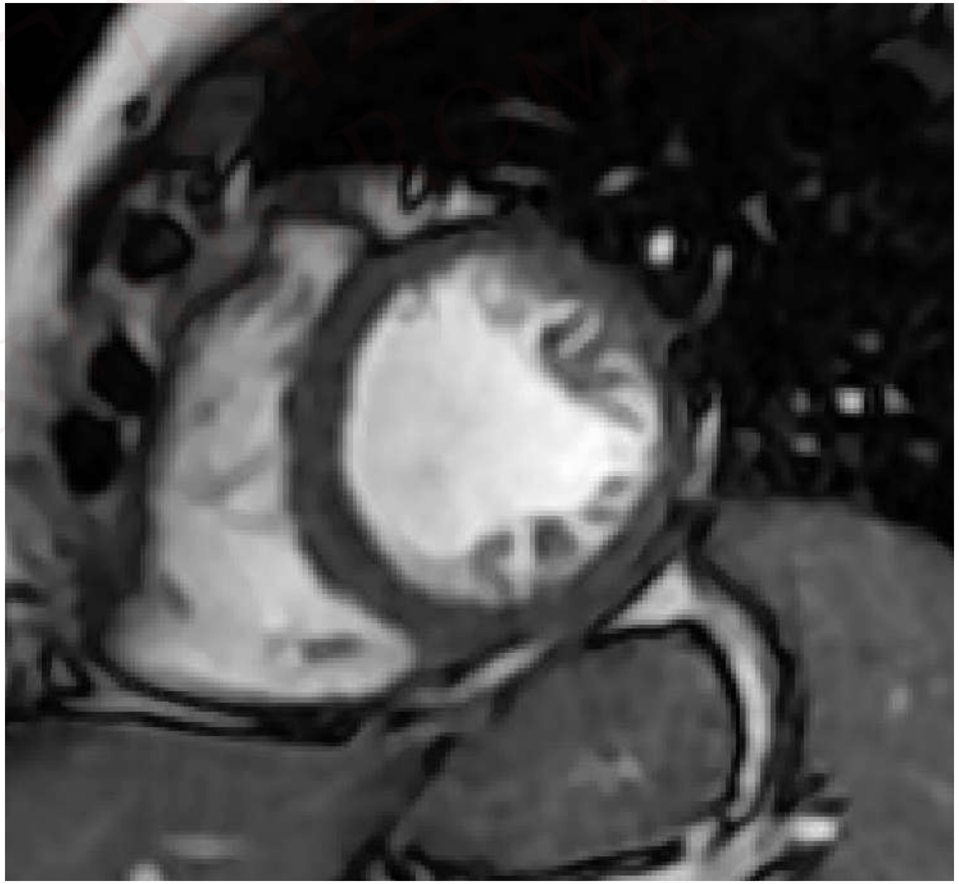




SCOUT LV SHORT AXIS

Aligned through the apex and center of the mitral valve



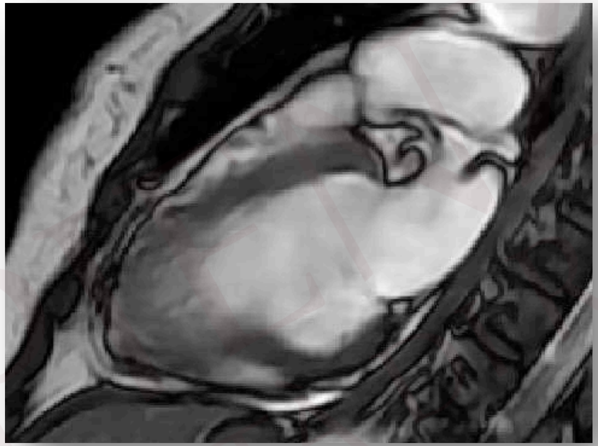


CINE SEQUENCES

Cine sequences are used to assess

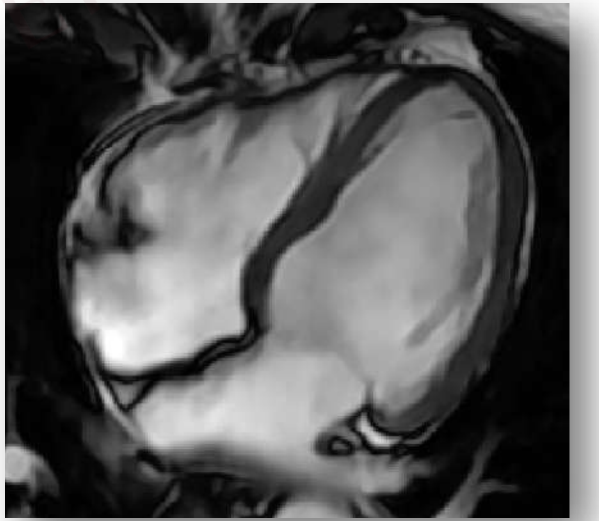
- Chamber Size
- Myocardial thickness
- Wall motion
- Ejection fraction
- Valvular function

2-Chamber

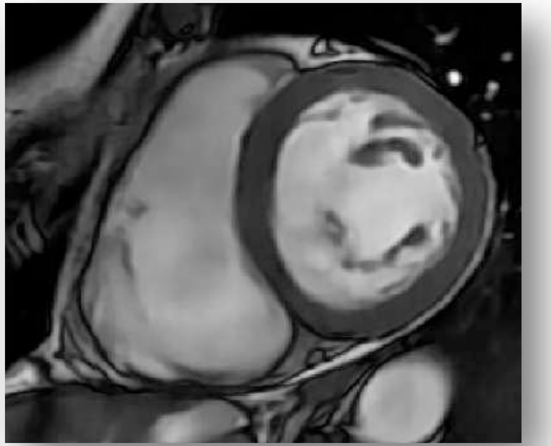


3-Chamber

4-Chamber



Short-axis

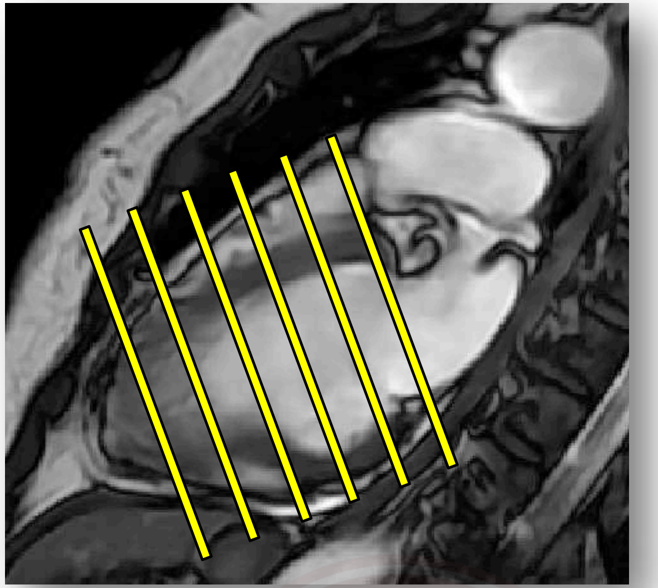


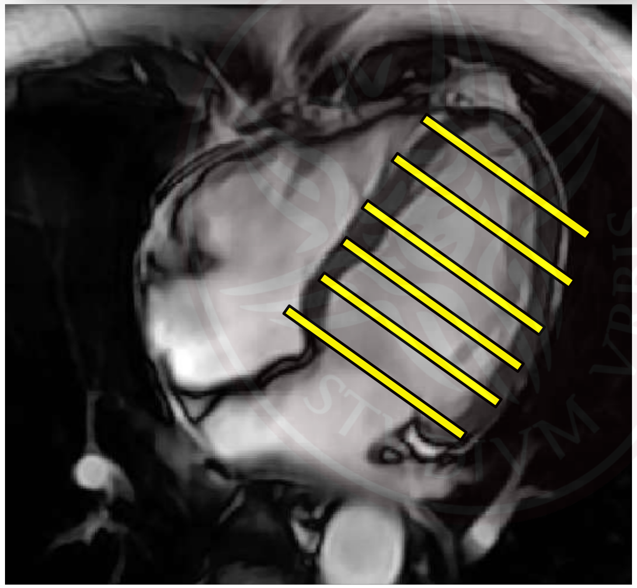
CINE SEQUENCES

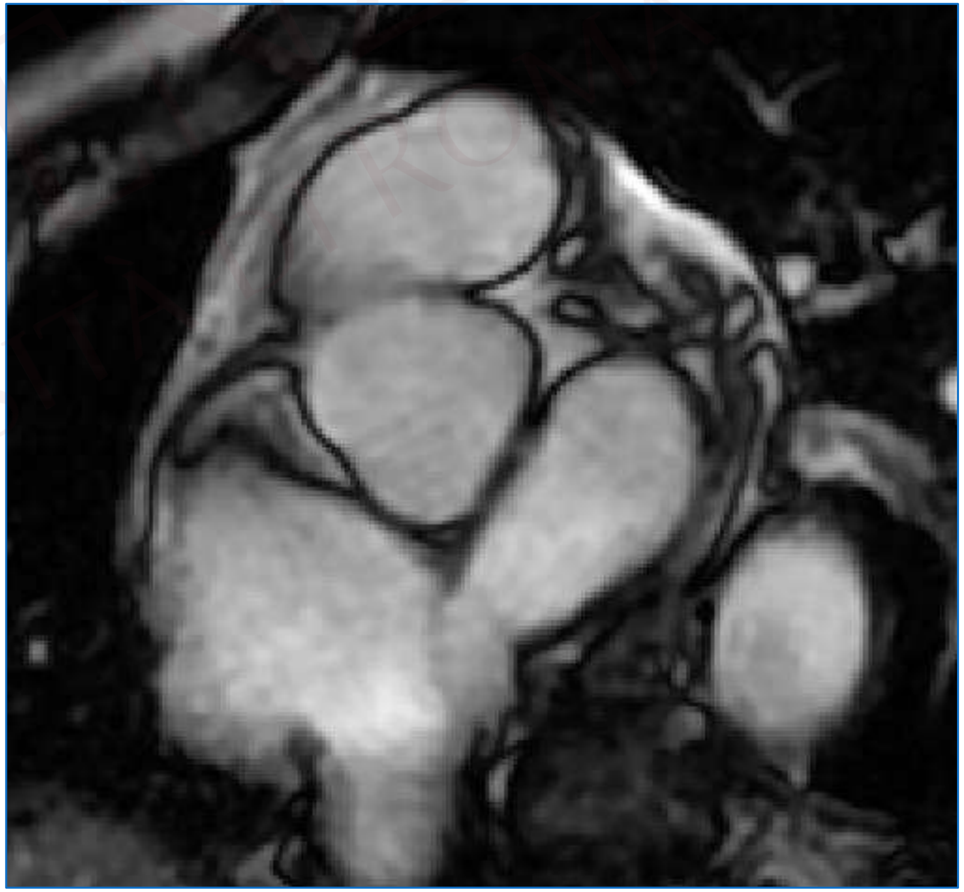
Anatomical markers

2-Chamber	3-Chamber	4-Chamber
Mitral Valve	Mitral Valve	Mitral Valve
Left Ventricle apex	Left Ventricle apex	Left Ventricle Apex
Interventricular Septum	Aortic Valve	Tricuspid Valve

SHORT AXIS CINE







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TRUE 2-CHAMBER CINE

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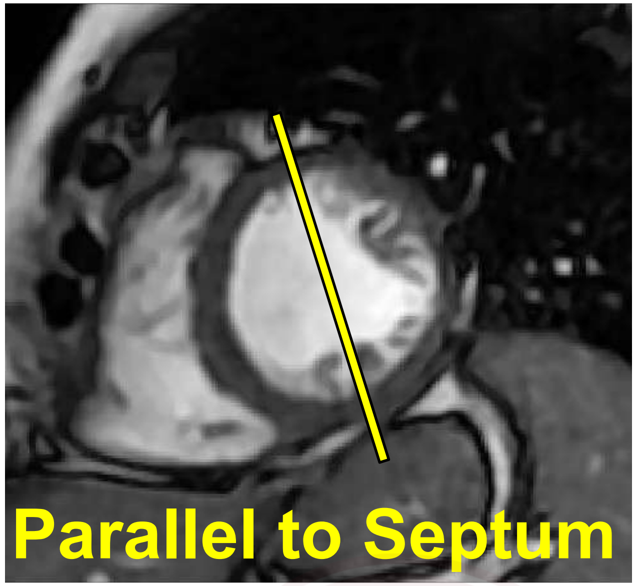
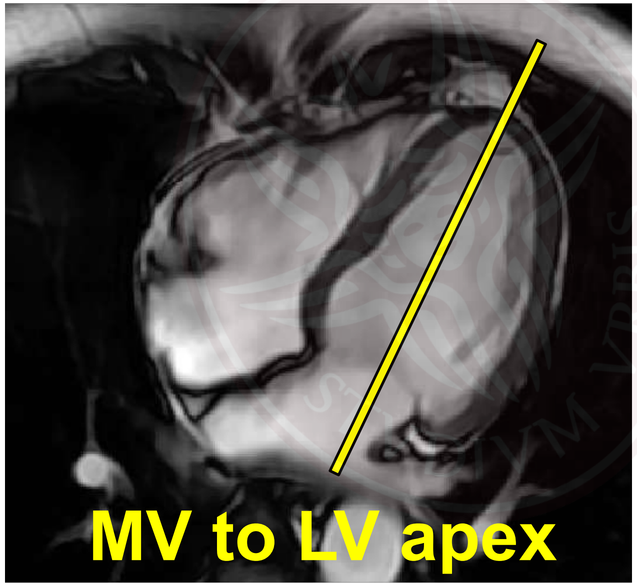
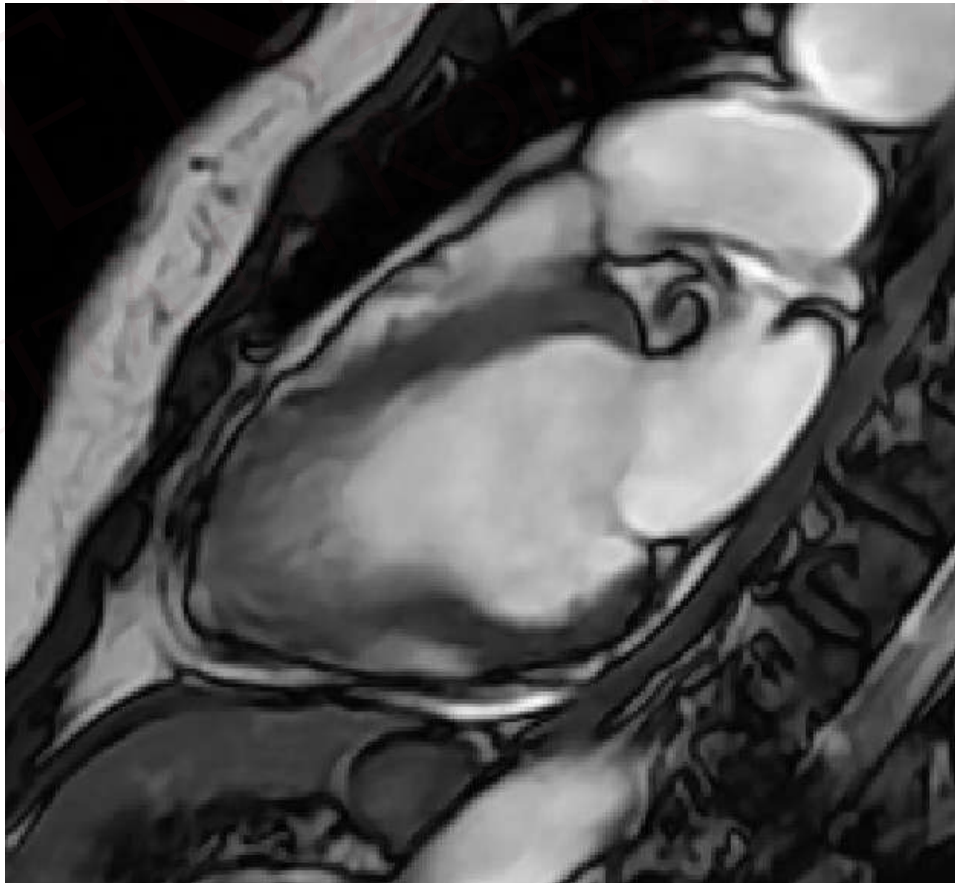
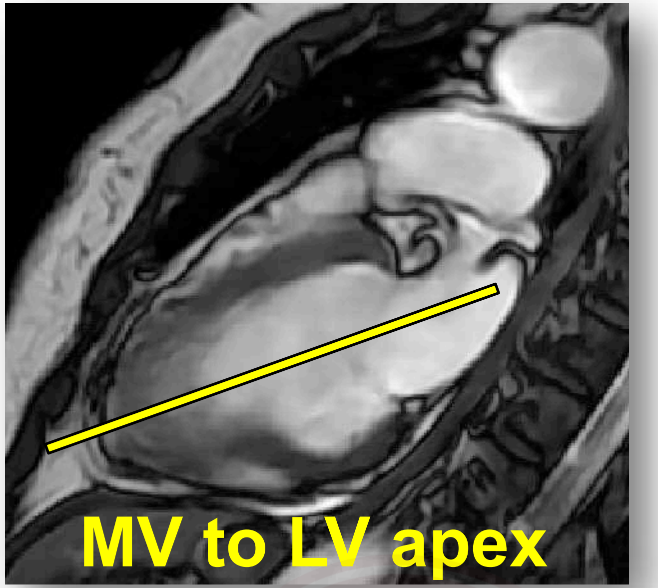
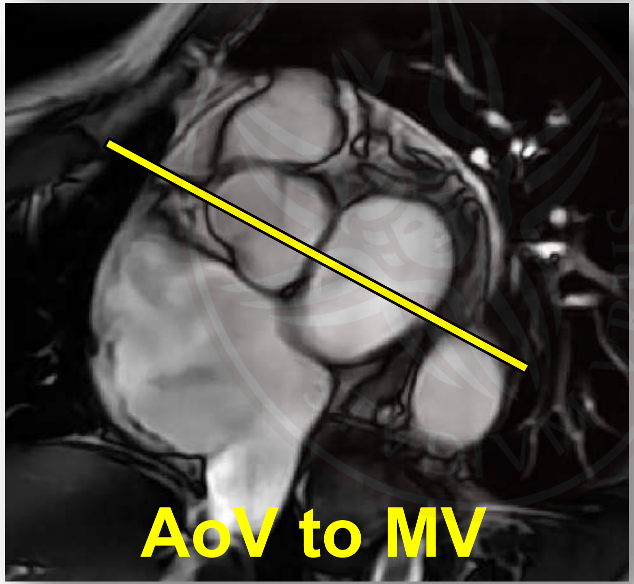


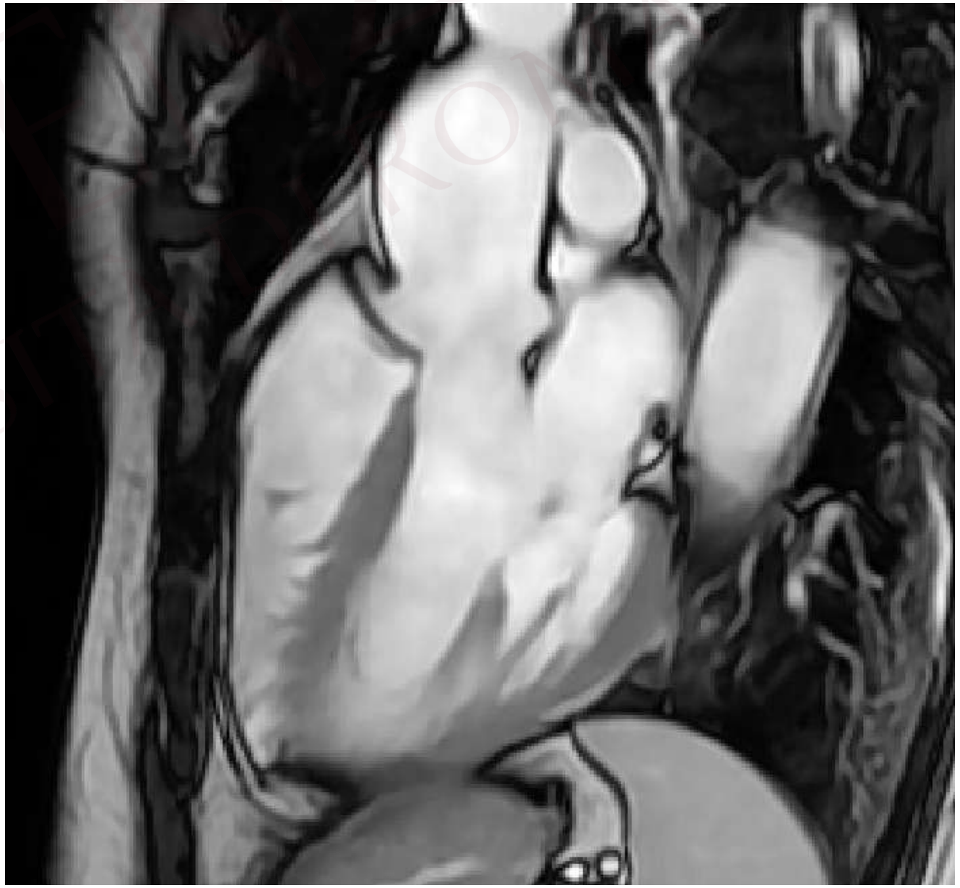




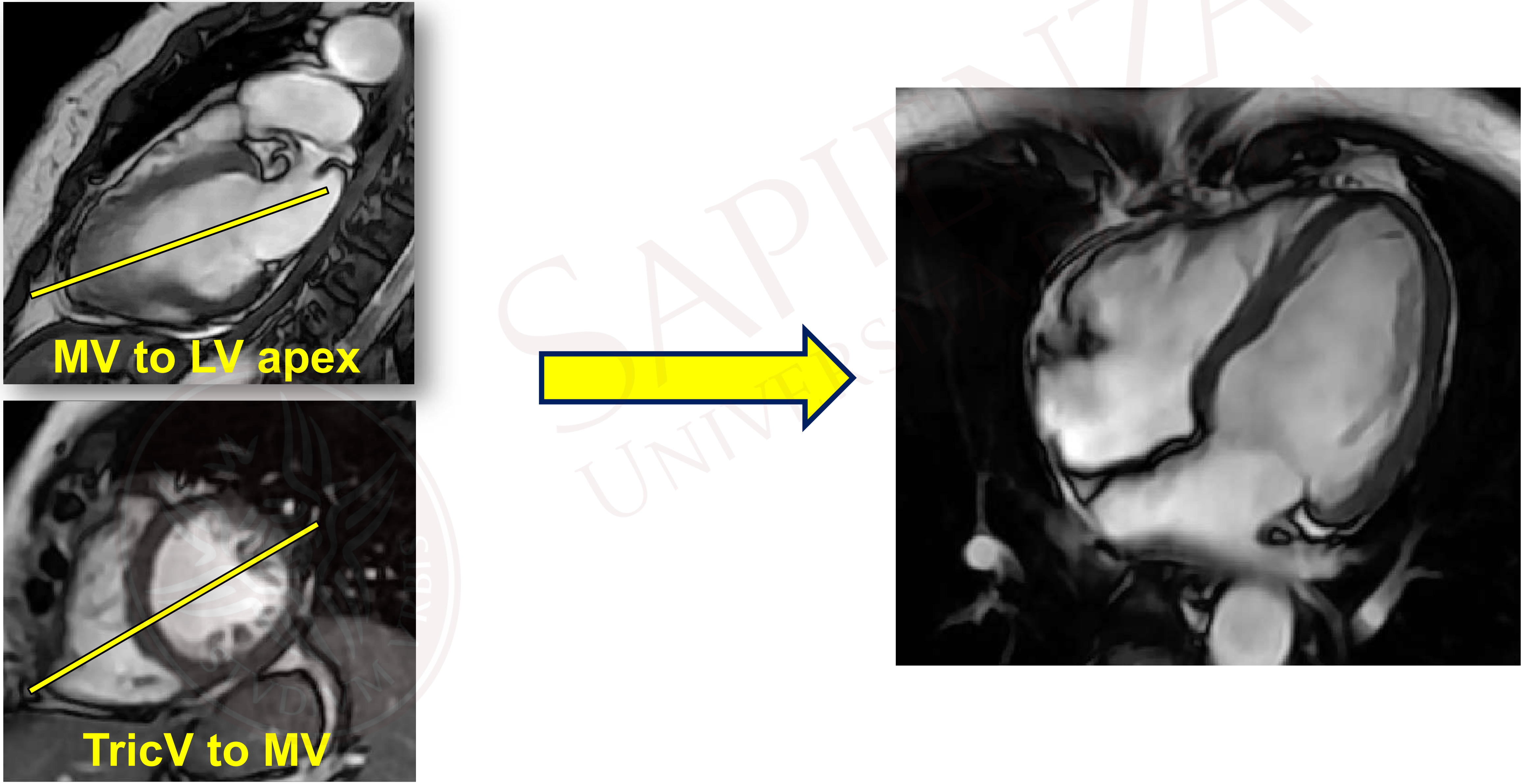
TRUE 3-CHAMBER CINE





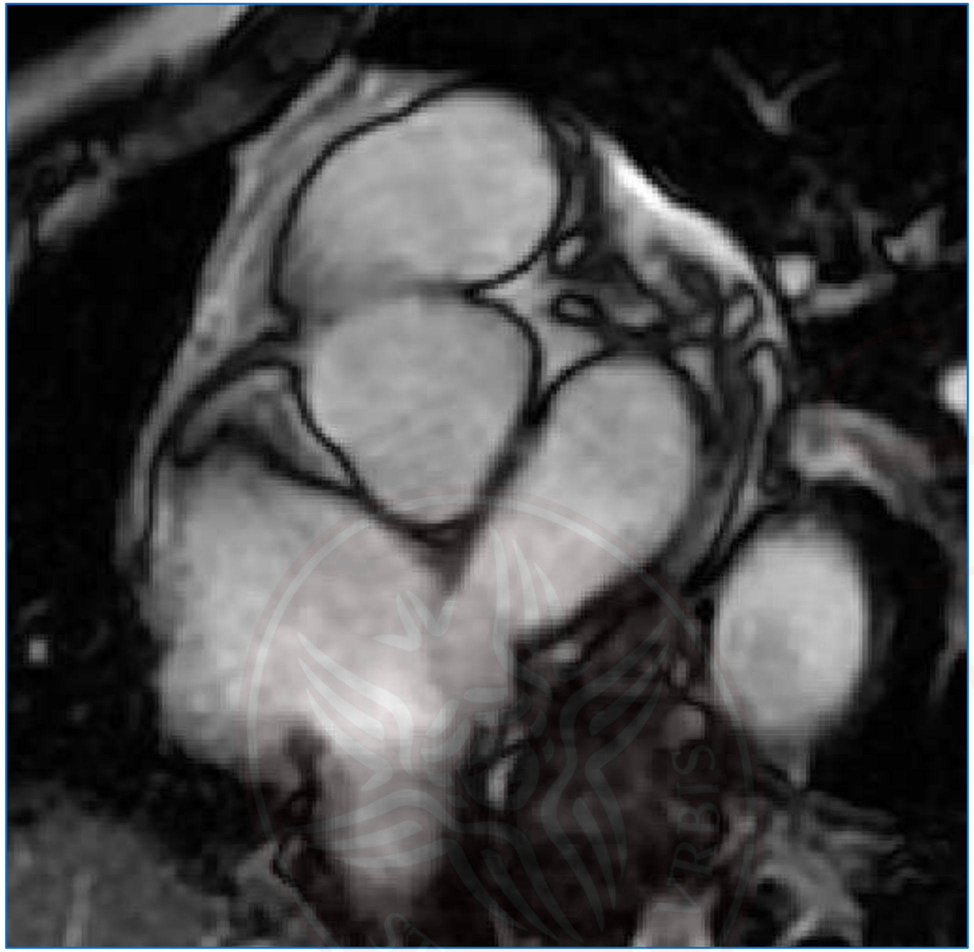


TRUE 4-CHAMBER CINE

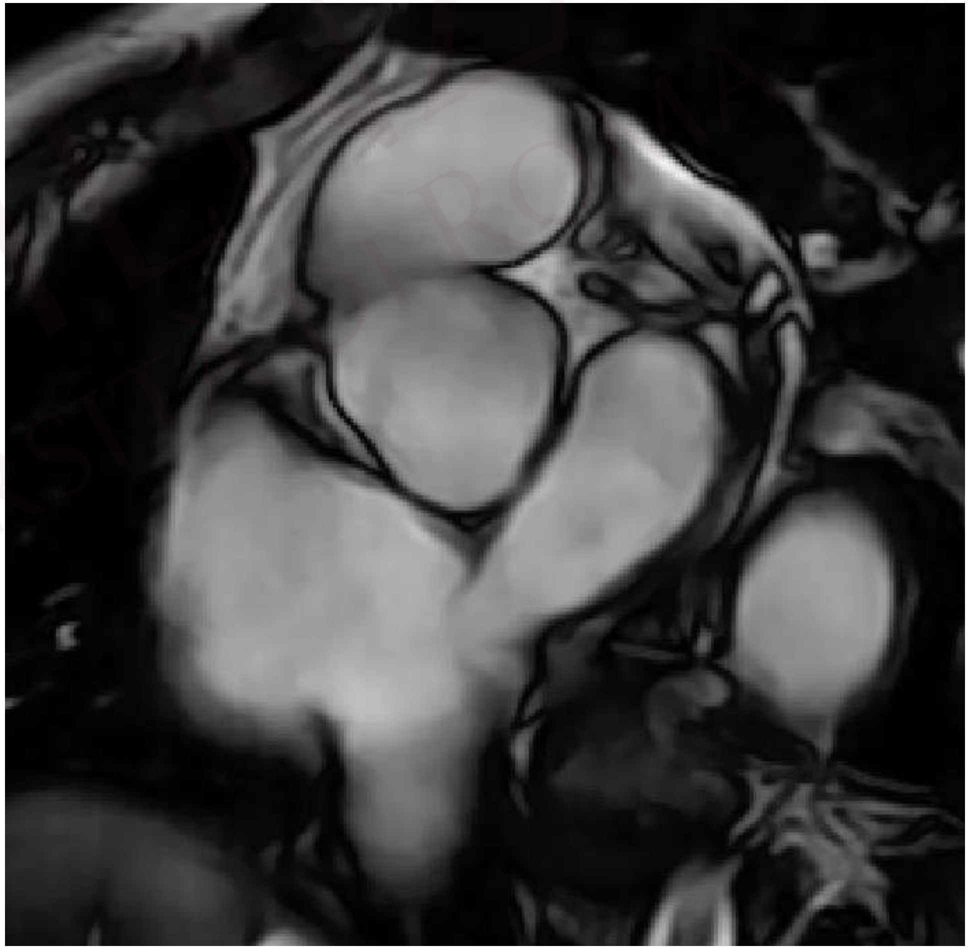


ARTIFICIAL INTELLIGENCE

bSSFP



DL-Cine



LV CHAMBER ASSESSMENT

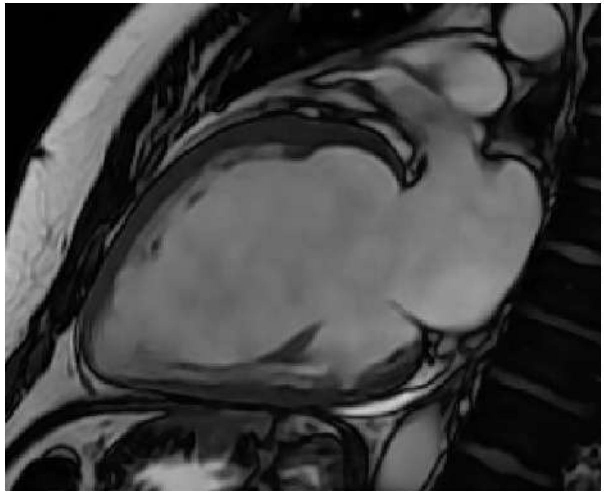
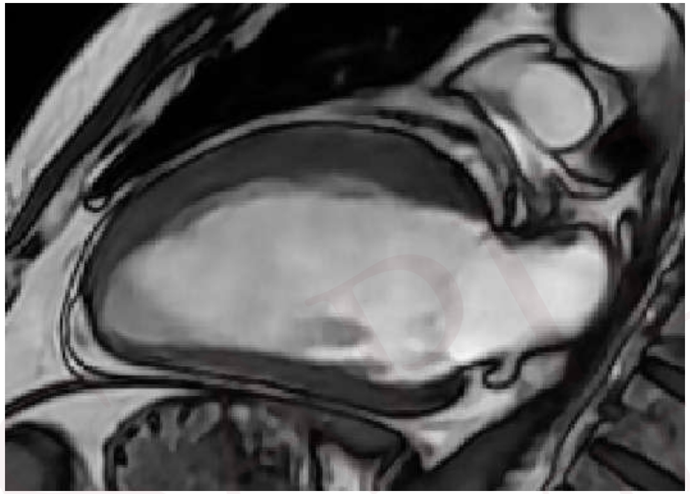
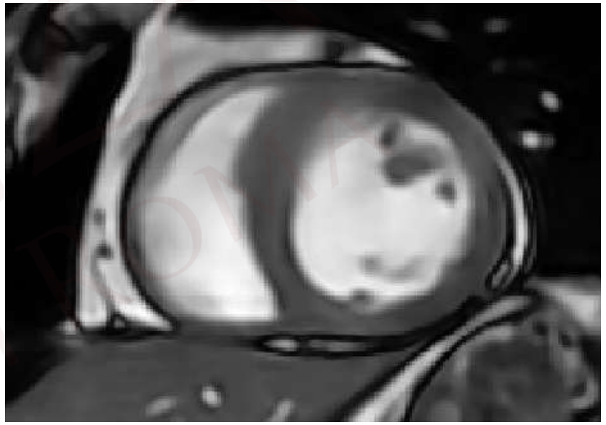
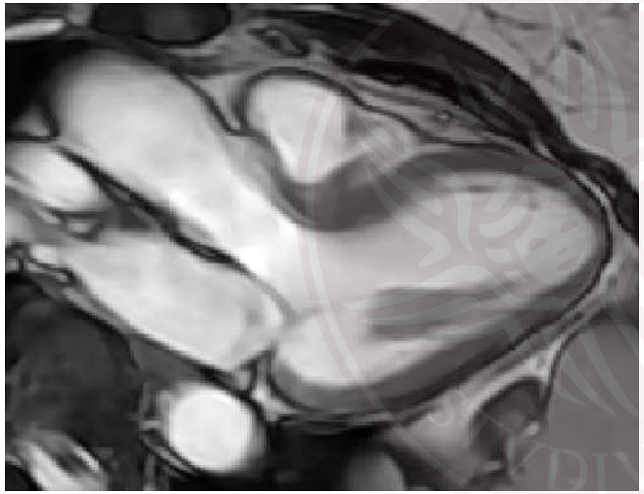
Visual Analysis

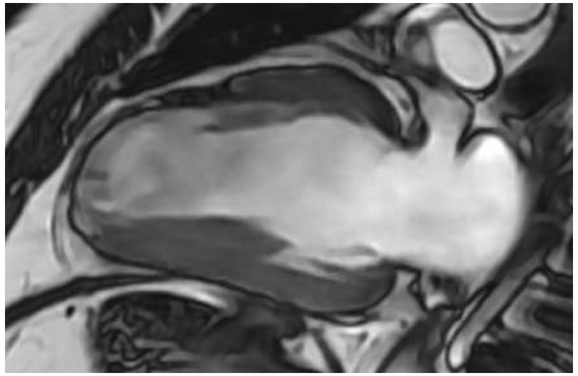
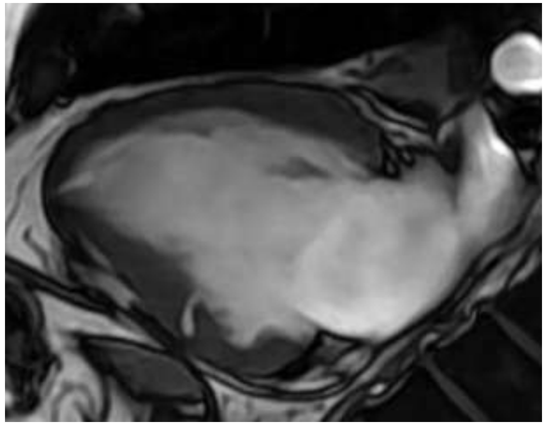
- Assessment of LV function from a global and segmental perspective.
- Segmental wall motion is based on segmental wall thickening during systole.
- Wall motion is categorized as:
  - Hyperkinetic
  - Normokinetic
  - Hypokinetic
  - Akinetic
  - Dyskinetic

Schulz-Menger J et al. J Cardiovasc Magn Reson. 2020 Mar 12;22(1):19. doi: 10.1186/s12968-020-00610-6

LV CHAMBER ASSESSMENT

Visual Analysis

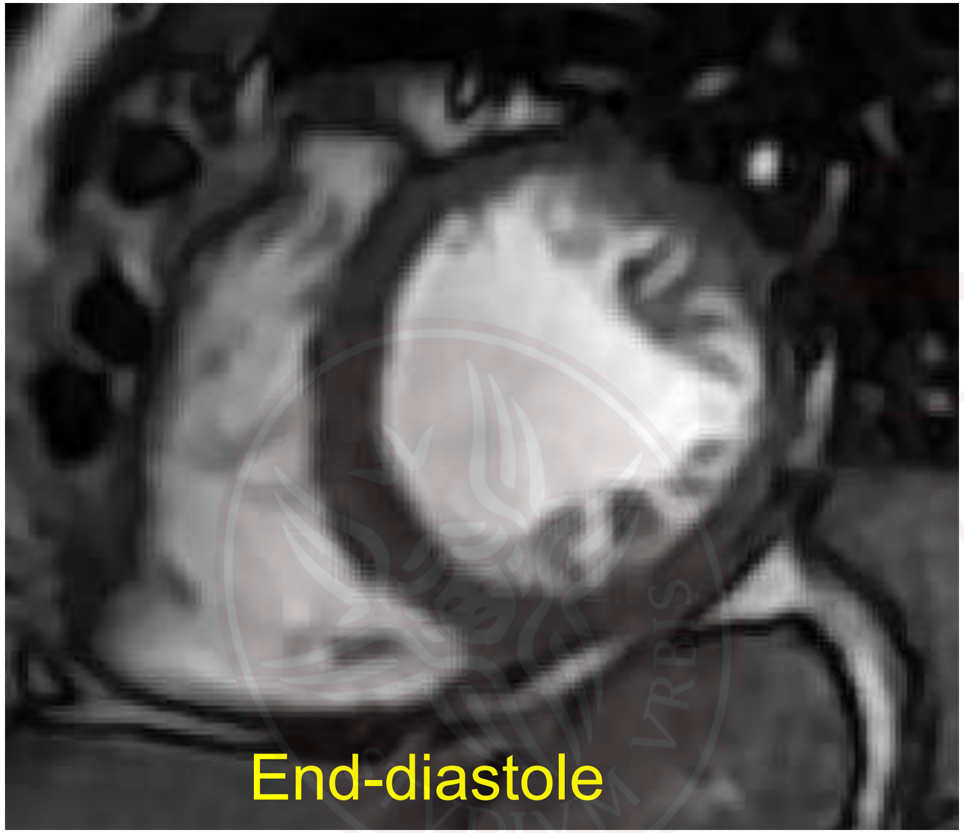





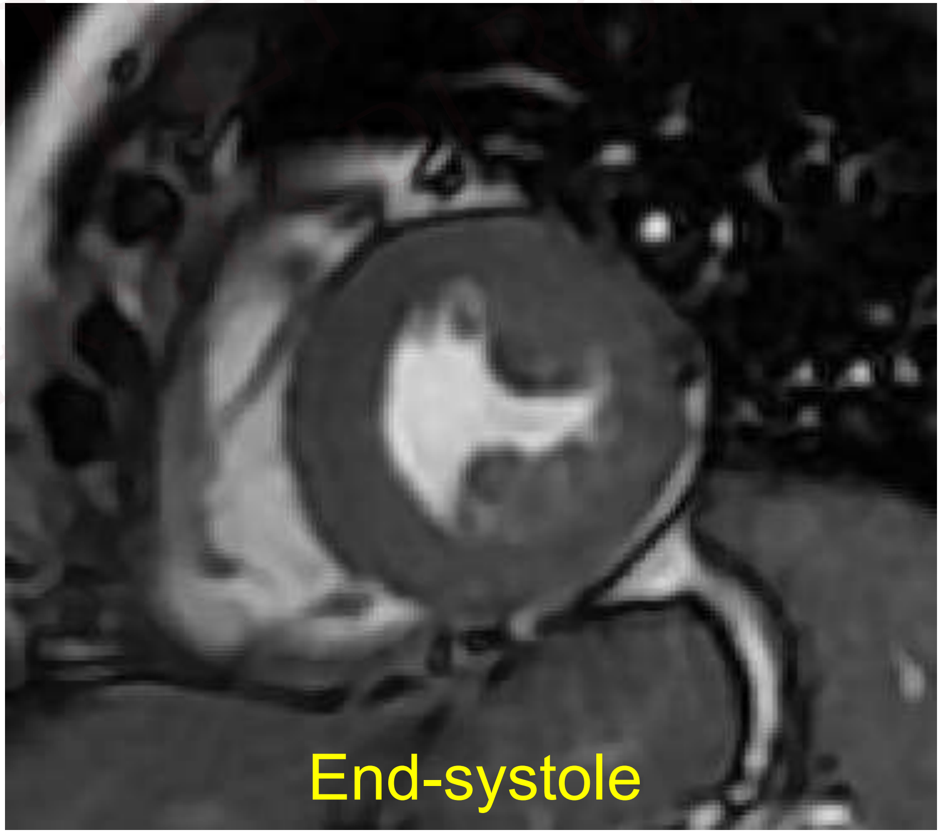



LV CHAMBER ASSESSMENT

Quantitative Analysis

- **Identification of end-diastole and end-systole**

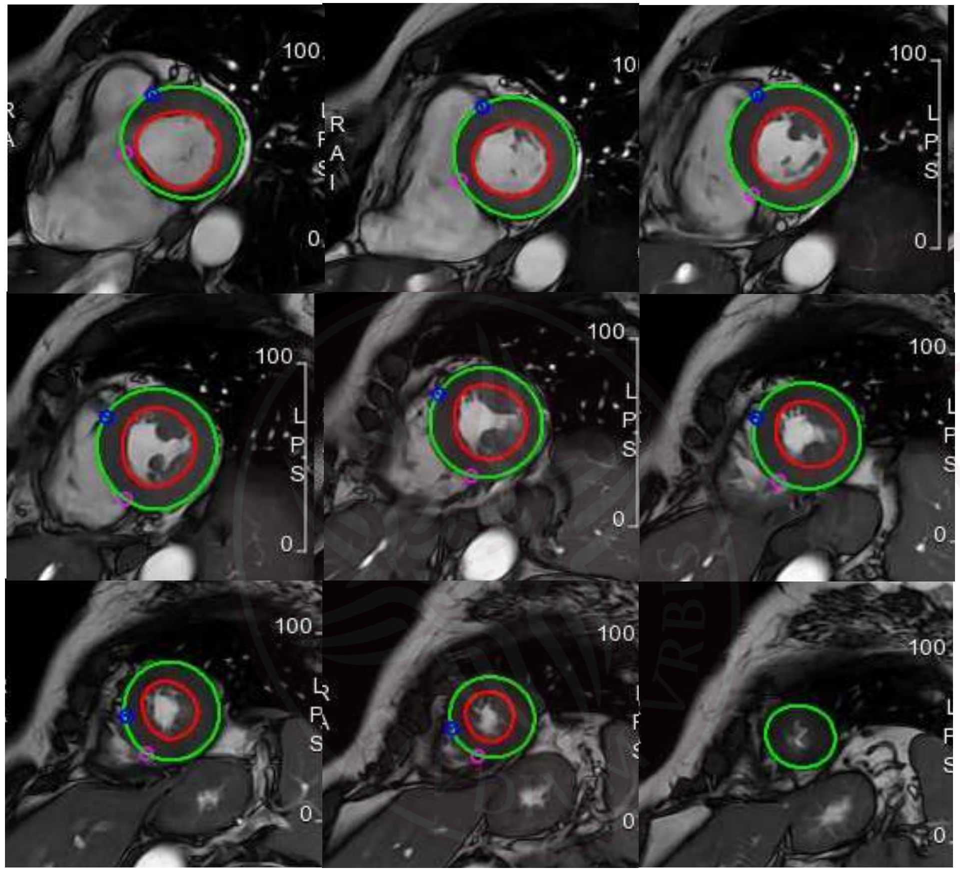


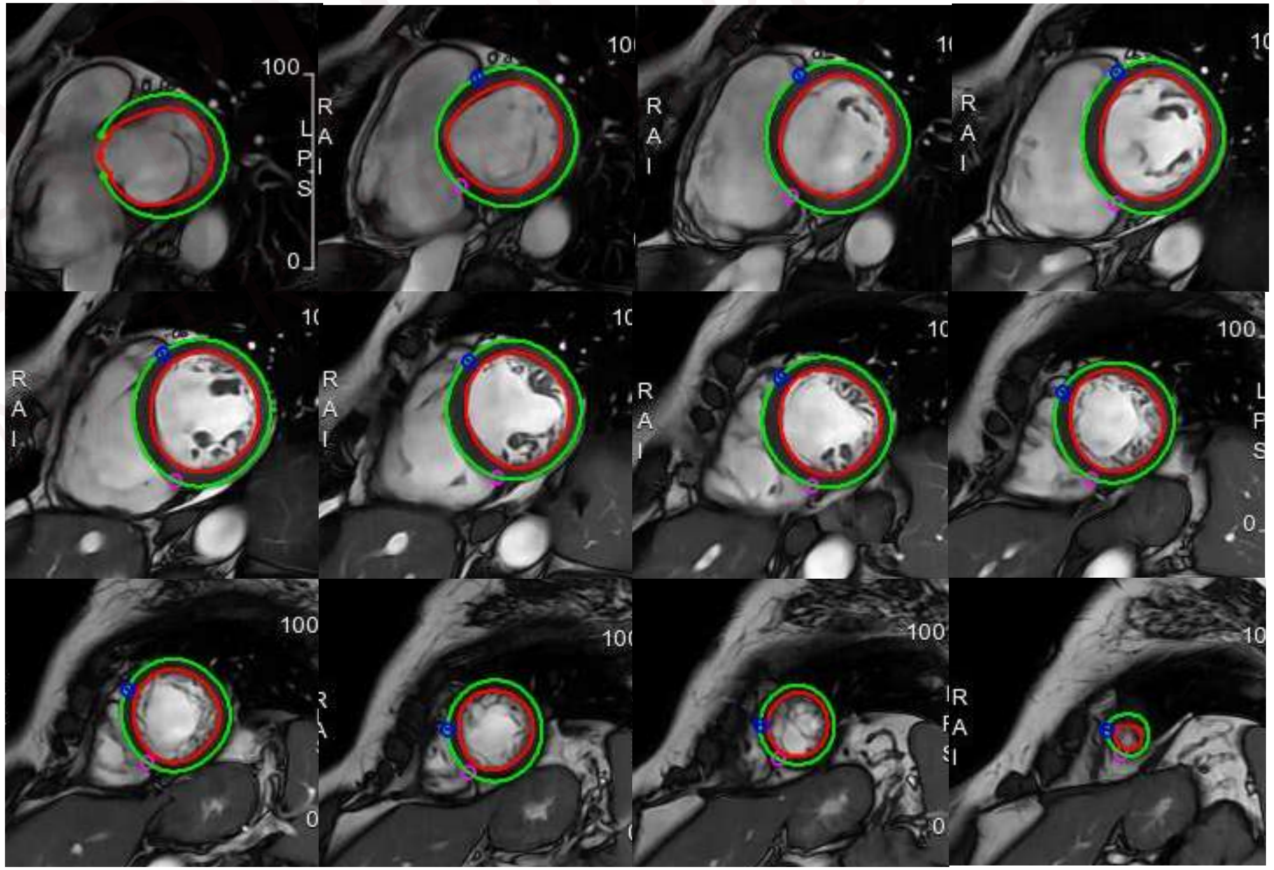


LV CHAMBER ASSESSMENT

Quantitative Analysis

- **Contour epicardial and endocardial borders in both end-diastole and end-systole**
- **Papillary muscles can be included in the myocardium or blood pool.**





LV CHAMBER ASSESSMENT

Quantitative Analysis

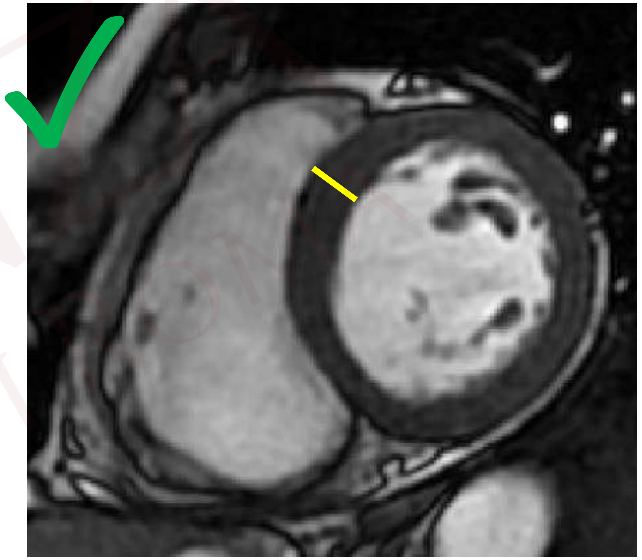
- **Evaluation of stack of short-axis images**
- **Parameters to be calculated**
  - LV EDV (absolute and indexed)
  - LV ESV (absolute and indexed)
  - LV SV (absolute and indexed)
  - LV EF
  - CO (absolute and indexed)
  - LV Mass (absolute and indexed)

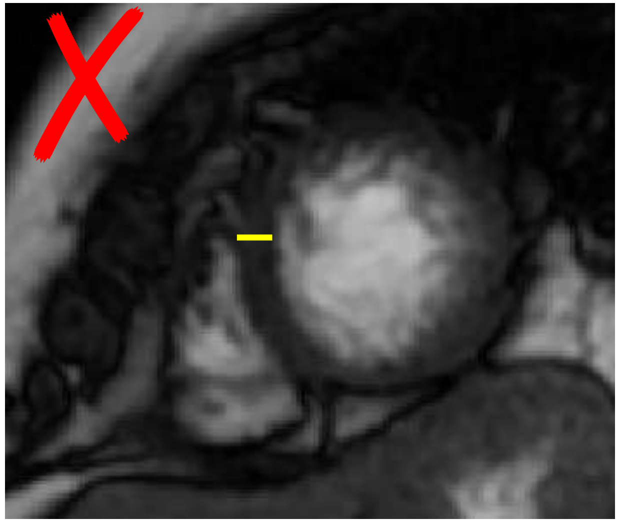
Schulz-Menger J et al. J Cardiovasc Magn Reson. 2020 Mar 12;22(1):19. doi: 10.1186/s12968-020-00610-6

LV CHAMBER ASSESSMENT

Quantitative Analysis

- **Cavity diameter and LV wall thickness can be obtained:**
  - **In basal short-axis slice**
    - Immediately basal to the tips of the papillary muscles.
  - **In 3-chamber view:**
    - In the LV minor axis plane at the mitral chordae level basal to the tips of the papillary muscles.
  - For maximal LV wall thickness, the measurement should be made perpendicular to the LV wall. At the apex, short-axis images are oblique to the axis of the wall and will be inaccurate. In this location in particular, long-axis views should be used.





Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

RV CHAMBER ASSESSMENT

Visual Analysis

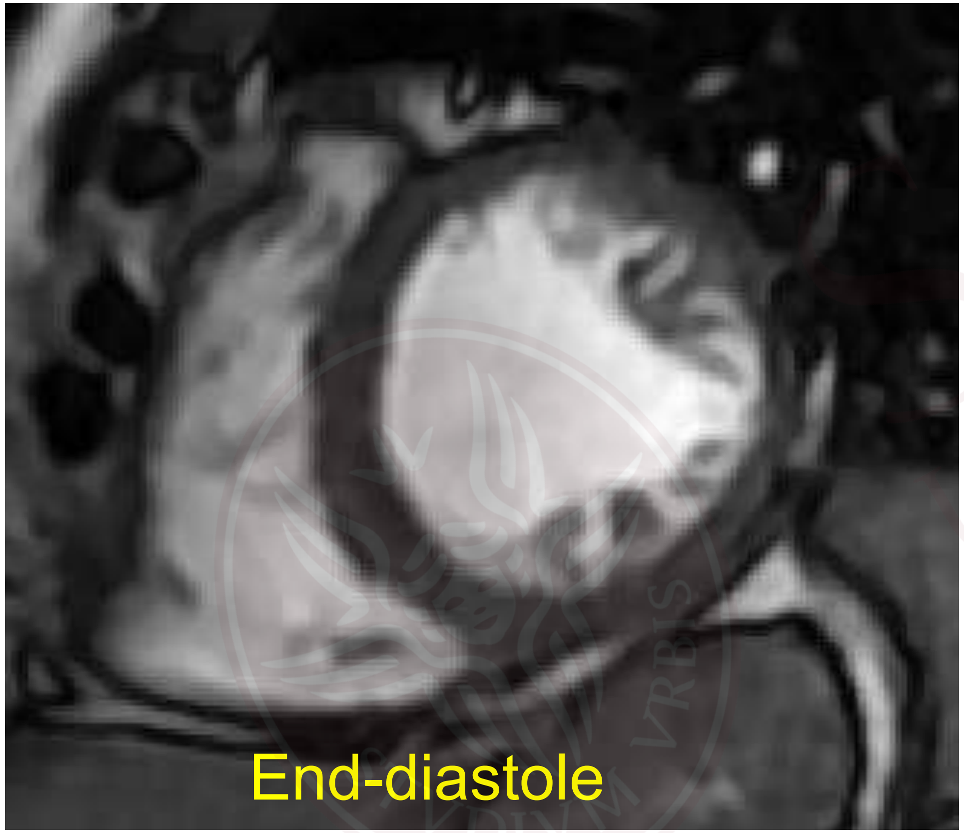
- Assessment of RV function from a global and regional (septal wall, free wall) perspective.
- Wall motion is categorized as:
  - Hyperkinetic
  - Normokinetic
  - Hypokinetic
  - Akinetic
  - Dyskinetic

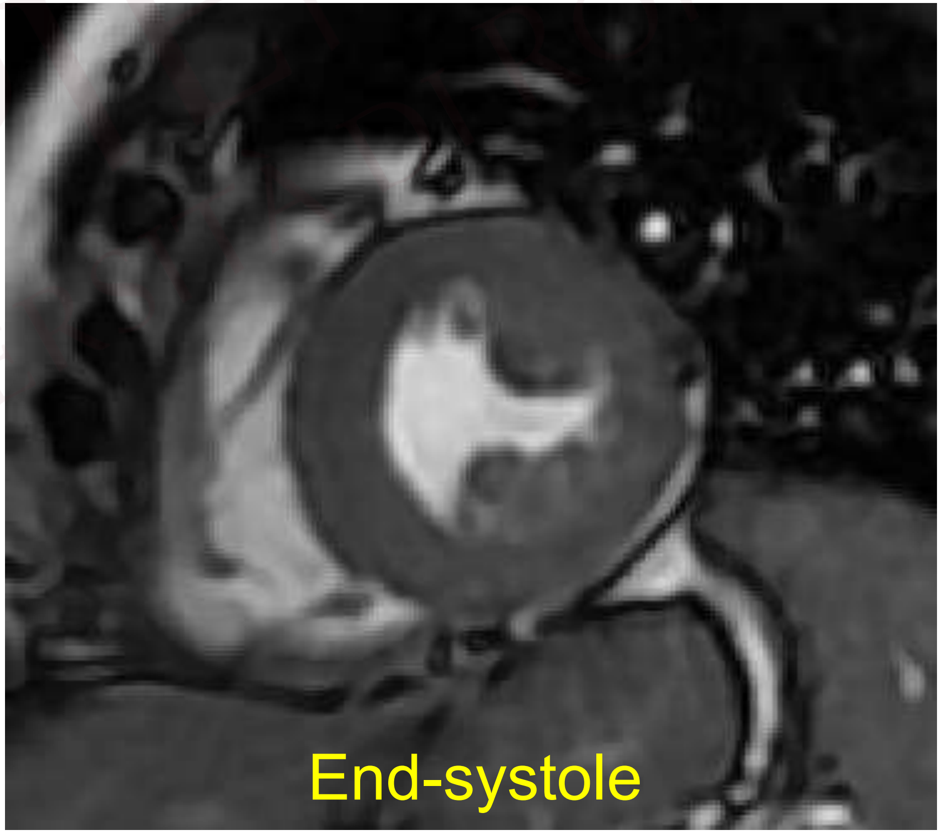
Schulz-Menger J et al. J Cardiovasc Magn Reson. 2020 Mar 12;22(1):19. doi: 10.1186/s12968-020-00610-6

LV CHAMBER ASSESSMENT

Quantitative Analysis

- **Identification of end-diastole and end-systole**

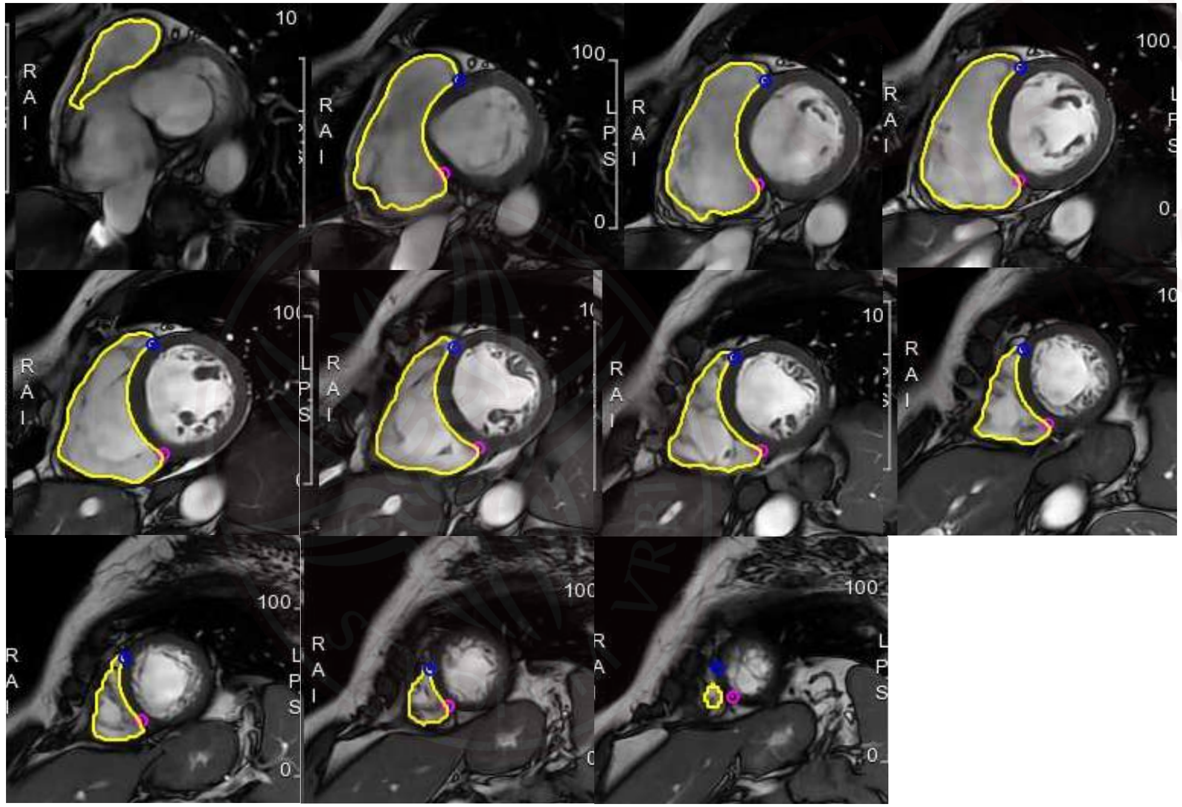


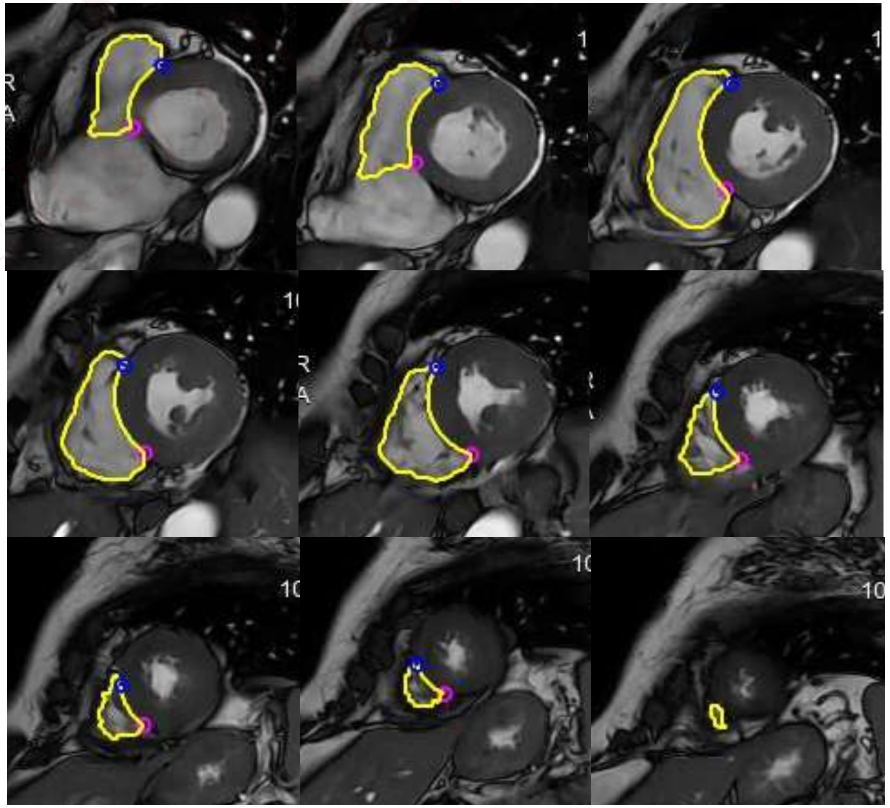


RV CHAMBER ASSESSMENT

Quantitative Analysis

- **Contour endocardial borders in both end-diastole and end-systole**
- **Contours should not pass the pulmonary valve**
- **RV trabeculae and papillary muscles are typically included in RV volumes**





RV CHAMBER ASSESSMENT

Quantitative Analysis

- **Evaluation of stack of short-axis images**
- **Parameters to be calculated**
  - RV EDV (absolute and indexed)
  - RV ESV (absolute and indexed)
  - RV SV (absolute and indexed)
  - RV EF
  - CO (absolute and indexed)

- RV mass is usually not quantified

CONFIRMATION OF RESULTS

- **If no shunts or valvular regurgitation is present, the RV and LV stroke volumes should be nearly equal.**
- **The LV data can be used to validate RV data.**

Funzione LV Stack SAX3D	
EDV:	176.97 ml
ESV:	75.13 ml
SV:	101.84 ml
EF:	57.55 %
CO:	5.59 l/min
CI:	2.98 l/min/m²
HR:	54.9/min
Massa mioc (diast):	127.59 g
Massa mioc (sist):	136.73 g
Fase diastole:	29
Fase sistole:	10
EDV/H:	104.71 ml/m
EDV/BSA:	94.31 ml/m²
ESV/H:	44.46 ml/m
ESV/BSA:	40.04 ml/m²

Funzione RV Stack SAX3D	
RVEDV:	158.22 ml
RVESV:	57.26 ml
RVSV:	100.96 ml
RVEF:	63.81 %
RVCO:	5.54 l/min
RVCI:	2.95 l/min/m²
HR:	54.9/min
Fase diastole:	29
Fase sistole:	10
RVEDV/H:	93.62 ml/m
RVEDV/BSA:	84.32 ml/m²
RVESV/H:	33.88 ml/m
RVESV/BSA:	30.52 ml/m²
RVSV/H:	59.74 ml/m
RVSV/BSA:	53.80 ml/m²

NORMAL VALUES FOR CMR

Kawel-Boehm *et al. J Cardiovasc Magn Reson* (2020) 22:87
https://doi.org/10.1186/s12968-020-00683-3

Journal of Cardiovascular
Magnetic Resonance

REVIEW **Open Access**

Check for updates

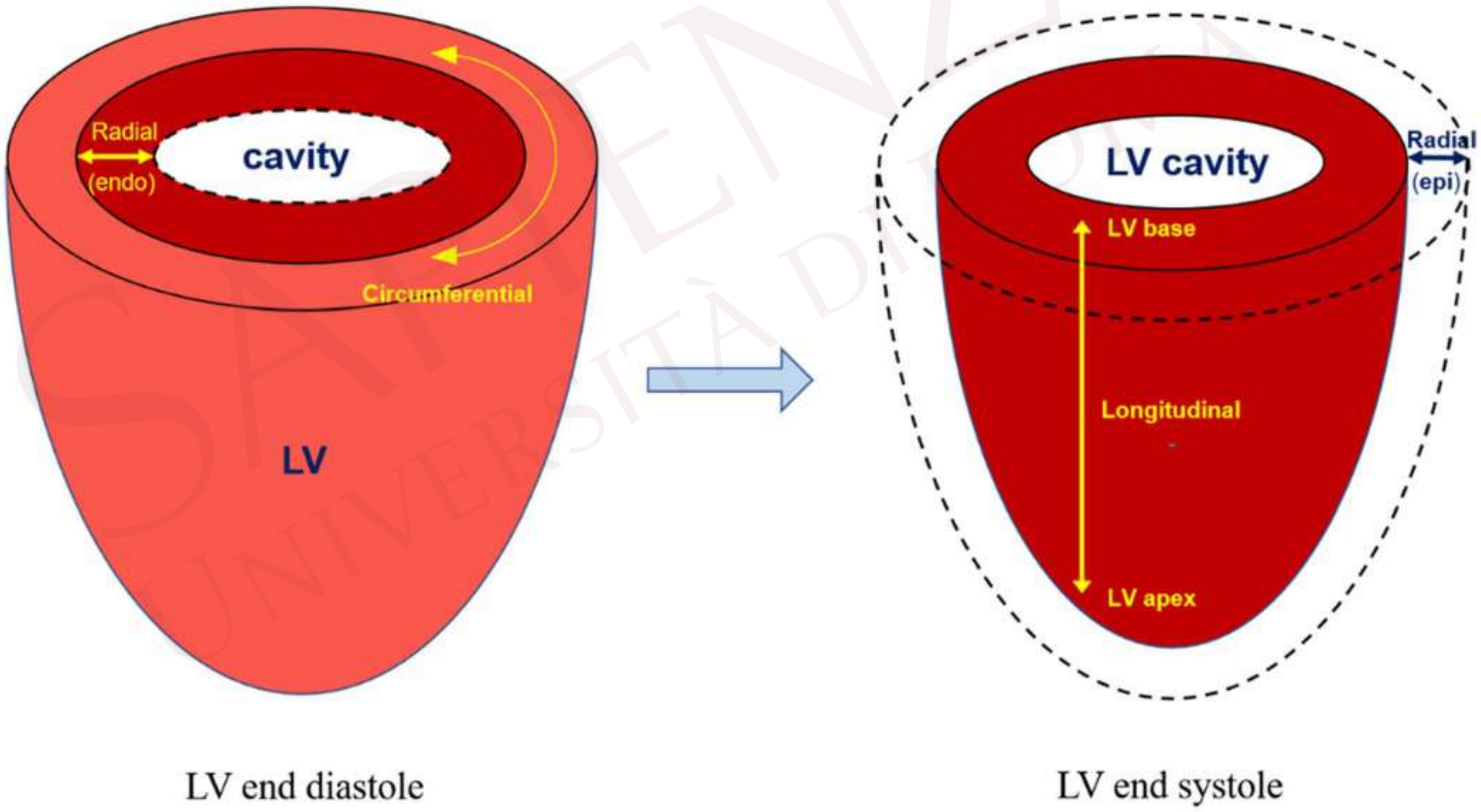
Reference ranges ("normal values") for cardiovascular magnetic resonance (CMR) in adults and children: 2020 update

Nadine Kawel-Boehm[1,2], Scott J. Hetzel[3], Bharath Ambale-Venkatesh[4], Gabriella Captur[5,6], Christopher J. Francois[7], Michael Jerosch-Herold[8], Michael Salerno[9], Shawn D. Teague[10], Emanuela Valsangiacomo-Buechel[11], Rob J. van der Geest[12] and David A. Bluemke[7*]

Kawel-Boehm N et al. J Cardiovasc Magn Reson. 2020 Dec 14;22(1):87. doi: 10.1186/s12968-020-00683-3

MYOCARDIAL STRAIN

- Longitudinal Strain
- Circumferential Strain
- Radial Strain



Xu J et al. Eur Radiol. 2022 Aug;32(8):5424-5435. doi: 10.1007/s00330-022-08629-2

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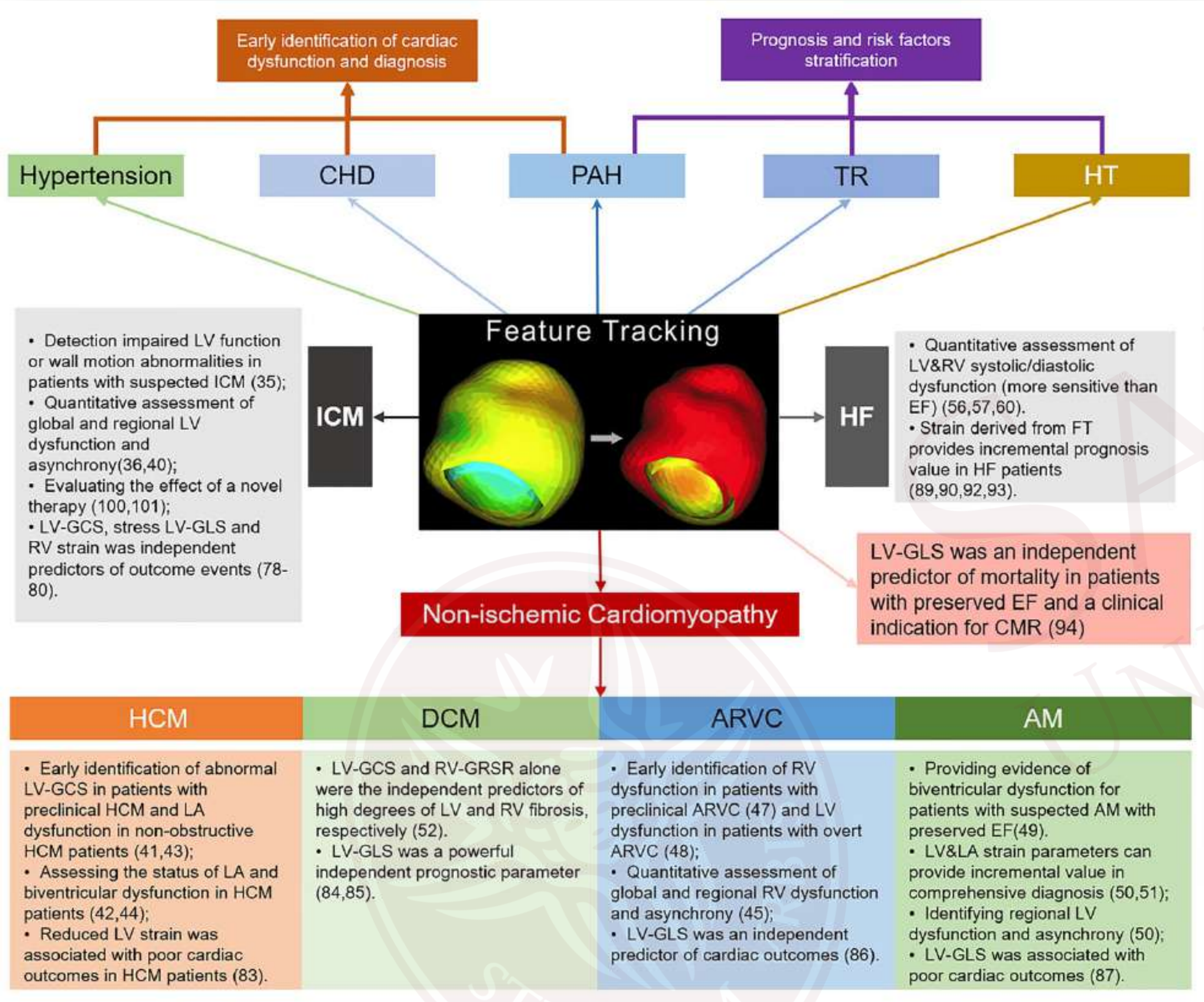
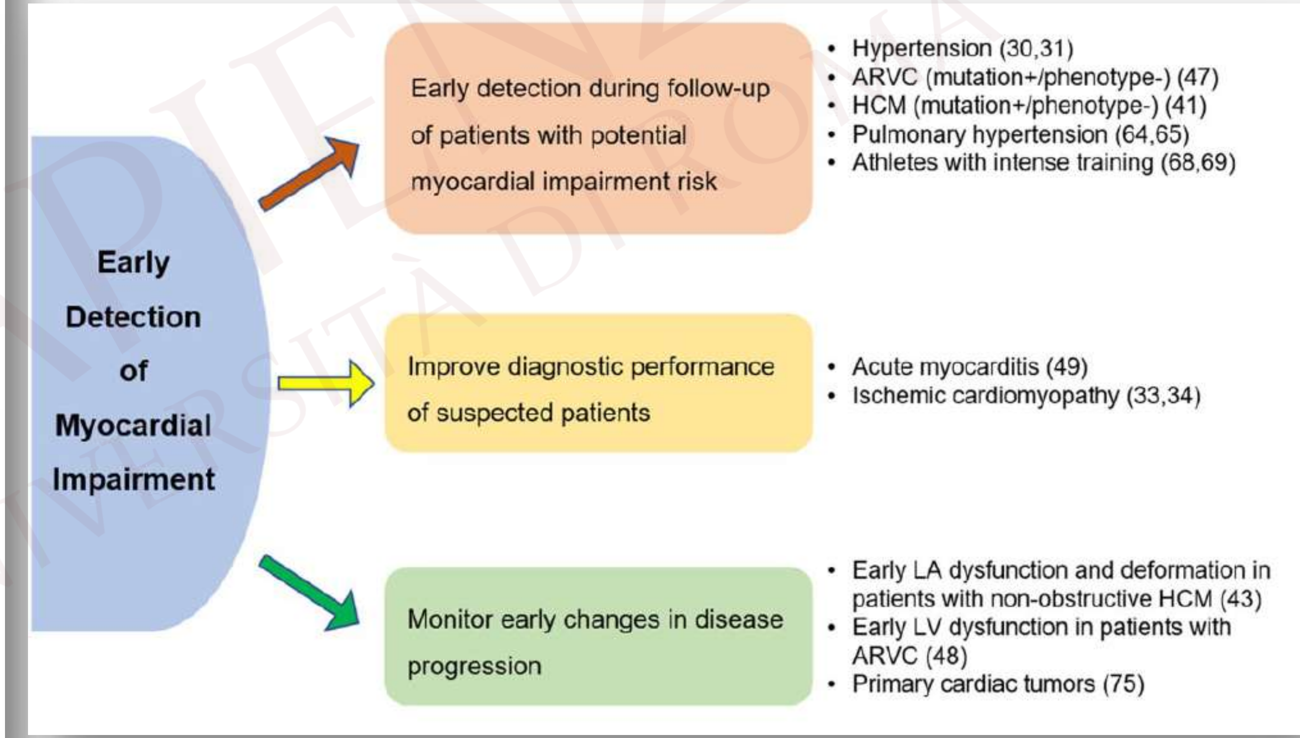
MYOCARDIAL STRAIN

SISTEMA SANITARIO REGIONALE
AZIENDA OSPEDALIERO-UNIVERSITARIA SANT'ANDREA





Xu J et al. Eur Radiol. 2022 Aug;32(8):5424-5435. doi: 10.1007/s00330-022-08629-2

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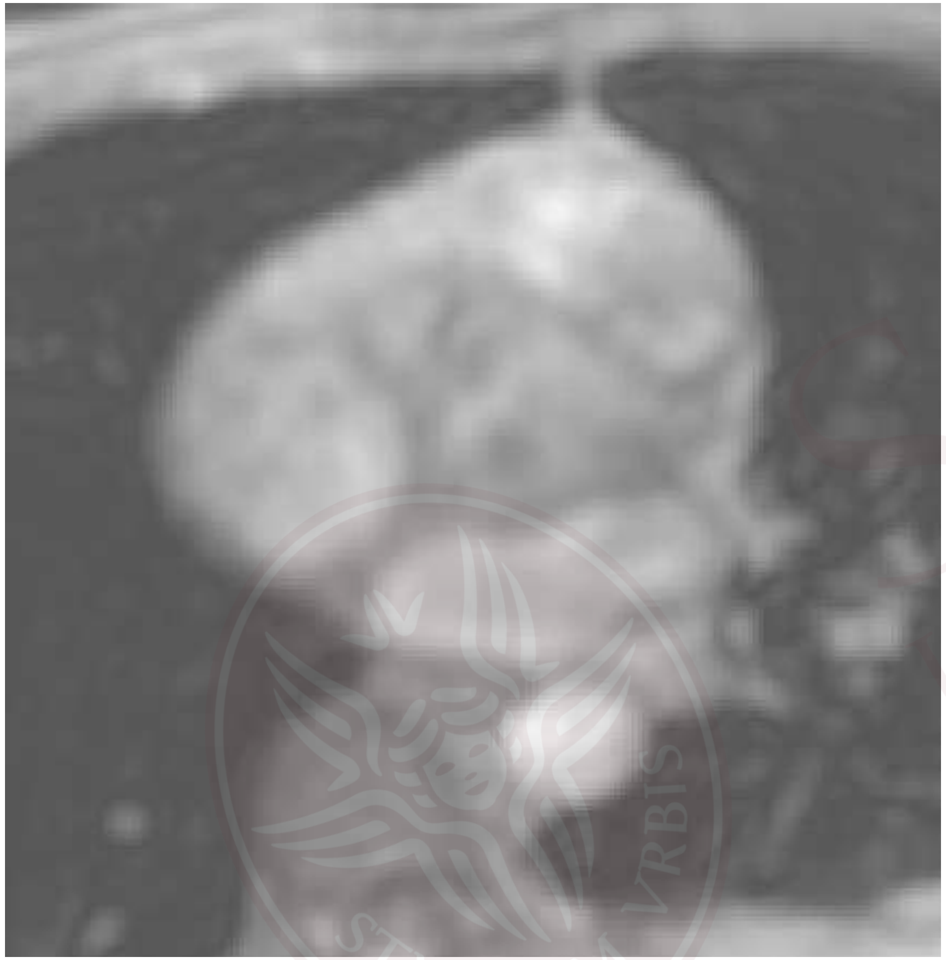
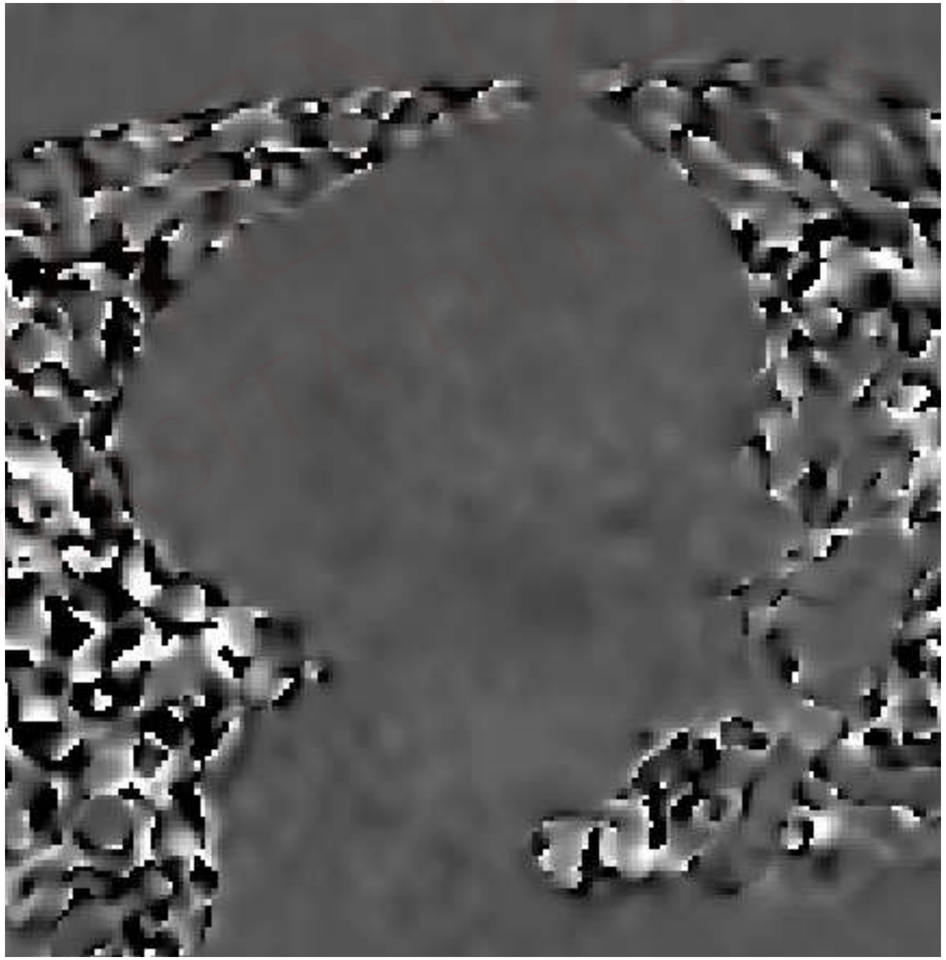
PHASE CONTRAST SEQUENCES

SISTEMA SANITARIO REGIONALE AZIENDA OSPEDALIERO-UNIVERSITARIA SANT'ANDREA

Quantification of flow and velocity

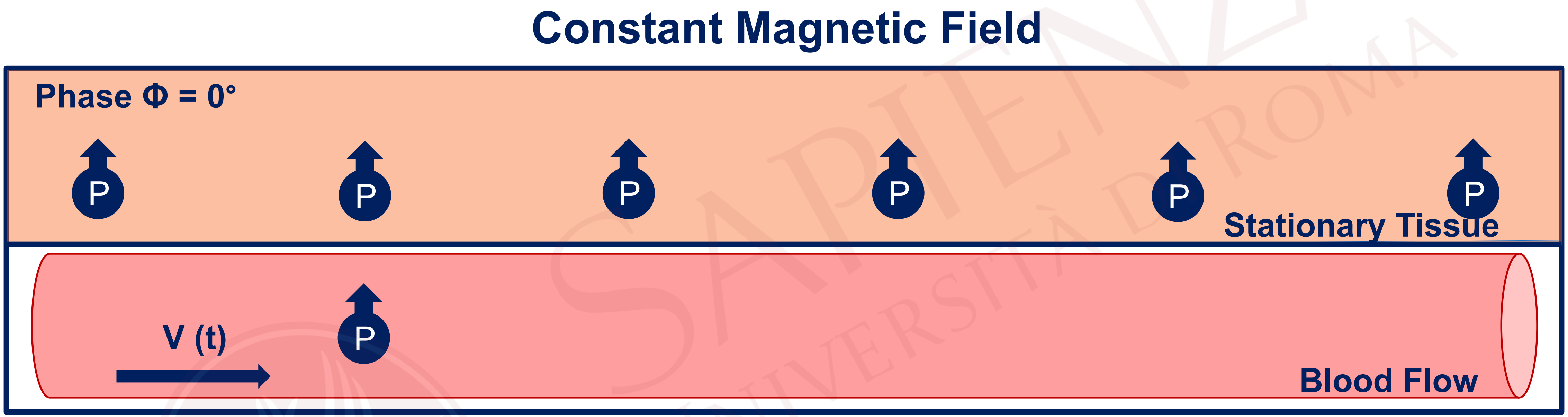


Magnitude



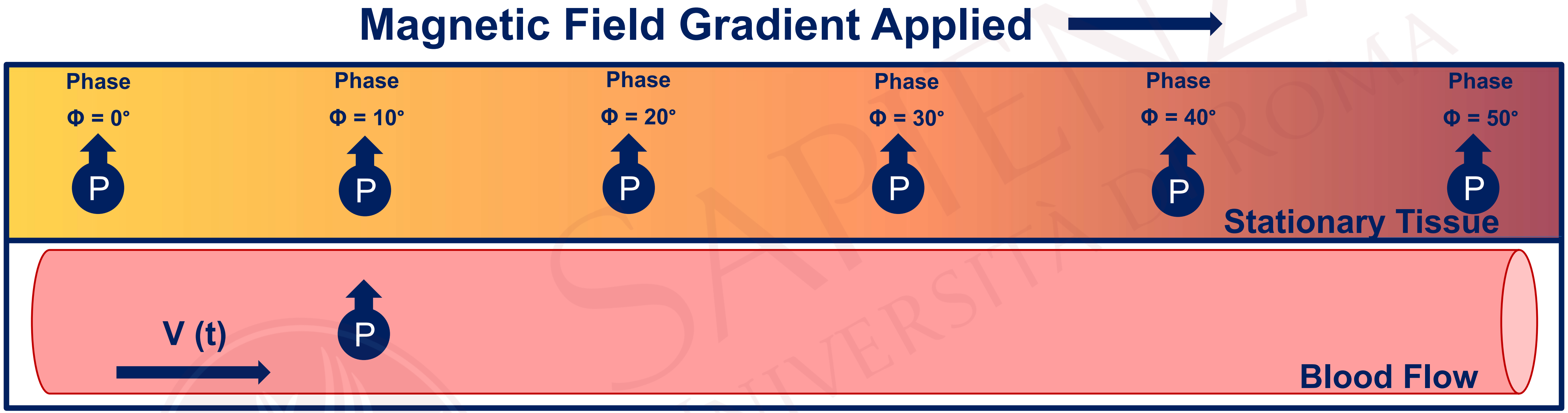
Phase Contrast

PHASE CONTRAST SEQUENCES



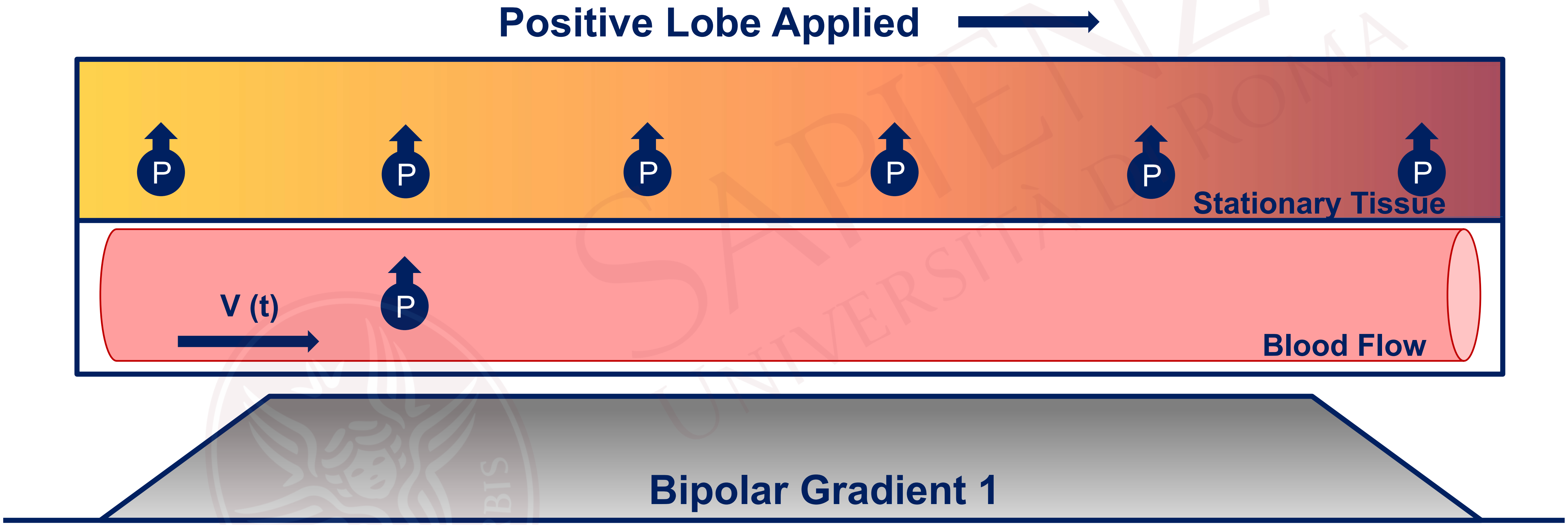
Adapted from Lotz J et al. Radiographics. 2002 May-Jun;22(3):651-71. doi: 10.1148/radiographics.22.3.g02ma11651

PHASE CONTRAST SEQUENCES



Adapted from Lotz J et al. Radiographics. 2002 May-Jun;22(3):651-71. doi: 10.1148/radiographics.22.3.g02ma11651

PHASE CONTRAST SEQUENCES



Adapted from Lotz J et al. Radiographics. 2002 May-Jun;22(3):651-71. doi: 10.1148/radiographics.22.3.g02ma11651

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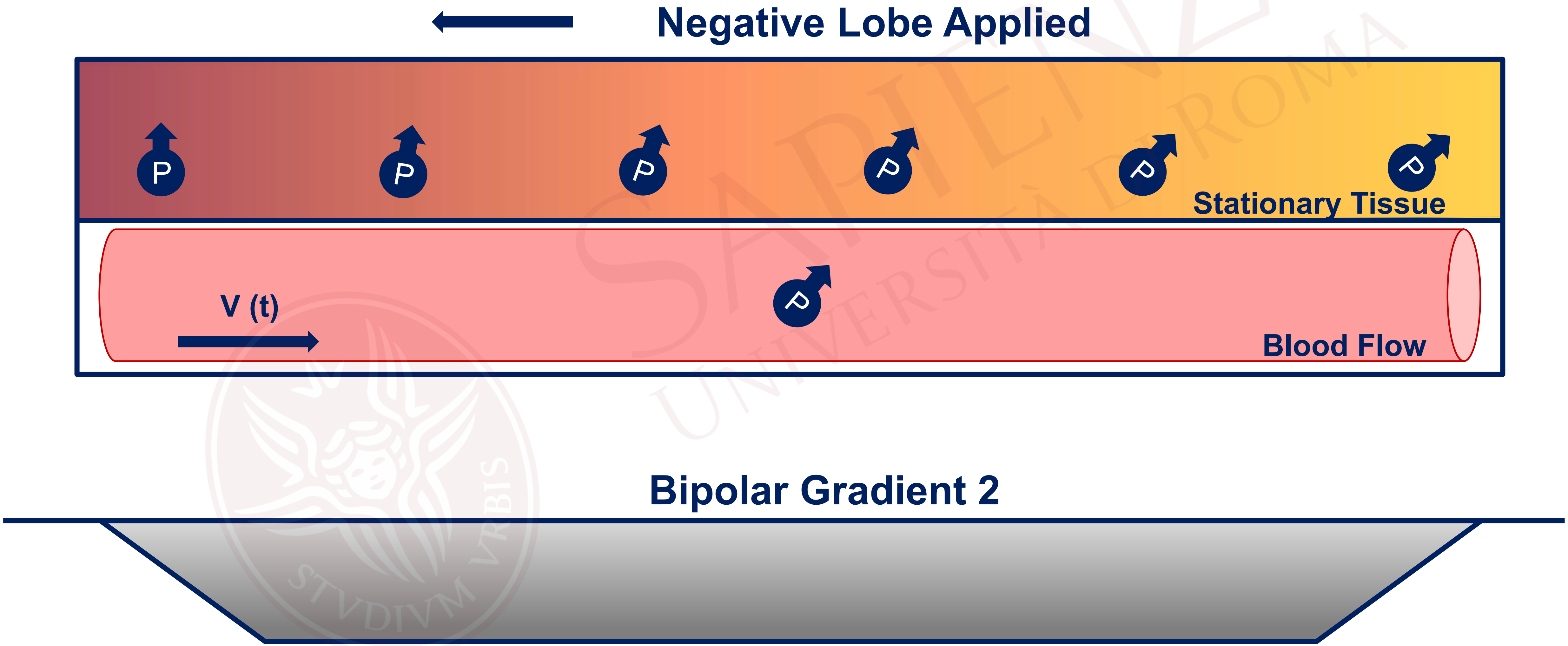
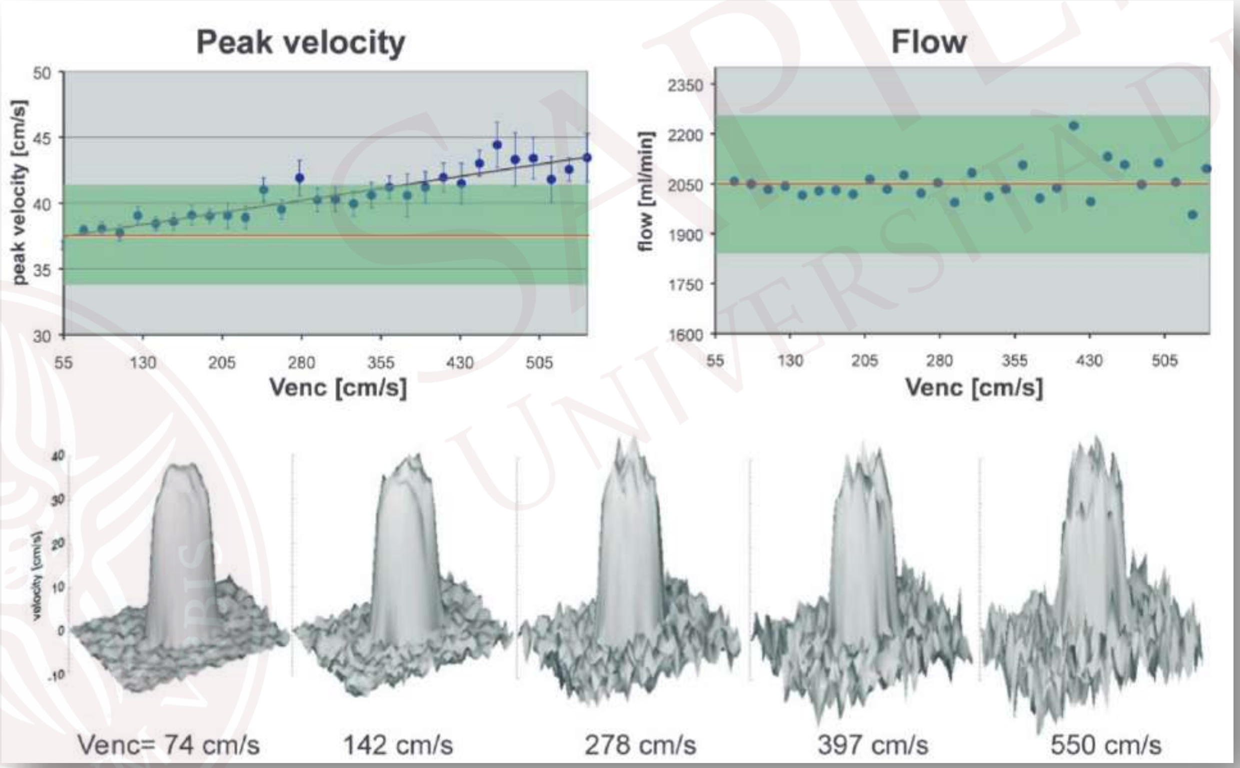


Adapted from Lotz J et al. Radiographics. 2002 May-Jun;22(3):651-71. doi: 10.1148/radiographics.22.3.g02ma11651

PHASE CONTRAST SEQUENCES

V_{enc} and Noise

- Max and min V_{enc} is expressed in cm/s
- If V_{enc} is too high → Noise



Lotz J et al. Radiographics. 2002 May-Jun;22(3):651-71. doi: 10.1148/radiographics.22.3.g02ma11651

PHASE CONTRAST SEQUENCES

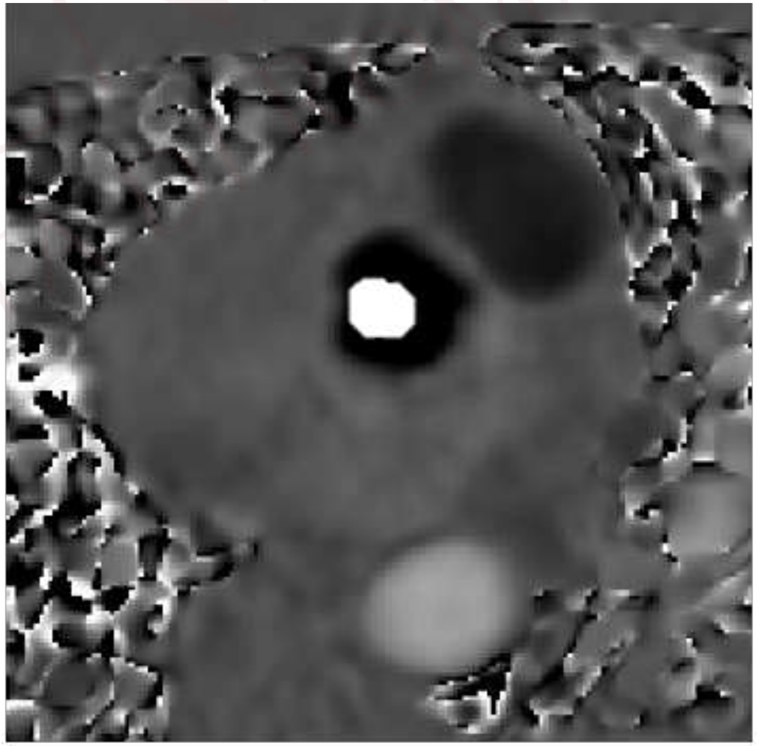
V_{enc} and Aliasing

- Max and min V_{enc} is expressed in cm/s
- If V_{enc} is too low → aliasing
- Aliasing can be perceived in the velocity images, in which the voxels of assumed peak velocities have an inverted signal intensity

↓

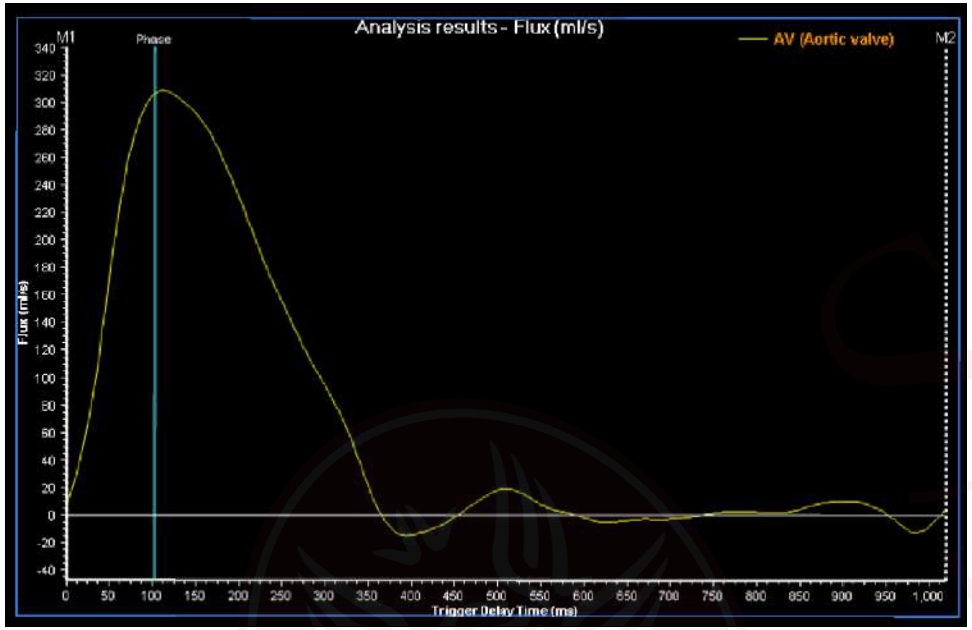
- Software/manual correction
- Repeat the flow measurement with higher V_{enc}

Aliasing

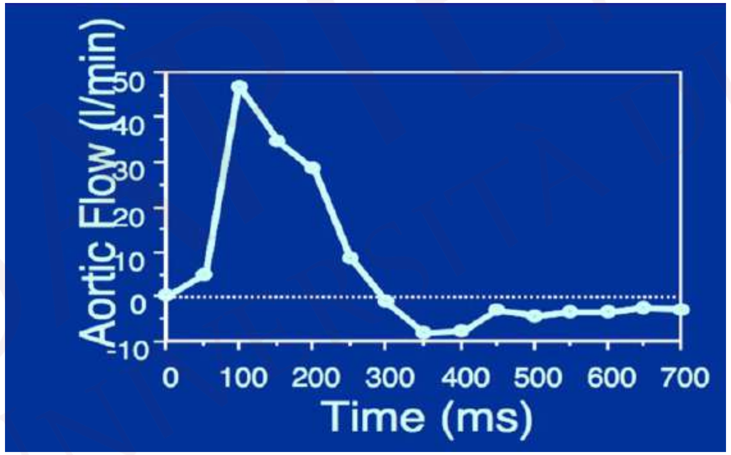


Lotz J et al. Radiographics. 2002 May-Jun;22(3):651-71. doi: 10.1148/radiographics.22.3.g02ma11651

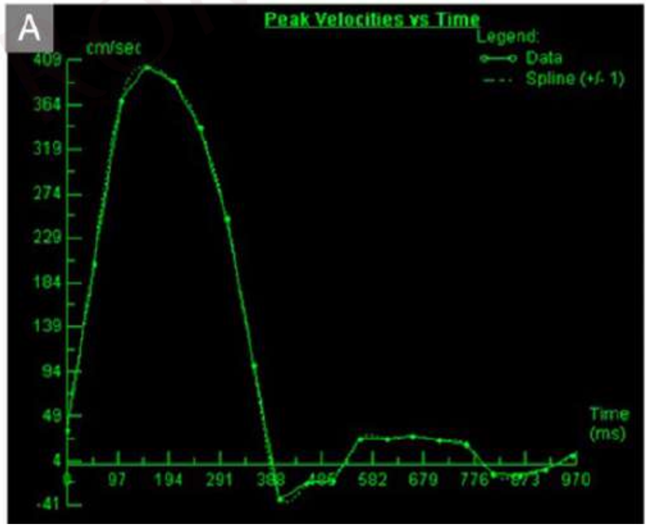
PHASE CONTRAST SEQUENCES



Normal



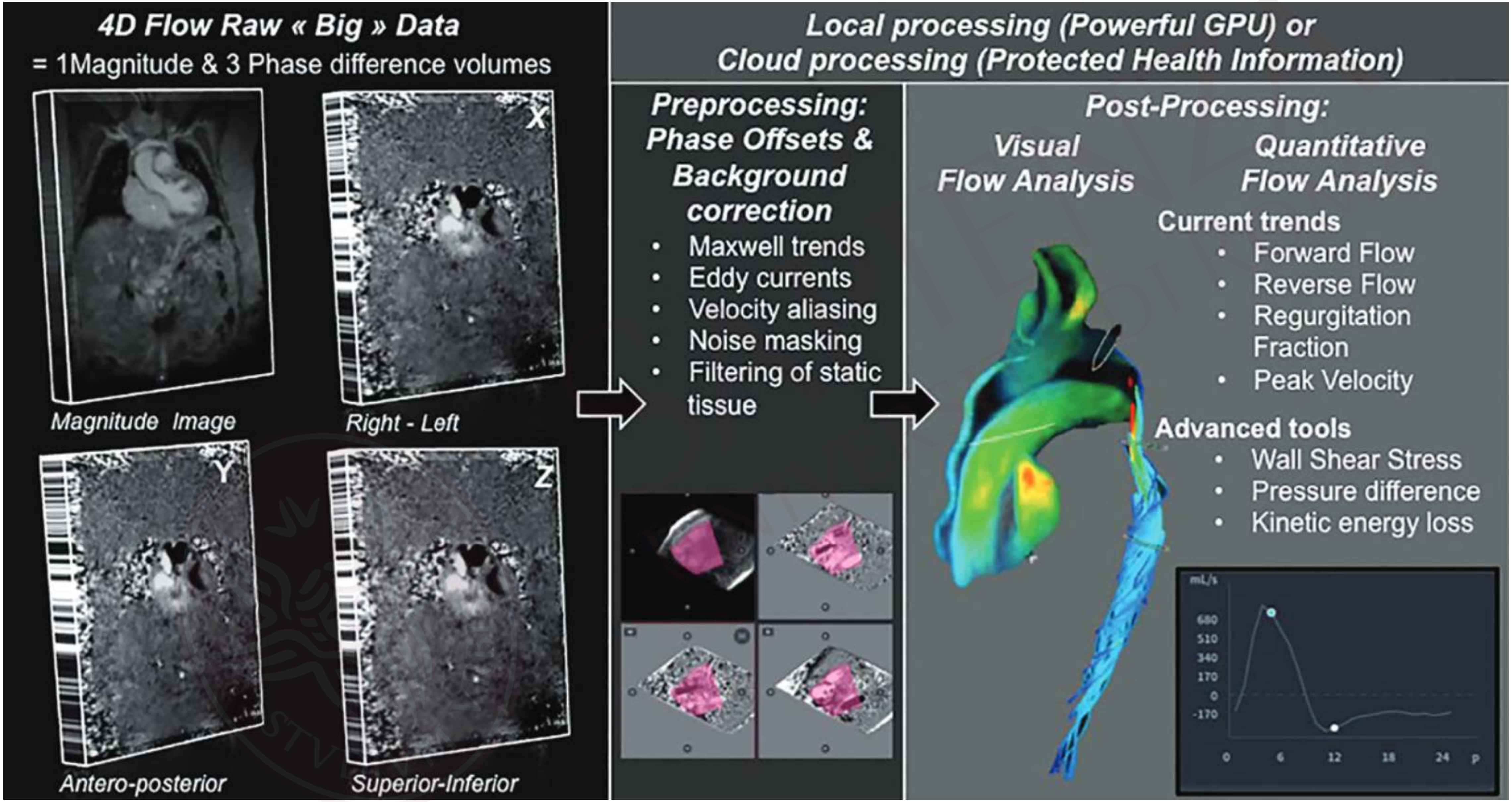
Aortic Regurgitation



Aortic Stenosis

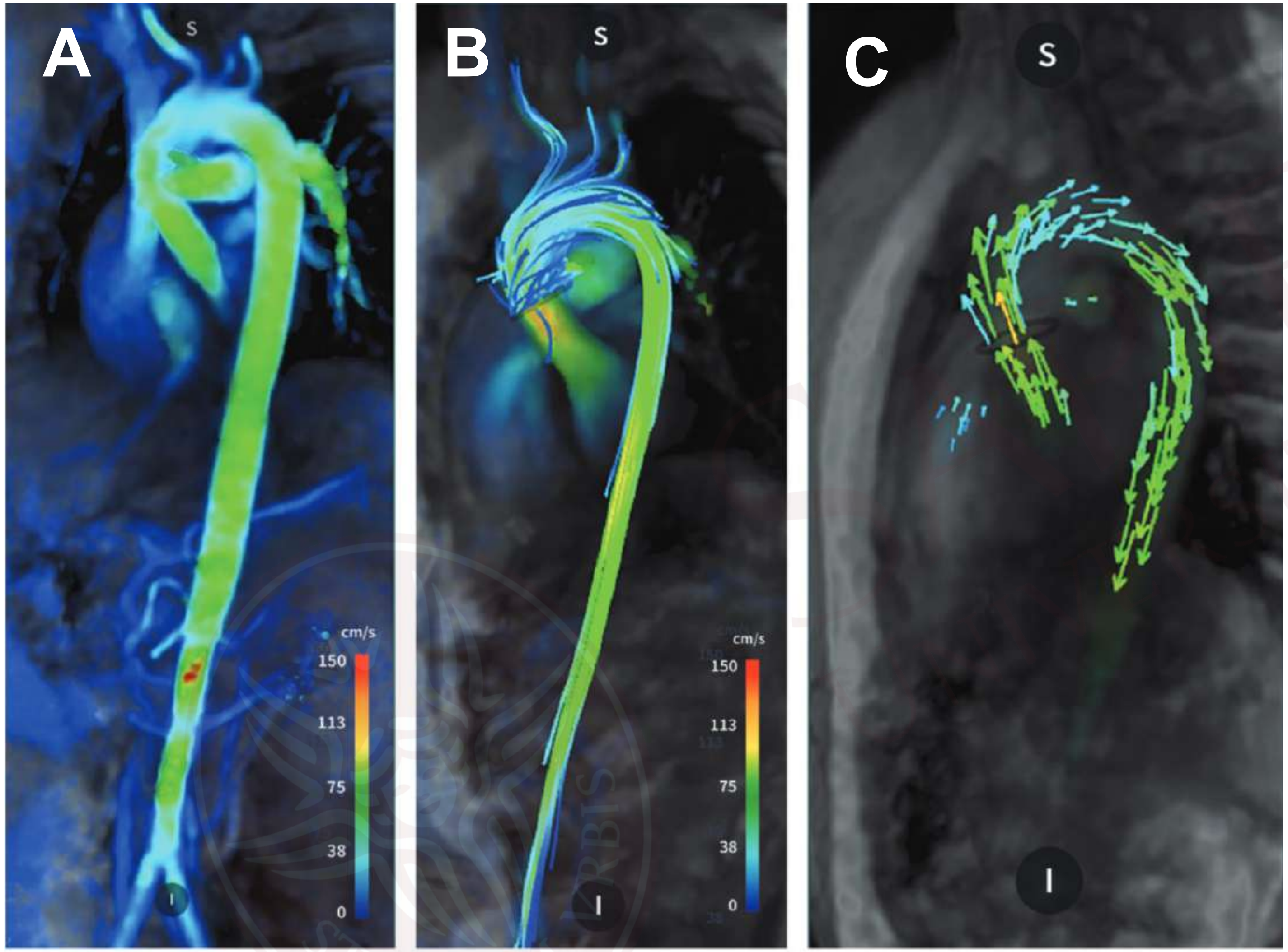
Nayak KS et al. J Cardiovasc Magn Reson. 2015 Aug 9;17(1):71. doi: 10.1186/s12968-015-0172-7

4D FLOW



Azarine A et al. Radiographics. 2019 May-Jun;39(3):632-648. doi: 10.1148/rg.2019180091

4D FLOW



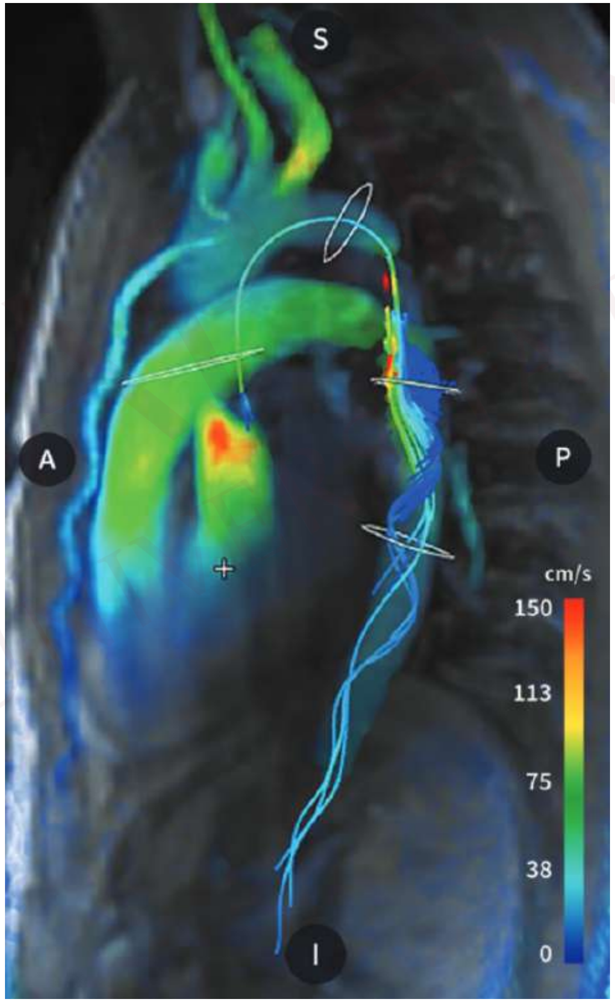
A. Color-coded 3D rendering shows areas of high velocity (red).
B. Streamlines. Streamlines show the path a particle would take if released into the velocity field, with the field held constant.
C. Velocity vectors

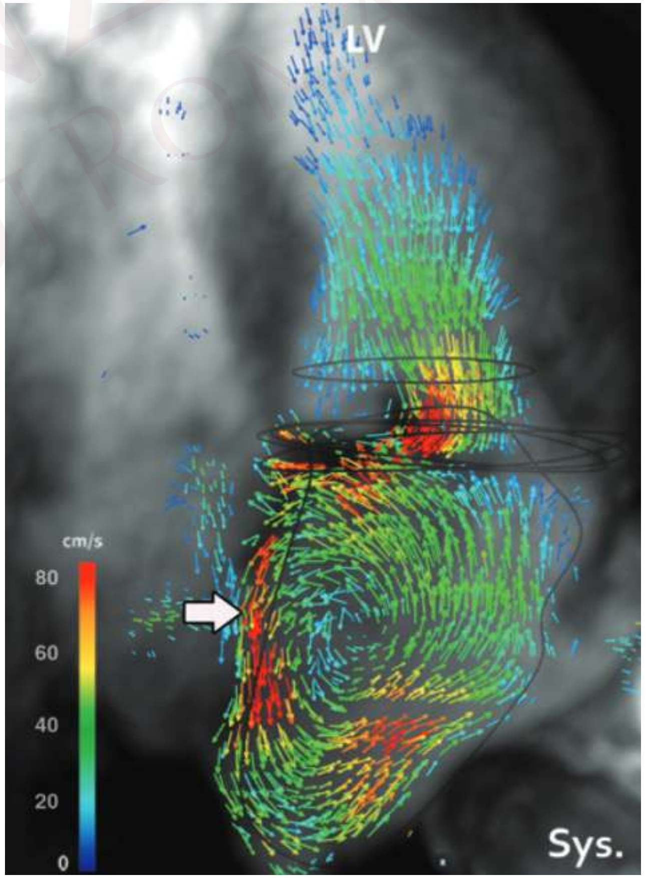
Azarine A et al. Radiographics. 2019 May-Jun;39(3):632-648. doi: 10.1148/rg.2019180091

4D FLOW

Clinical Applications

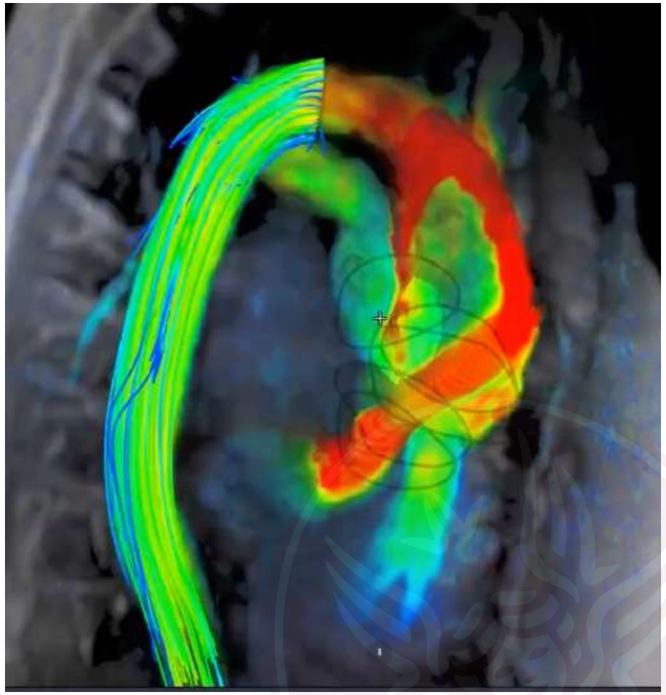
- Congenital Heart Disease
- Valvular disease
- Aortic disease
- Pulmonary hypertension
- Abdomen: portal hypertension
- Neuro: cerebral aneurysms
- Peripheral arterial disease



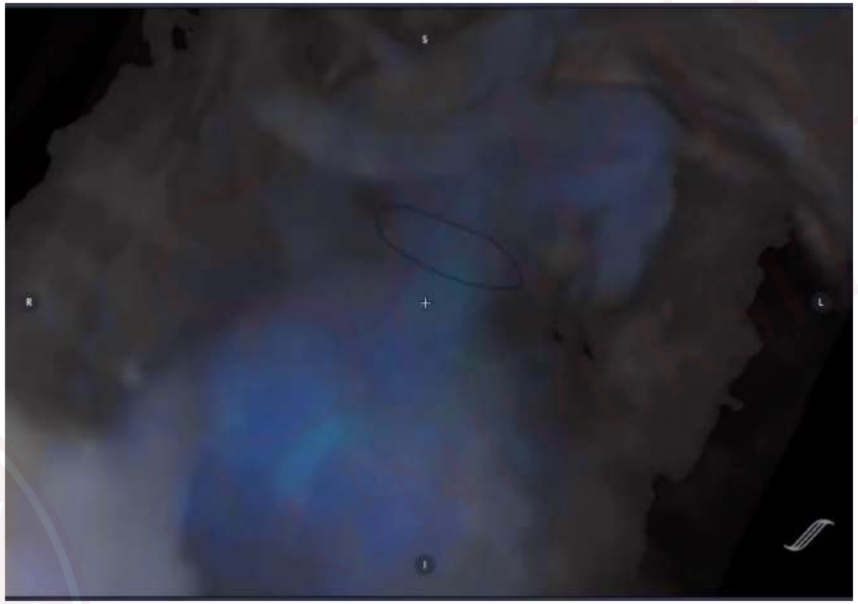


Azarine A et al. Radiographics. 2019 May-Jun;39(3):632-648. doi: 10.1148/rg.2019180091

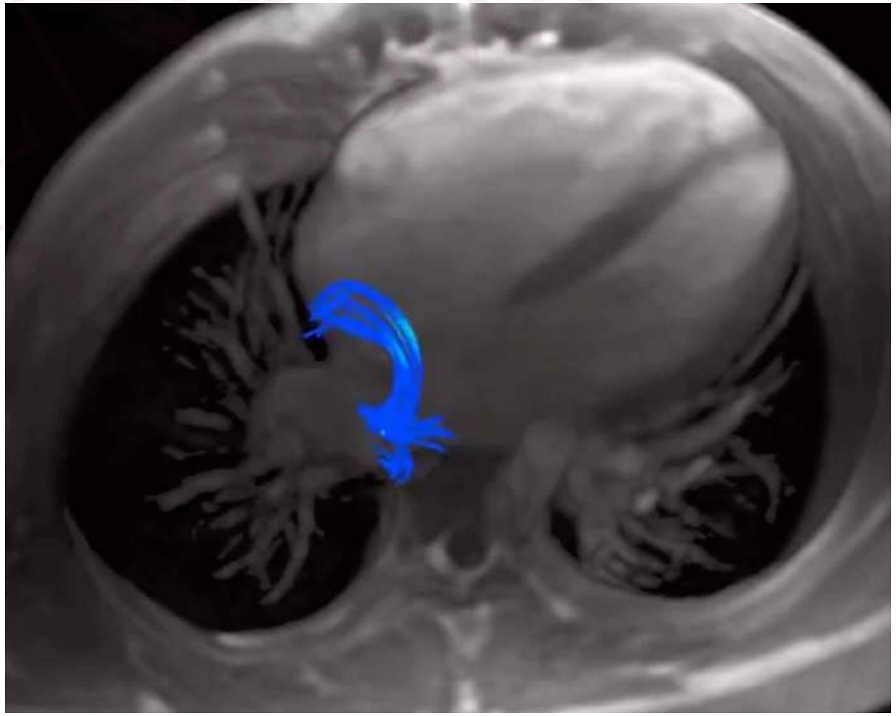
4D FLOW



Aortic Regurgitation



Pulmonary Regurgitation



Atrial Defect

Azarine A et al. Radiographics. 2019 May-Jun;39(3):632-648. doi: 10.1148/rg.2019180091

CONTRAST MEDIUM

- Volumes and injection rates vary depending on the contrast agent and scan protocol.
- Injection rates are different for 1 mmol/ml contrast agents (e.g., gadobutrol) and 0.5 mmol/ml agents. As a guideline, divide the given injection rates by a factor of 2 for the 1 mmol/ml formulation.
- GBCA contrast agents with higher relaxivity require smaller doses

Table 1 Contrast and chasing bolus doses and injection rates

Indication	Contrast dose (mmol/kg body weight)	Injection rate	Saline chasing bolus	Injection rate
Perfusion	0.05–0.1	3–7 ml/s	30 ml	3–7 ml/s
Late gadolinium enhancement	0.1–0.2		20 ml	
Angiography (carotids, renals, aorta)	0.1–0.2	2–3 ml/s	20 ml	2–3 ml/s
Time-resolved angiography	0.05	3–5 ml/s	30 ml	3–5 ml/s
Peripheral angiography	0.2	first 10 ml @ 1.5 ml/s, rest @ 0.4–0.8 ml/s	20 ml	0.4–0.8 ml/s

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

STRESS AGENTS

Stress agents

Vasodilator stress perfusion testing is more commonly performed than inotropic stress functional testing.

Vasodilator stress agents:

1. Adenosine:140 μg/kg body weight/min for 2–4 min (consider an increase up to 210 μg/kg body weight/min depending on institutional and local norms if, after 2–3 min, heart rate (HR) does not increase by 10 bpm and or systolic blood pressure does not drop by > 10 mmHg)
2. Dipyridamole: 0.142 μg/kg/min over 4 min
3. Regadenoson: 0.4 mg single injection
4. Adenosine triphosphate (ATP) – 140 μg /kg/min for 3–5 min (consider an increase up to 210 μg/kg body weight/min depending on institutional and local norms if, after 2–3 min, HR does not increase by 10 bpm and or blood pressure does not drop by > 10 mmHg)

Inotropic stress agents:

1. Dobutamine: typical maximum dose 40μg/kg/min ± atropine: 0.25 mg fractions typical (maximal dose 2 mg) (ischemia) or 2.5–10 μg/kg/min dobutamine (viability)

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

PERFUSION

- Saturation-recovery imaging with bSSFP, gradient echo (GRE), or GRE-echo planar (GRE-EPI) hybrid readout
- Short-axis view imaging (at least 3 slices per heart beat)
- Contrast medium (0.05–0.1 mmol/kg, 3–7 ml/s) followed by at least 30 ml saline flush (3–7 ml/sec)
- Breathhold starts before contrast reaches the LV cavity.
- Acquire sufficient number of images to ensure contrast has passed through the LV myocardium (typically at least 50–60 heart beats)

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

PERFUSION

Stress (Adenosine/Dipyridamole)

- Option – initial adenosine infusion may be performed with the patient outside the bore of the scanner and move the patient inside for the second half of the infusion.
- First pass perfusion
- During last minute of adenosine, Gd is injected

Rest

- At least 10 min wait for to wash out from stress perfusion imaging. During this period cine imaging can be completed.
- Perfusion imaging repeated without adenosine using same dose of Gd
- Additional Gd may be given as needed for late gadolinium enhancement (total of 0.1– 0.2 mmol/kg)

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

PERFUSION

Stress (Regadenoson)

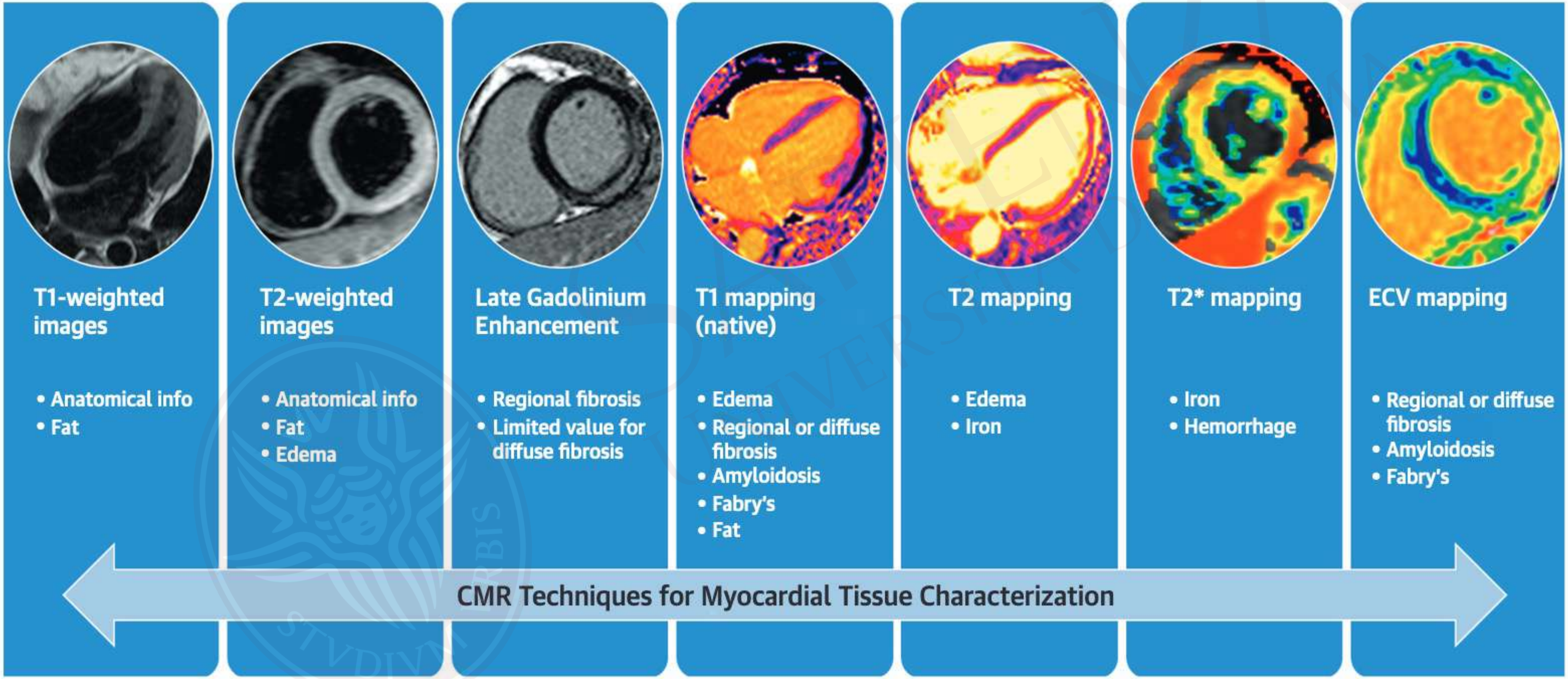
- (Bolus injection of 0.4 mg)
- First pass perfusion
- Approx 45-60 sec after Regadenoson, Gd is injected

Rest

- At least 10 min wait for to wash out from stress perfusion imaging. During this period cine imaging can be completed.
- Perfusion imaging repeated without regadenoson using same dose of Gd
- Additional Gd may be given as needed for late gadolinium enhancement (total of 0.1– 0.2 mmol/kg)

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

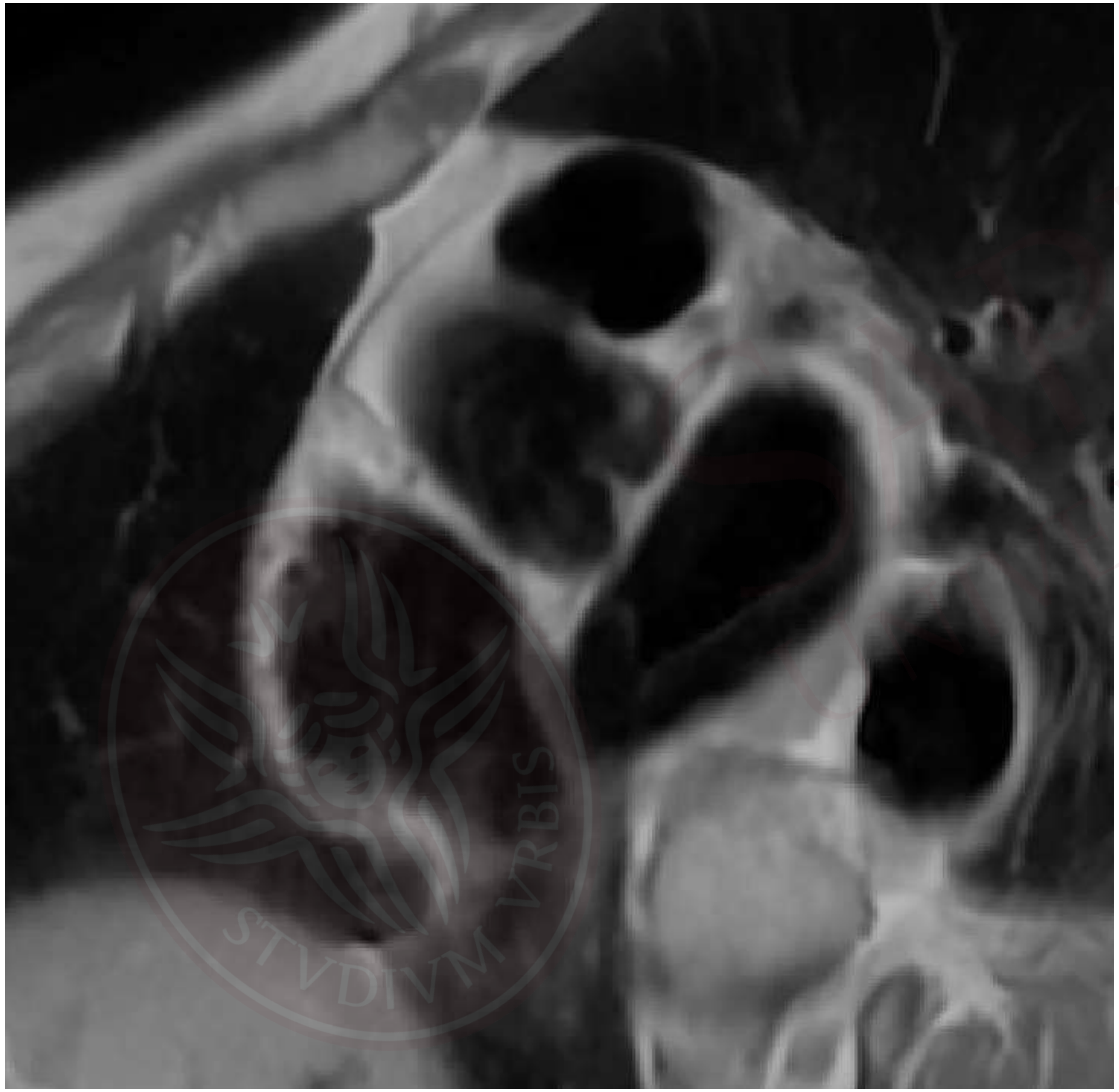
TISSUE CHARACTERIZATION



Karamitsos TD et al. JACC Cardiovasc Imaging. 2020 May;13(5):1221-1234. doi: 10.1016/j.jcmg.2019.06.030

DIR

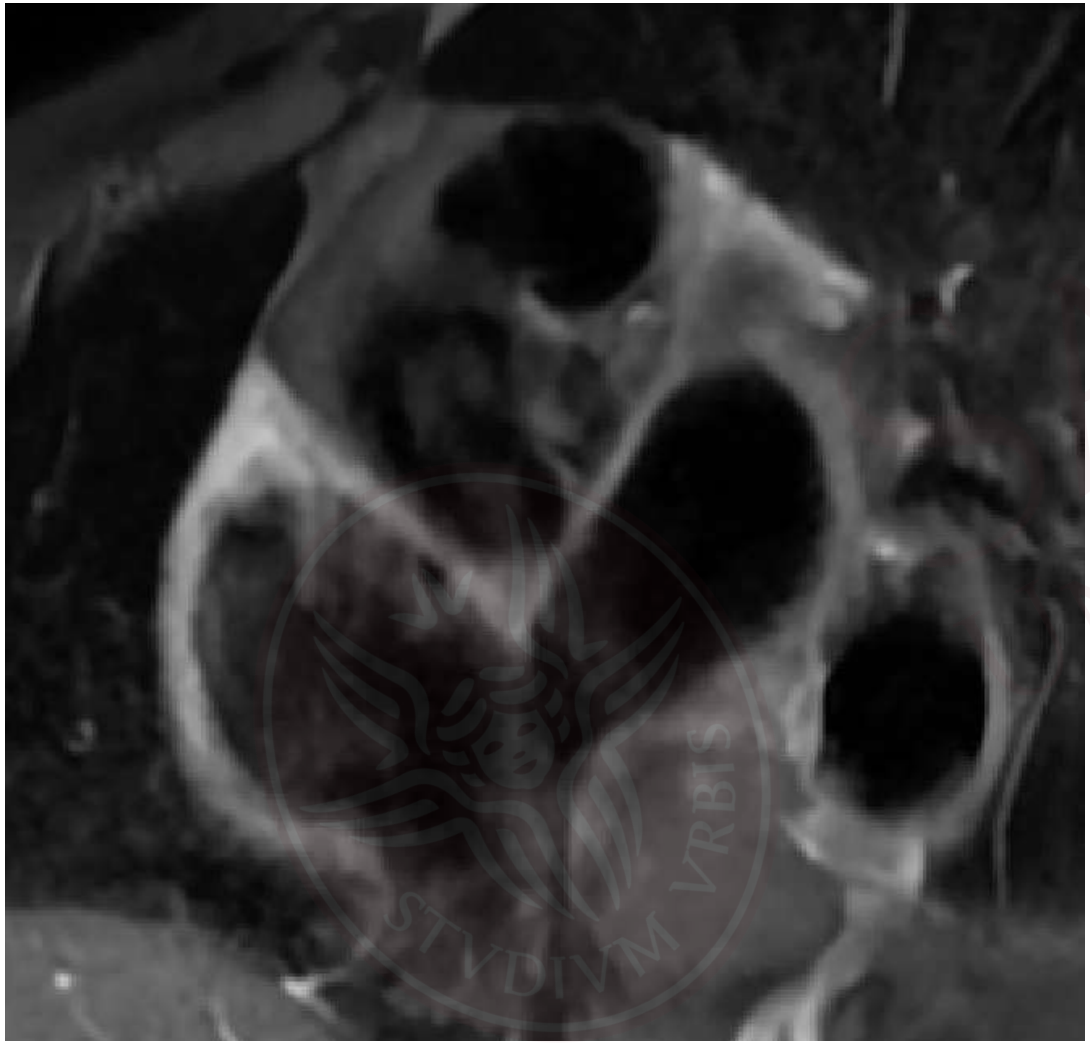
black blood double inversion recovery



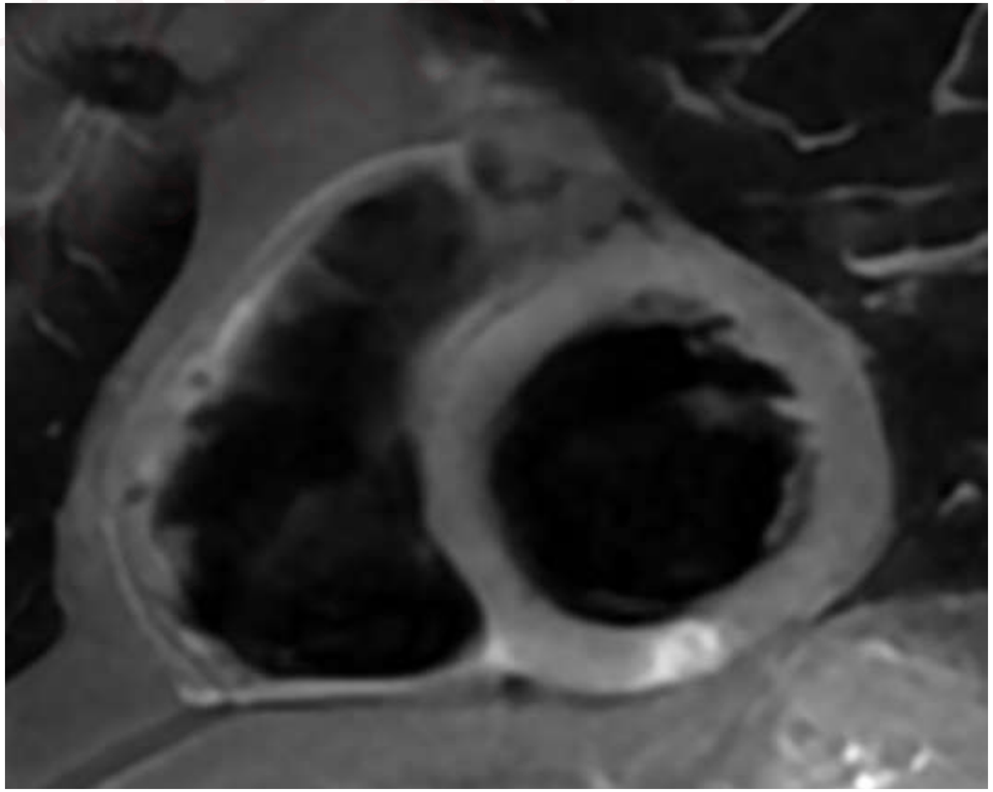
Blood signal nulled

STIR

Identification of myocardial edema



Blood and fat signal nulled



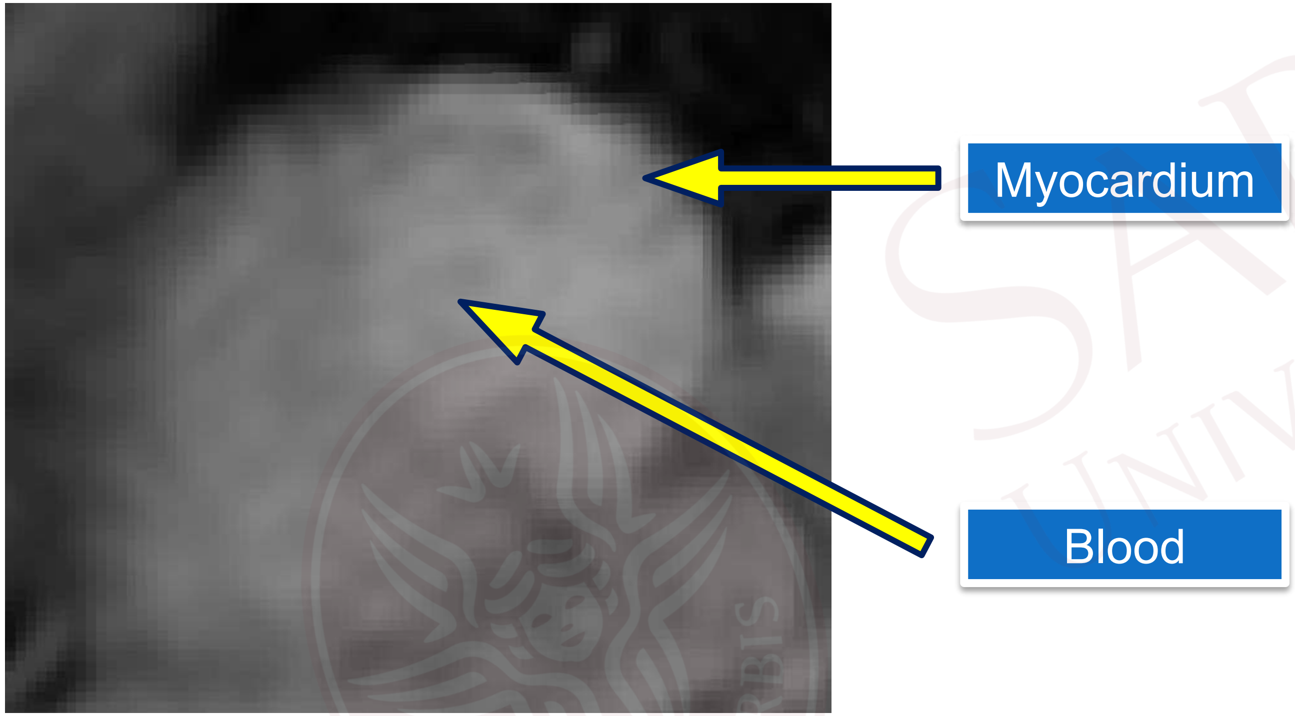
LGE (Late Gadolinium Enhancement)

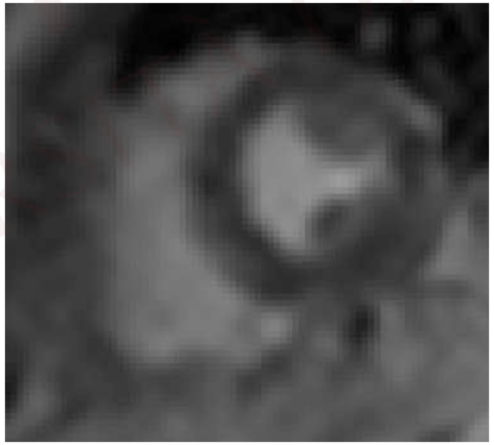
Identification of fibrosis, myocardial infarct, or infiltration

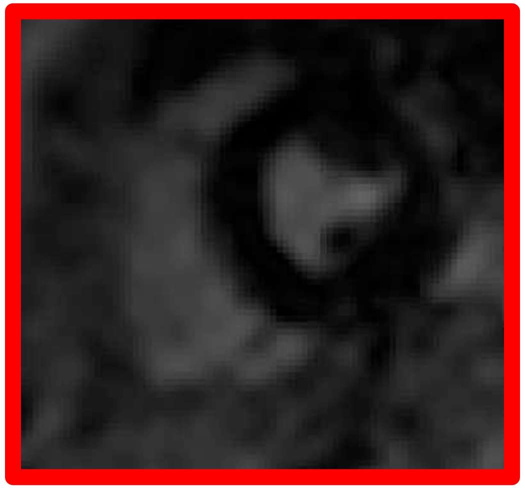
- 2D segmented inversion recovery GRE or bSSFP, Phase-Sensitive Inversion-Recovery (PSIR) sequences acquired about 10–30 min after intravenous administration of Gd.
- The inversion time is chosen to null myocardial signal using "inversion time scout" or "Look-Locker" sequences.
- Gd is an extracellular agent, which enhances in certain conditions such as necrotic or fibrotic myocardium.

TI SCOUT

Identification optimal inversion time for LGE







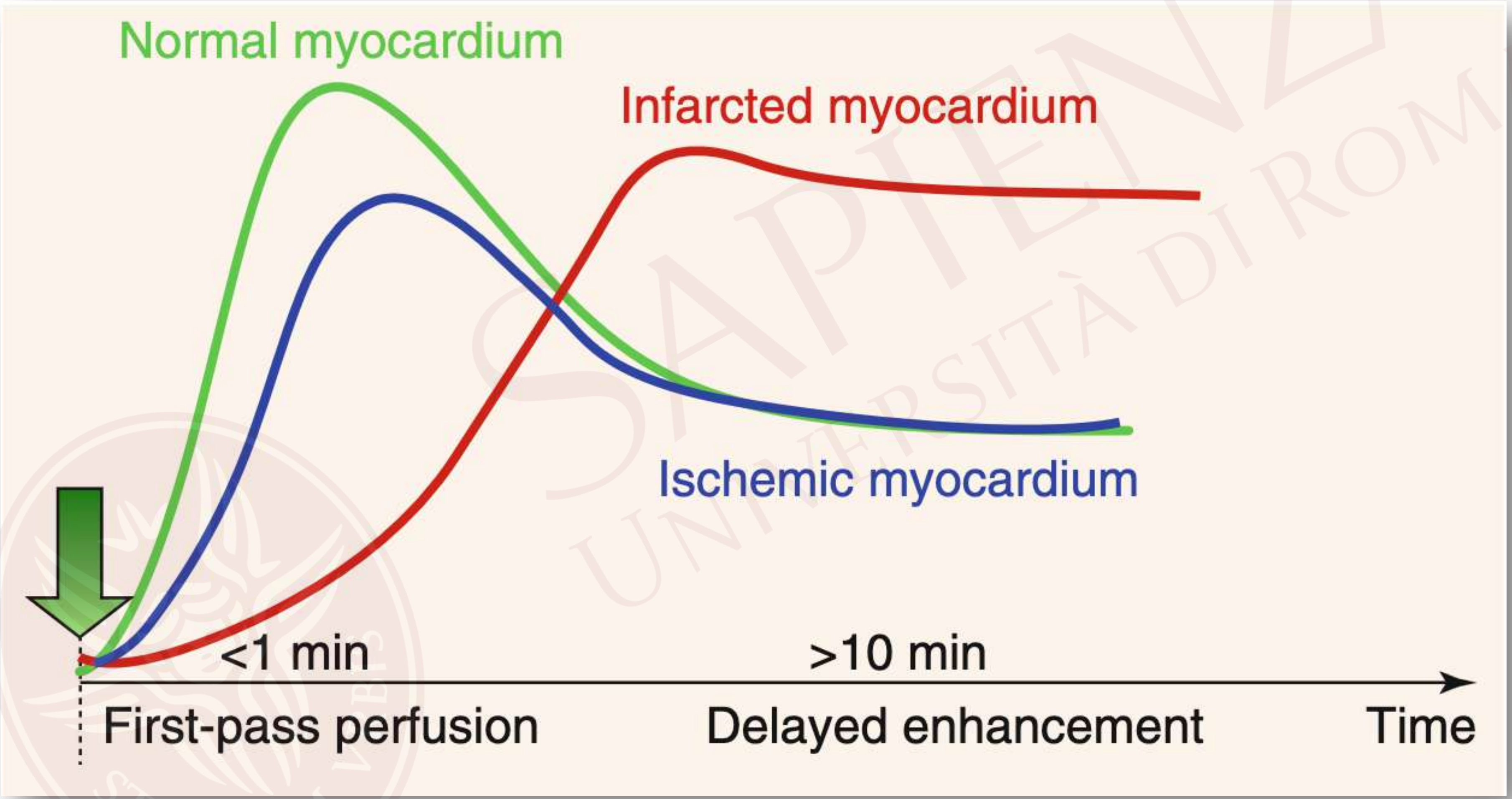
LGE (Late Gadolinium Enhancement)

- At least 10 min wait after GBCA injection.
  - Acquisition in diastolic standstill.
  - 5-minute wait after 2nd CM injection if performing stress and rest perfusion.

- Same views and slice thickness of cine imaging

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

Gadolinium Uptake and Wash-out



Kim, JA et al. (2015). Acute Myocardial Infarction. In: Lim, TH. (eds) Practical Textbook of Cardiac CT and MRI. Springer, Berlin, Heidelberg. 10.1007/978-3-642-36397-9_11

LGE POST-PROCESSING

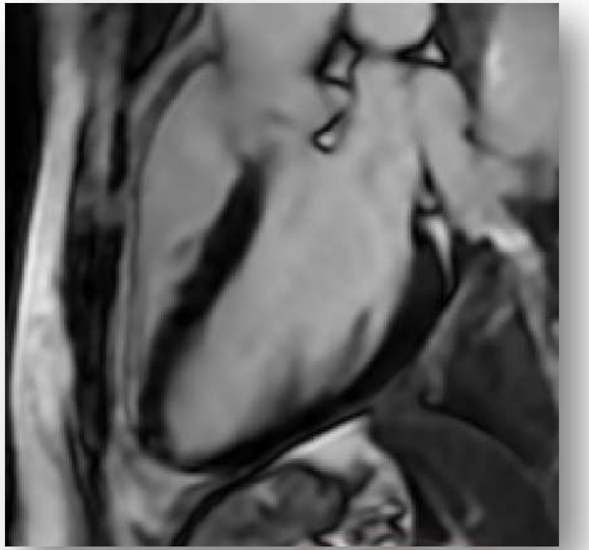
Visual Assessment

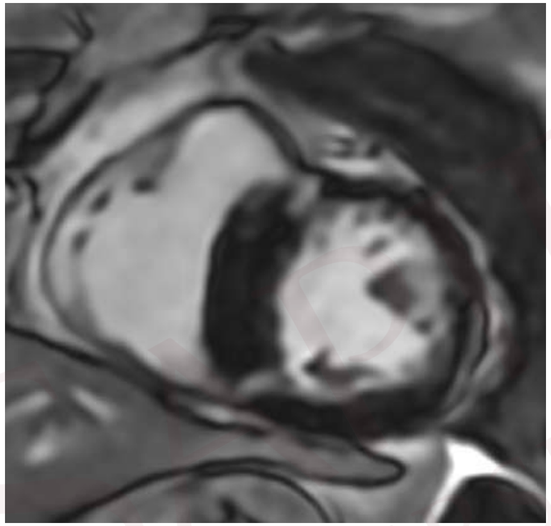
- W/L setting: noise should be detectable, LGE should not be saturated.
- LGE present if
  - Area of high signal intensity brighter than "nulled" myocardium.
  - Verify in at least another orthogonal plane

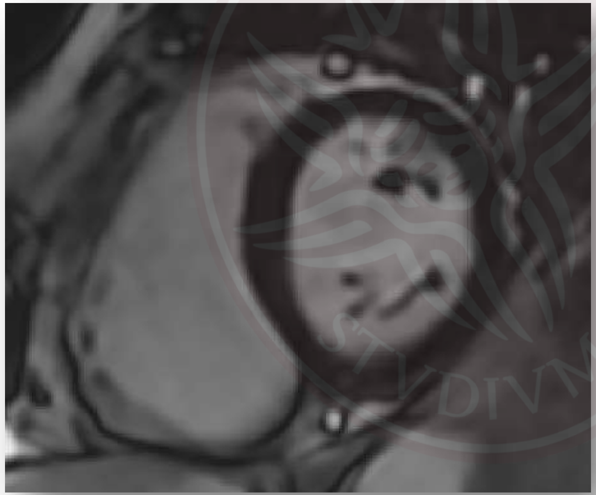
Schulz-Menger J et al. J Cardiovasc Magn Reson. 2020 Mar 12;22(1):19. doi: 10.1186/s12968-020-00610-6

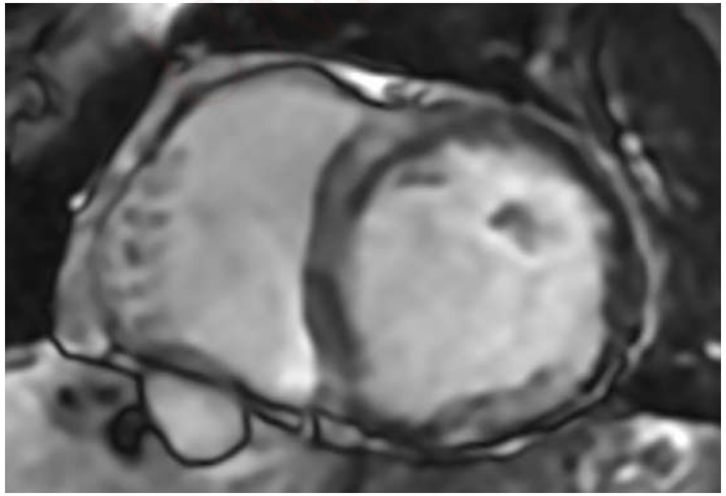
LGE (Late Gadolinium Enhancement)

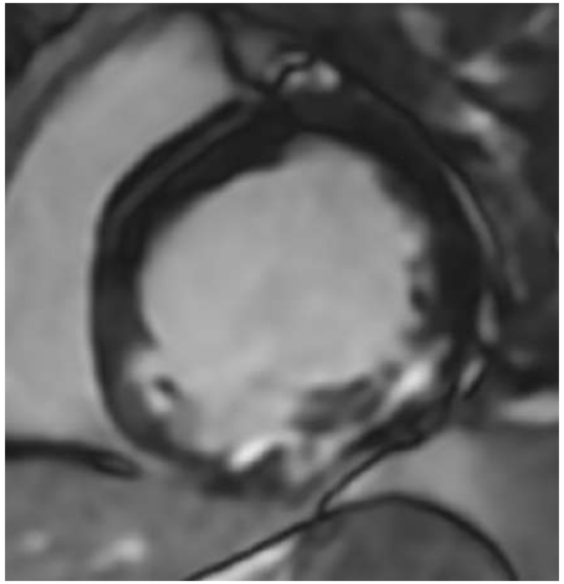
Identification of fibrosis, myocardial infarct, or infiltration







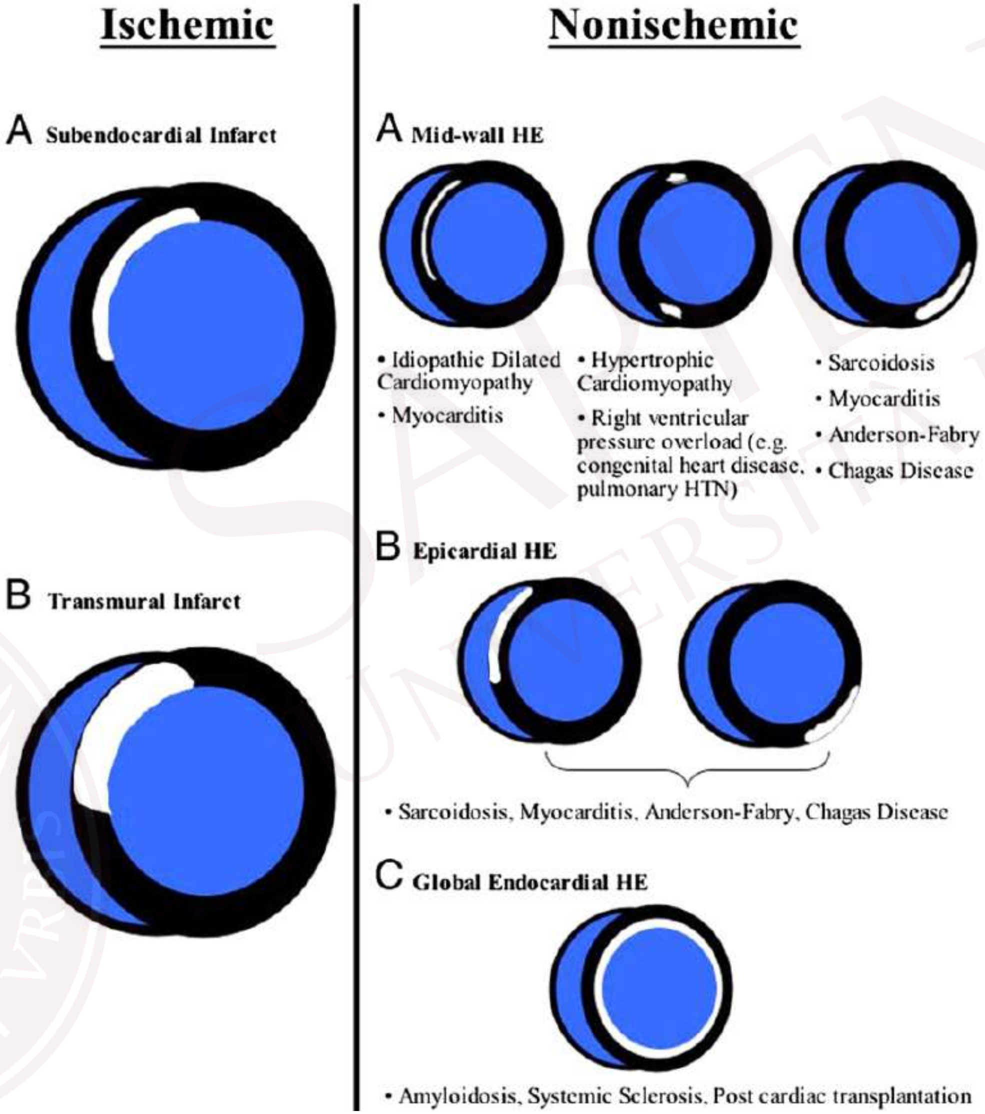




LGE POST-PROCESSING

Visual Assessment

- **Pattern of LGE**



Schulz-Menger J et al. J Cardiovasc Magn Reson. 2020 Mar 12;22(1):19. doi: 10.1186/s12968-020-00610-6

LGE POST-PROCESSING

Visual Assessment

Location of LGE

Transmurality

- 0%
- 1–25%
- 26–50%
- 51–75%
- 76–100%

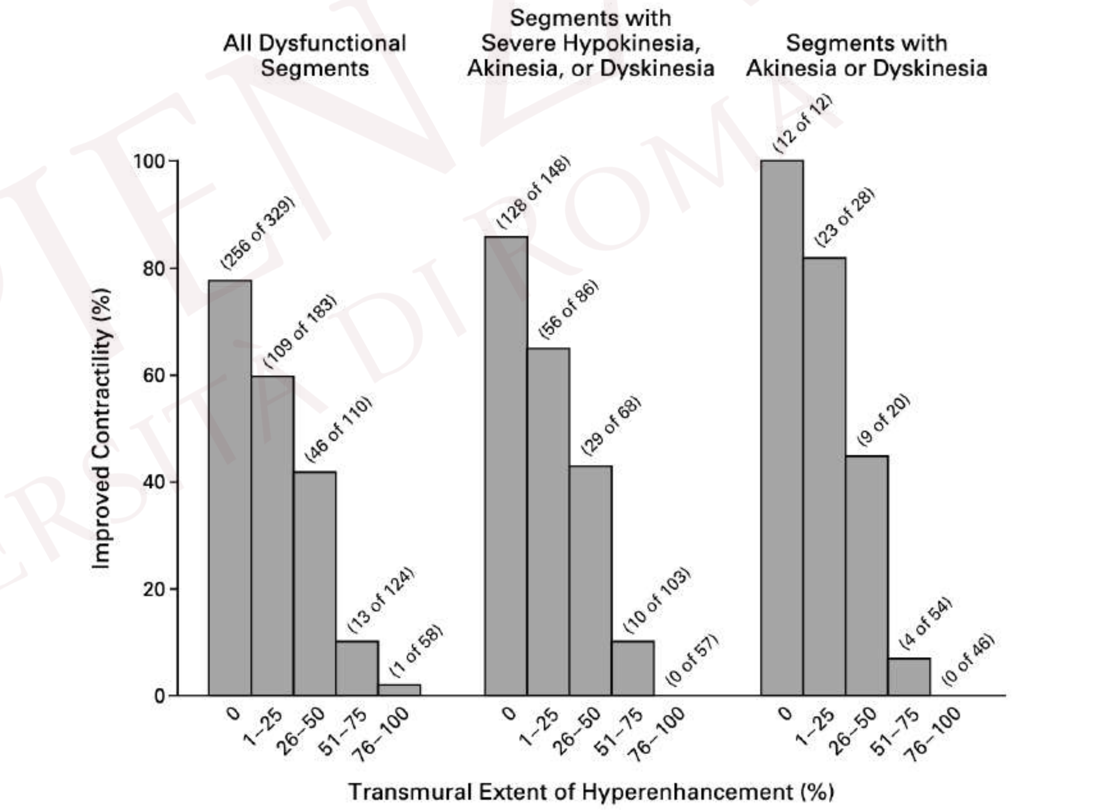


Figure 4. Relation between the Transmural Extent of Hyperenhancement before Revascularization and the Likelihood of Increased Contractility after Revascularization.

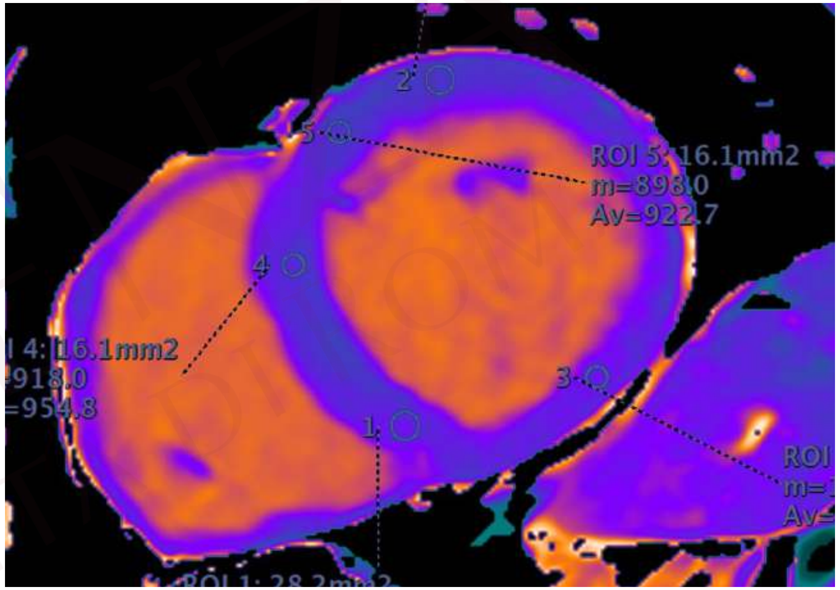
Kim RJ et al. N Engl J Med. 2000 Nov 16;343(20):1445-53. doi: 10.1056/NEJM200011163432003

Kim RJ et al. J Cardiovasc Magn Reson. 2003 Jul;5(3):505-14. doi: 10.1081/jcmr-120022267

Ordovas KG et al. Radiology. 2011 Nov;261(2):358-74. doi: 10.1148/radiol.11091882

T1 MAPPING

- T1 mapping measures the longitudinal or spin-lattice relaxation time, which is determined by how rapidly protons re-equilibrate their spins after being excited by a radiofrequency pulse
- Illustrations of absolute T1 relaxation times on a map.
- Native T1 mapping is performed without contrast medium.
- Modified Look Locker Inversion recovery (MOLLI) or shortened MOLLI (ShMOLLI)
- At least one short-axis map should always be obtained.
- For ECV measurements, T1 mapping should be performed prior to contrast and at least 1 time point between 10 and 30 min post contrast bolus
- The hematocrit should be measured, ideally within 24 h of imaging, for the most accurate ECV measurement.



		T1 (native)	ECV	T2	T2*
Infiltration	Iron	+	?	+	++
	Amyloid	++	++	?	–
	Anderson-Fabry	++	–	+	–
Acute myocardial injury	Edema	++	+	++	?
	Necrosis	++	++	+	++
	Hemorrhage	+	?	+	++
Fibrosis	Diffuse/global*	+	++	?	–
	Focal/regional*	+	++	–	–

Haaf P et al. J Cardiovasc Magn Reson. 2016 Nov 30;18(1):89. doi: 10.1186/s12968-016-0308-4
Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

NATIVE T1 MAPPING

- Influenced by the field strength (higher native T1 values at 3T than 1.5 T)
- Influenced by the pulse sequence, cardiac phase and region of measurement
- Each site has to establish its own normal values

Increased Native T1	Decreased Native T1
Edema	↑ Lipid
↑ Interstitial space	↑ Iron

Native T1 values are a composite signal of myocytes and ECV with the potential of pseudo-normalization of abnormal values (e.g. low native T1 values of Fabry disease cancelled out by infero-lateral fibrosis)

Haaf P et al. J Cardiovasc Magn Reson. 2016 Nov 30;18(1):89. doi: 10.1186/s12968-016-0308-4
Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

POST-Gd T1 MAPPING and ECV

- Post-contrast T1 mapping is used to calculate ECV
- Gd distributes in the extra-cellular space and shortens the T1
- Scar and fibrosis will have shorter T1 after Gd injection

- Hematocrit = cellular fraction of the blood

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

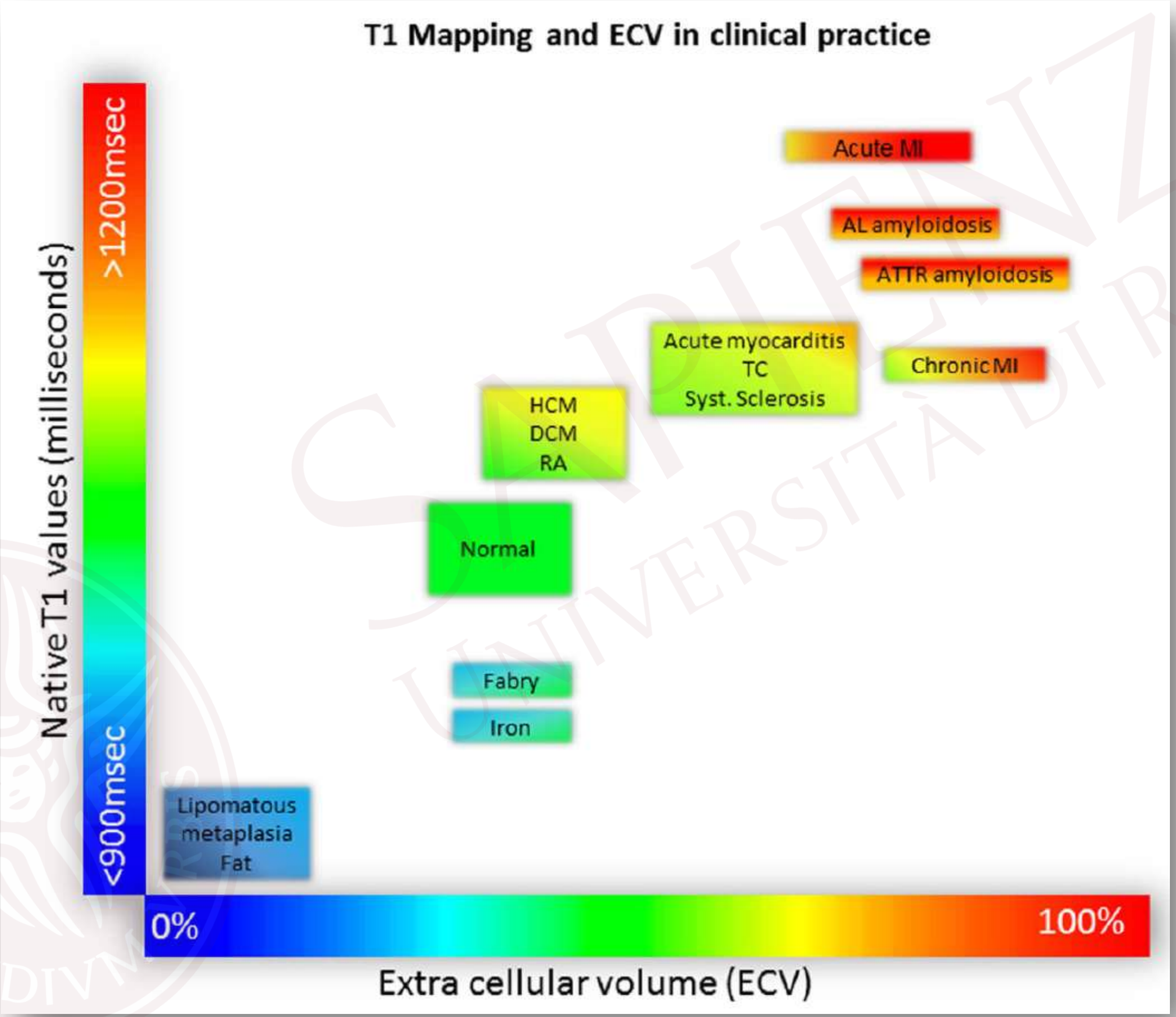
Normal ECV: 25.3% ± 3.5%

Increased ECV	Decreased ECV
Amyloid	Fat/lipomatous metaplasia
Collagen (fibrosis)	Thrombus

ECV is more reproducible than native and post-Gd T1

Haaf P et al. J Cardiovasc Magn Reson. 2016 Nov 30;18(1):89. doi: 10.1186/s12968-016-0308-4
Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

CLINICAL USE OF T1 MAPPING AND ECV

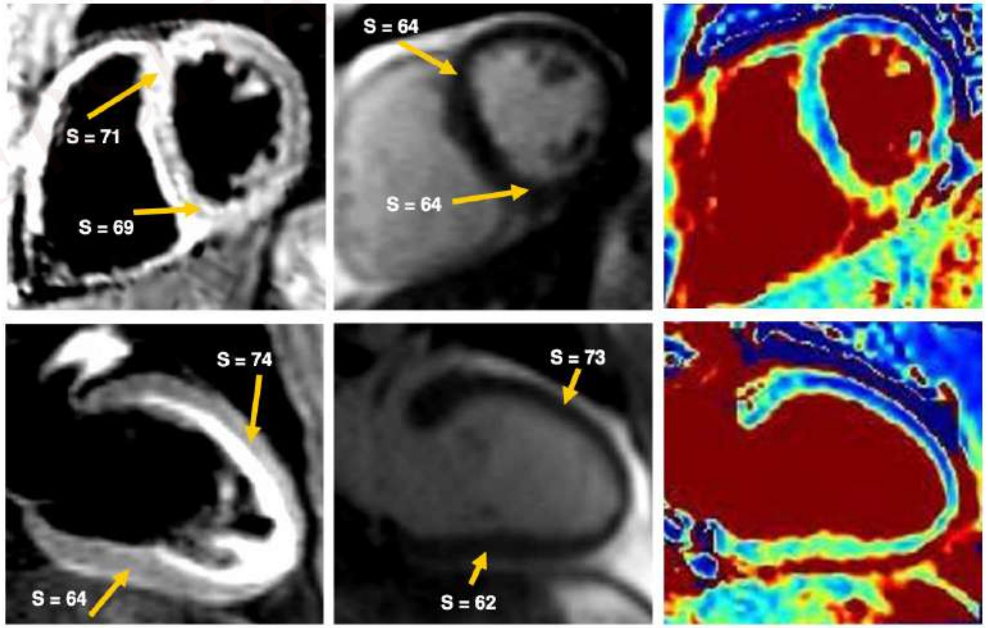


Haaf P et al. J Cardiovasc Magn Reson. 2016 Nov 30;18(1):89. doi: 10.1186/s12968-016-0308-4

T2 MAPPING

- T2-prepared single-shot bSSFP sequences acquired with different T2 prep time, gradient and spin echo (GraSE) or FSE-based pulse sequences.
- The number and orientation of slices obtained will depend upon the indication.
- Short-axis maps should always be obtained.
- Edema = Increased T2

T2 map is more accurate than T2w in evaluating myocardial edema.

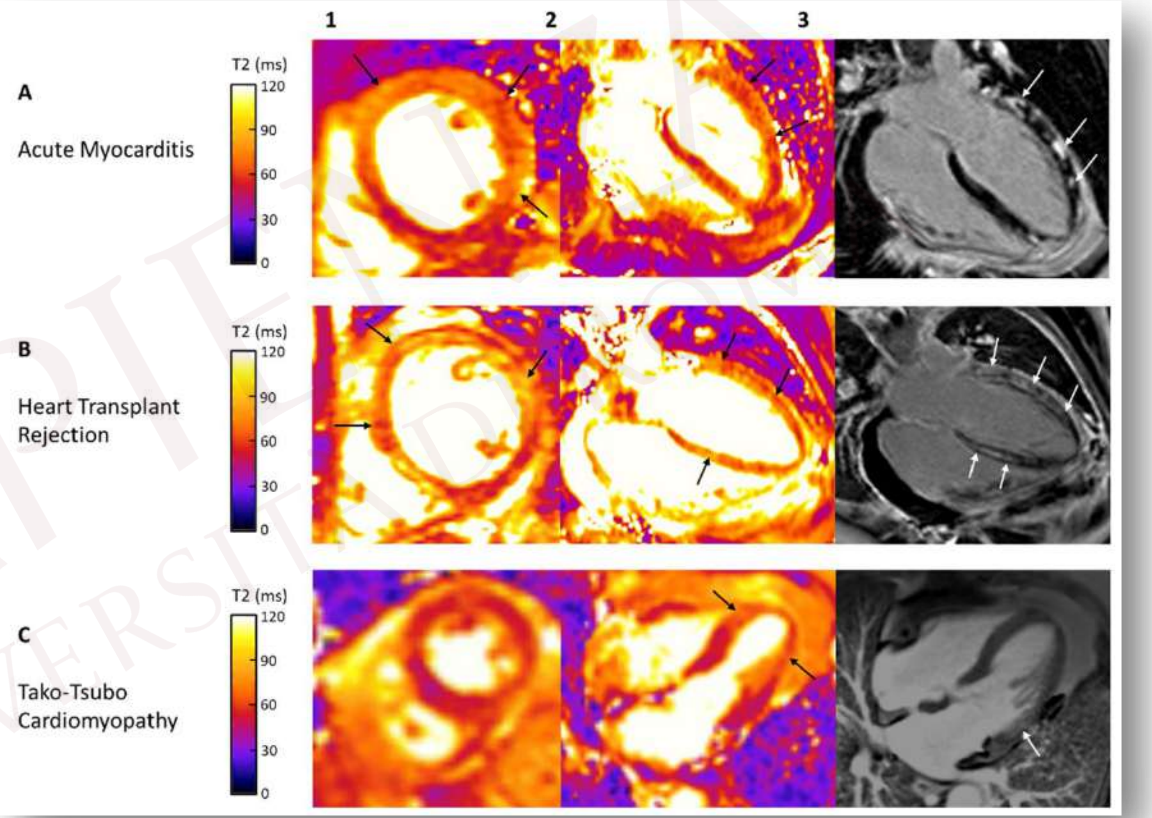


Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1
Giri S et al. J Cardiovasc Magn Reson. 2009 Dec 30;11(1):56. doi: 10.1186/1532-429X-11-56

T2 MAPPING

- Myocardial T2 time may be elevated by changes in myocardial water state, and not only net water content
- Compared to T2w. T2 mapping is less sensitive to motion, improves detection of endocardial borders, and increases objectivity.

Each site has to establish its own normal values



Increased T2	Decreased T2
Edema	Intramyocardial hemorrage
	↑ Iron

O'Brien AT et al.. J Cardiovasc Magn Reson. 2022 Jun 6;24(1):33. doi: 10.1186/s12968-022-00866-0

T2* MAPPING

- T2* images should be obtained prior to contrast administration.
- A single mid-ventricular short-axis image is acquired.
- Slice thickness of 8–10 mm; in-plane resolution, ~ 1.6–3.0 mm
- (Optional) An imaging sequence similar to the above, though non-ECG-gated, is acquired in the axial orientation through the mid portion of the liver to evaluate hepatic iron deposition.

Kramer CM et al. J Cardiovasc Magn Reson. 2020 Feb 24;22(1):17. doi: 10.1186/s12968-020-00607-1

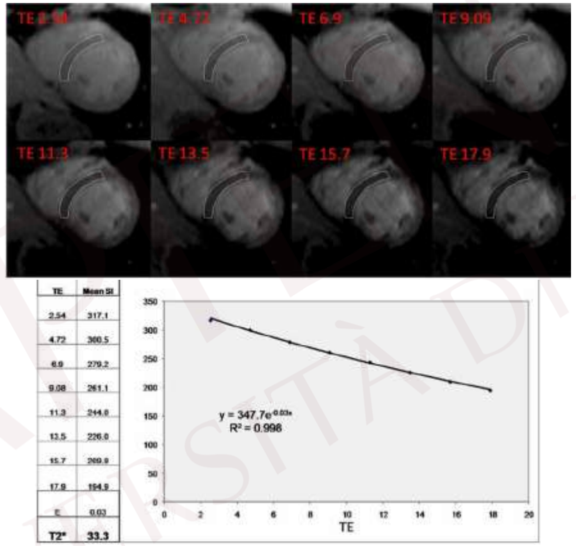
T2* MAPPING POST-PROCESSING

Quantitative Analysis

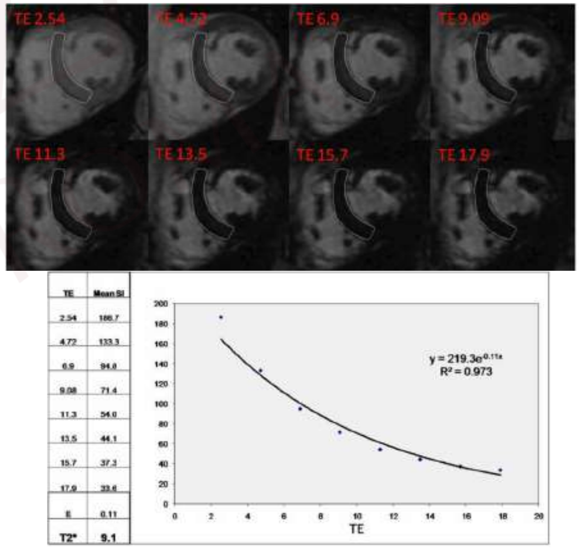
- **Septal ROI**
- **SI of the ROI is plotted against TE**
  - SI decreases when TE increases
  - SI decreases faster with increasing iron burden, resulting in a shorter T2*

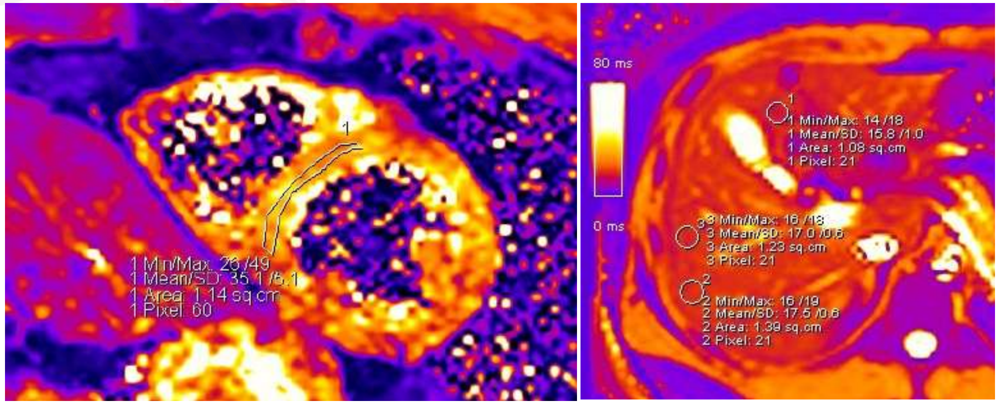
- **Cut-off values at 1.5 T:**
  - Normal cardiac T2*: **40 ms**
  - T2* **< 20 ms:** cardiac iron overload
  - T2* **< 10 ms:** ↑ risk of heart failure

Normal



Iron Overload

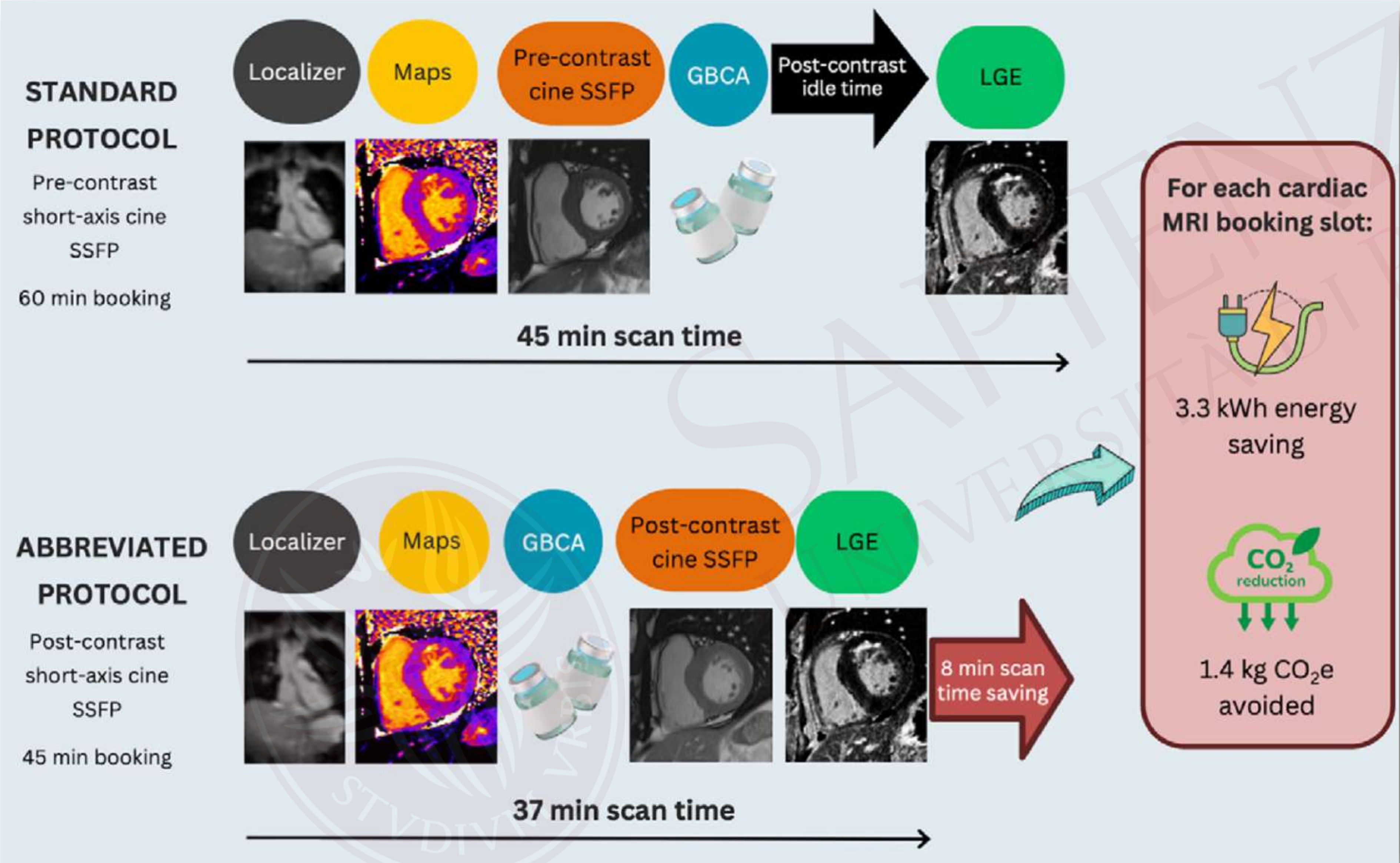




Case Courtesy of Dr. Luca Arcari, MD

Schulz-Menger J et al. J Cardiovasc Magn Reson. 2020 Mar 12;22(1):19. doi: 10.1186/s12968-020-00610-6

IMAGE PROTOCOL



Ibrahim F et al. Radiology. 2024 Apr;311(1):e240588. doi: 10.1148/radiol.240588

SISTEMA SANITARIO REGIONALE
AZIENDA OSPEDALIERO-UNIVERSITARIA SANT'ANDREA

SAPIENZA UNIVERSITÀ DI ROMA

Cardio-TC/RM WEBINAR FAD

Dal 16 maggio 2024 all'11 Luglio 2024

PROGRAMMA

16 Maggio – ore 17.00/18.00
Introduzione al Corso (A. Laghi)
Saluti Direzione Generale AOUSA (D. Donetti)
Tecnica di acquisizione della Cardio TC/Utilizzo del Mdc e Triple-rule-out (D. Caruso)

23 Maggio – ore 17.00/18.00
Anatomia coronarica (L. Pugliese)

30 Maggio – ore 17.00/18.00
Caratteristiche di placca: calcifica, non calcifica, vulnerabile (D. De Santis)

6 Giugno – ore 17.00/18.00
La definizione della stenosi secondo CAD-RADS v.2 (D. De Santis)

13 Giugno – ore 17.00/18.00
Indicazione alla Cardio RM, protocollo di acquisizione e sequenze principali (D. De Santis)

27 Giugno – ore 17.00/18.00
Patologia infiammatoria (miocarditi, pericarditi) (D. De Santis)

4 Luglio – ore 17.00/18.00
Cardiopatia ischemica (L. Pugliese)

11 Luglio – ore 17.00/18.00
Cardiomiopatie (ipertrofica, dilatativa, aritmogena) e patologie da Accumulo (L. Pugliese)

Il Corso Webinar CardioTC e CardioRM del Sant'Andrea 2024 è un corso di Cardio TC (Tomografia Computerizzata) e Cardio RM (Risonanza Magnetica) progettato per fornire ai discenti una comprensione approfondita delle due principali tecniche di imaging cardiaco utilizzate nella pratica clinica moderna.
Questo corso mira a fornire una panoramica completa dei principi di base, delle applicazioni cliniche e delle sfide associate all'uso della TC e della RM nel contesto della valutazione cardiaca. Il corso inizia con una discussione delle tecniche di acquisizione della Cardio TC, compreso l'uso dei mezzi di contrasto e i protocolli come il "Triple-rule- out". I discenti impareranno a interpretare le immagini TC per valutare l'anatomia coronarica, identificare caratteristiche delle placche aterosclerotiche e definire stenosi coronariche secondo il sistema CAD-RADS.
Successivamente, il focus si sposta sulla Cardio RM, esplorando le indicazioni per questo tipo di imaging, i protocolli di acquisizione e le sequenze principali utilizzate per valutare la struttura e la funzione cardiaca per diagnosticare patologie cardiache, tra cui infiammazioni miocardiche, cardiomiopatie e malattie da accumulo.

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GE HealthCare

SISTEMA SANITARIO REGIONALE
AZIENDA OSPEDALIERO-UNIVERSITARIA SANT'ANDREA

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