Basic CMR Pulse Sequences to Assess Morphology, Structure and Flow

Debakey CMR Workshop, September 2022

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Disclosures: Guerbet, LLC (Research Support)

Outline

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- Morphology assessment sequences
  - Gradient echo and Spin echo
  - Acceleration methods
- Cine acquisitions and techniques
  - Spoiled gradient echo
  - Steady state free precession
- Flow assessment

Routine sequences in cardiac MRI
Assessment of structure and function

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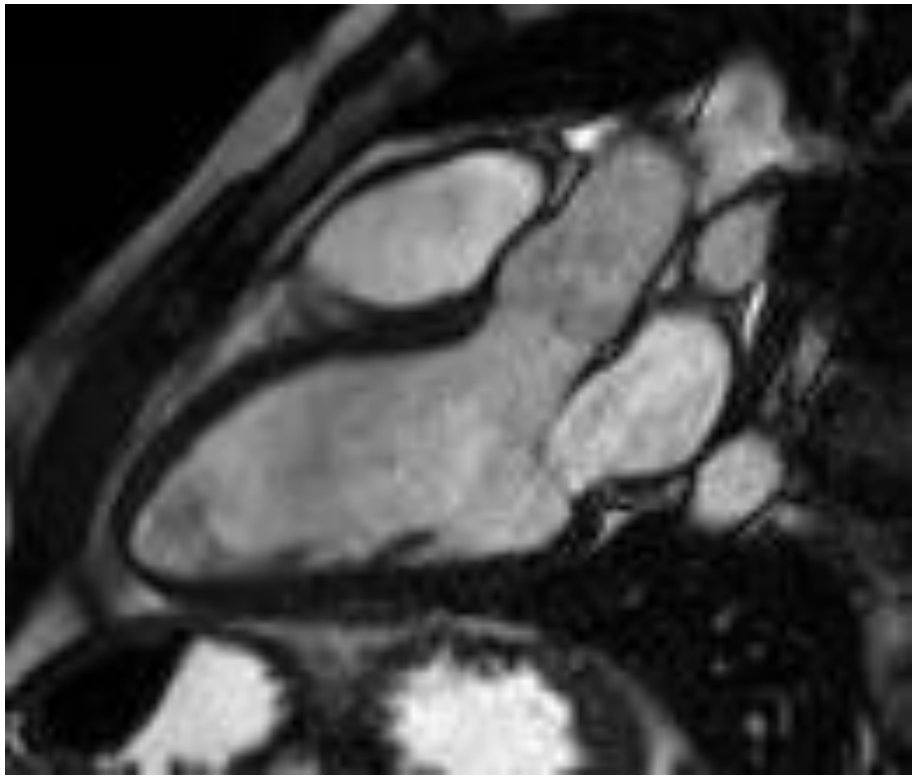

Cine Steady State Free Precession (SSFP) sequences

Routine sequences in cardiac MRI
Assessment of structure and function

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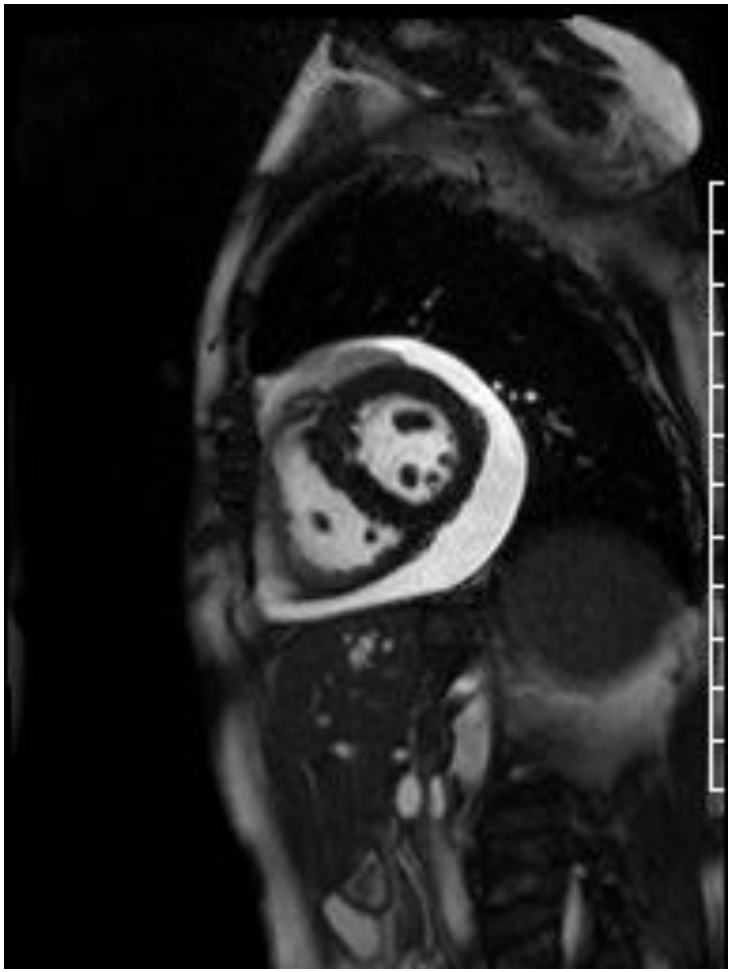
T1 weighted turbo spin echo
With black blood preparation



SSFP cine

Routine sequences in cardiac MRI
Assessment of structure and function

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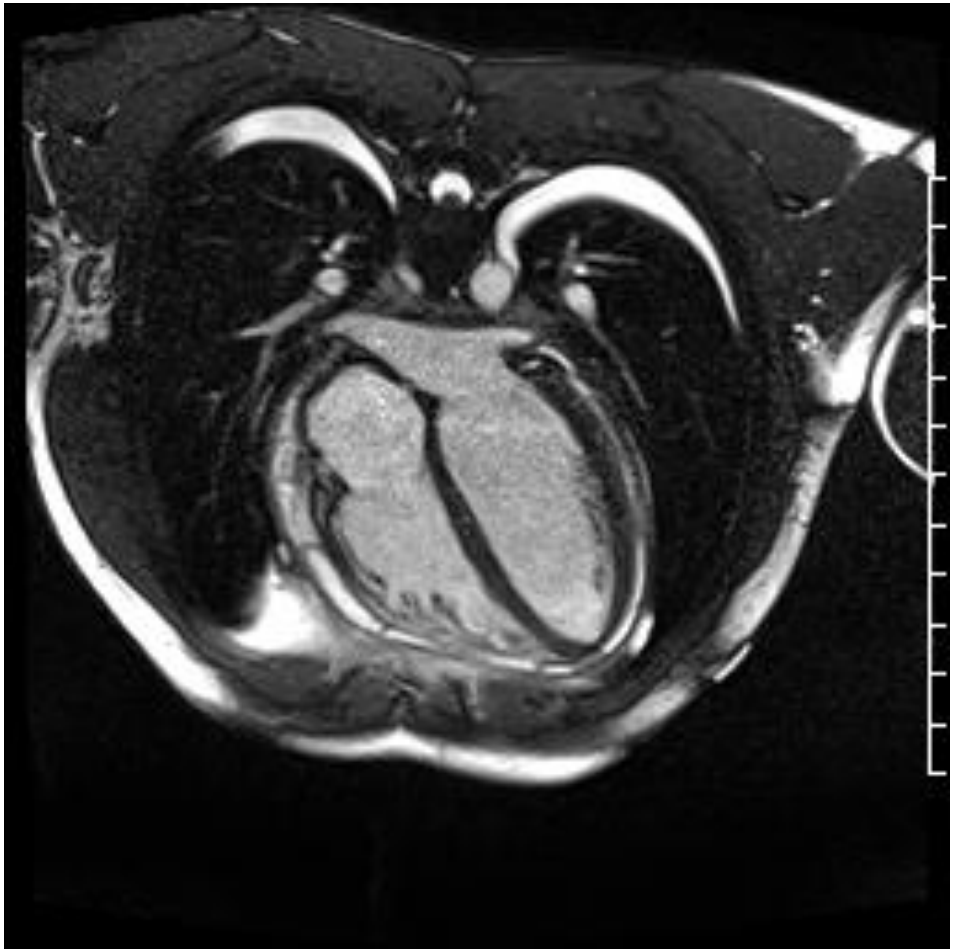
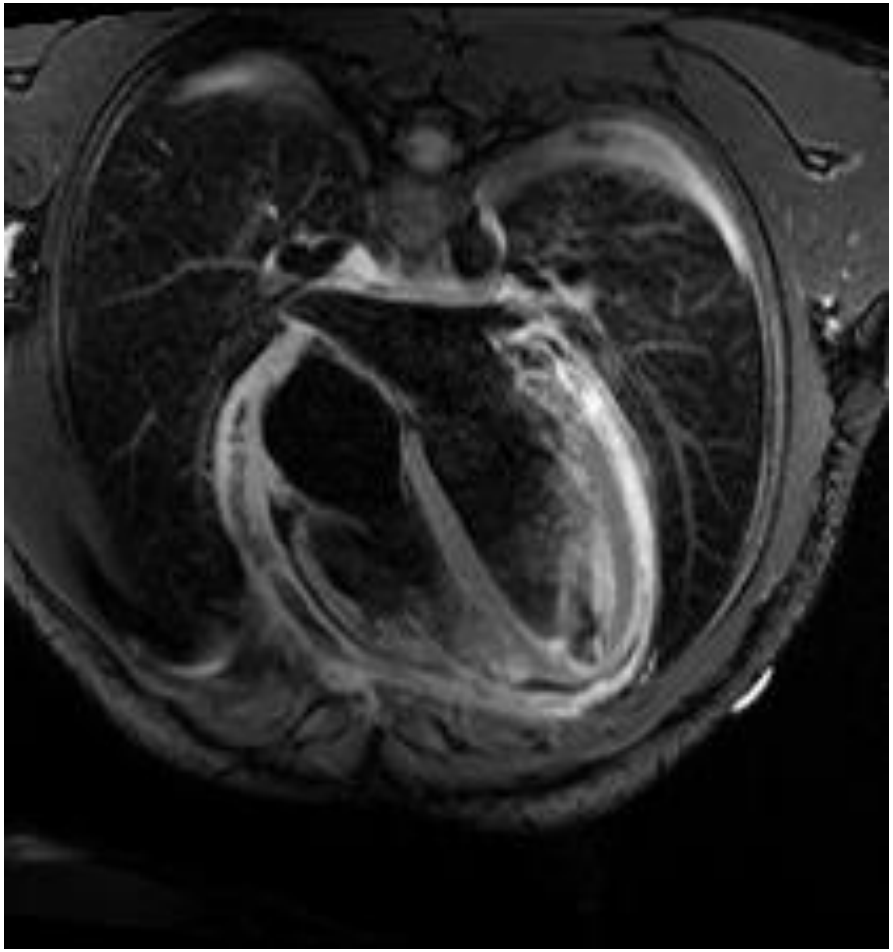


SSFP cine



T2 weighted turbo spin echo
With fat suppression and black blood preparation

Routine sequences in cardiac MRI
Anatomical assessment

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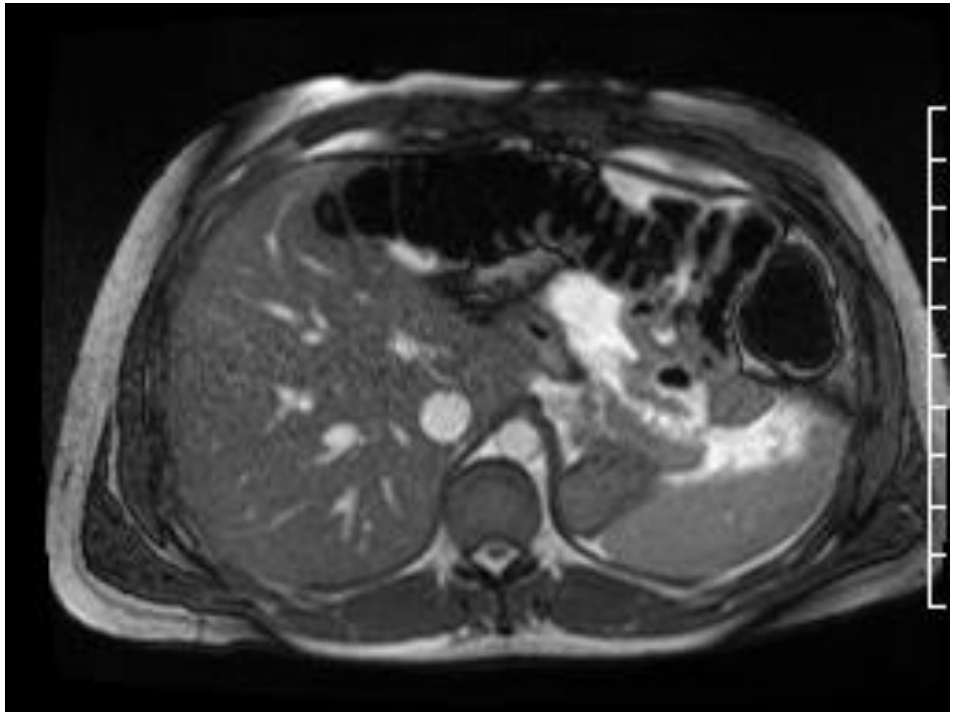
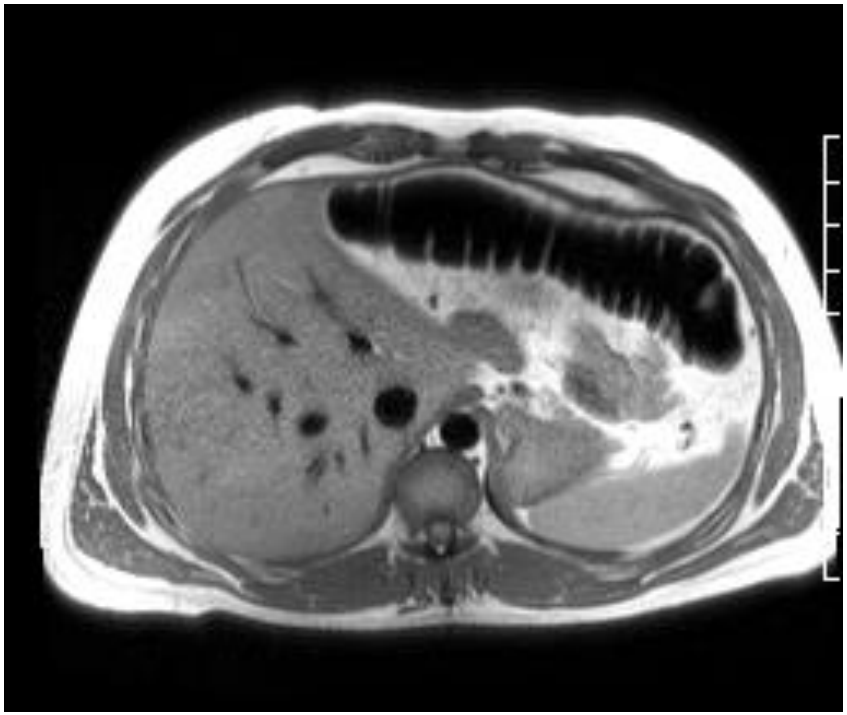


Axial bright blood imaging



Axial black blood imaging

Routine sequences in cardiac MRI

Assessment of flow, velocities, and gradients

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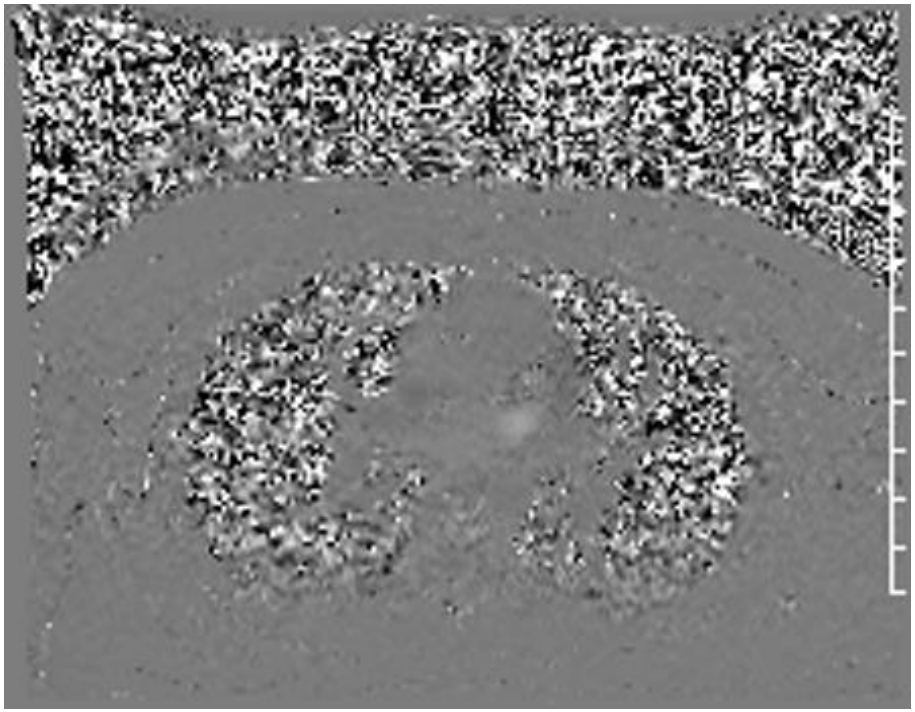

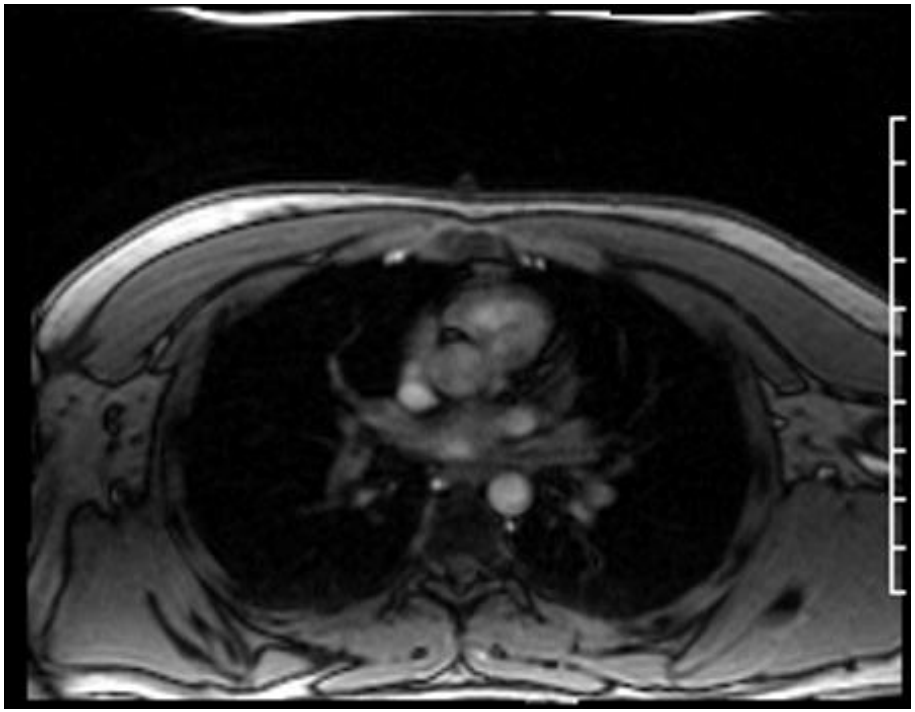

Phase contrast velocity mapping

Introduction

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- These sequences form the majority of a routine CMR exam
- Additional workhorse sequences
  - Magnetic resonance angiography
  - Delayed enhancement (viability etc) imaging
    - Covered in other talks
  - Also, mapping techniques, special sequences for specific conditions

Let's backtrack for a bit

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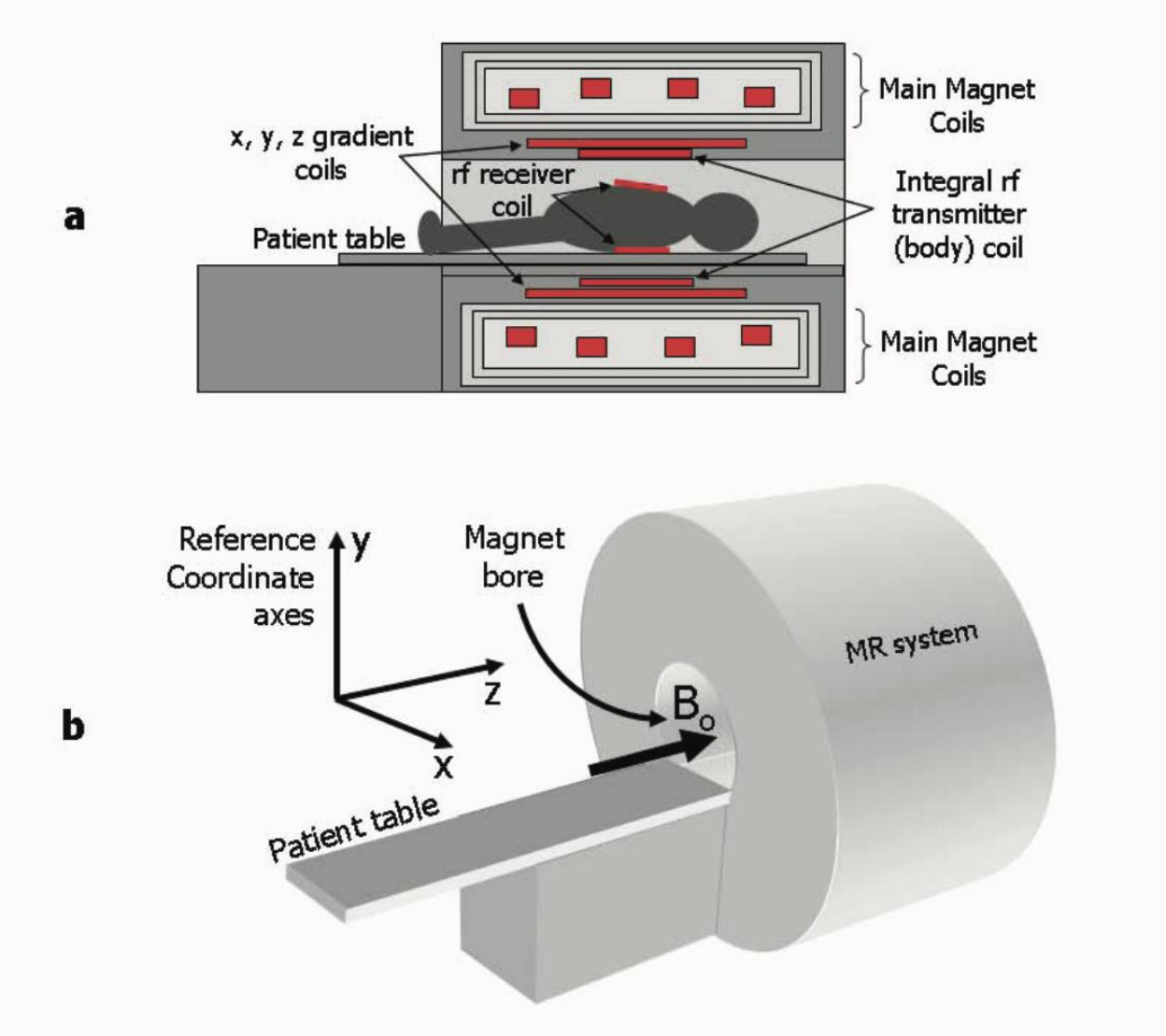

Preturbations

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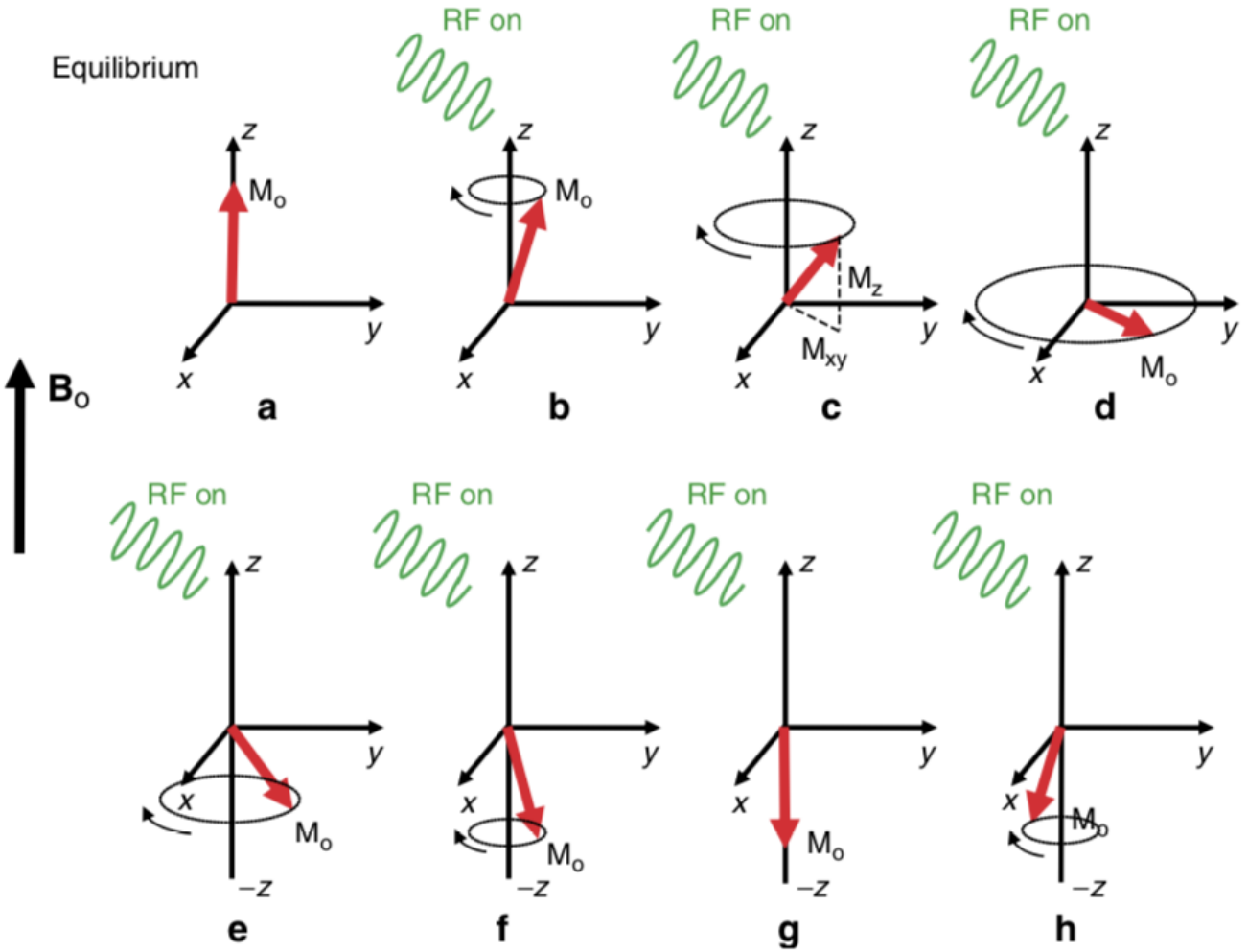

Flip Angle Types

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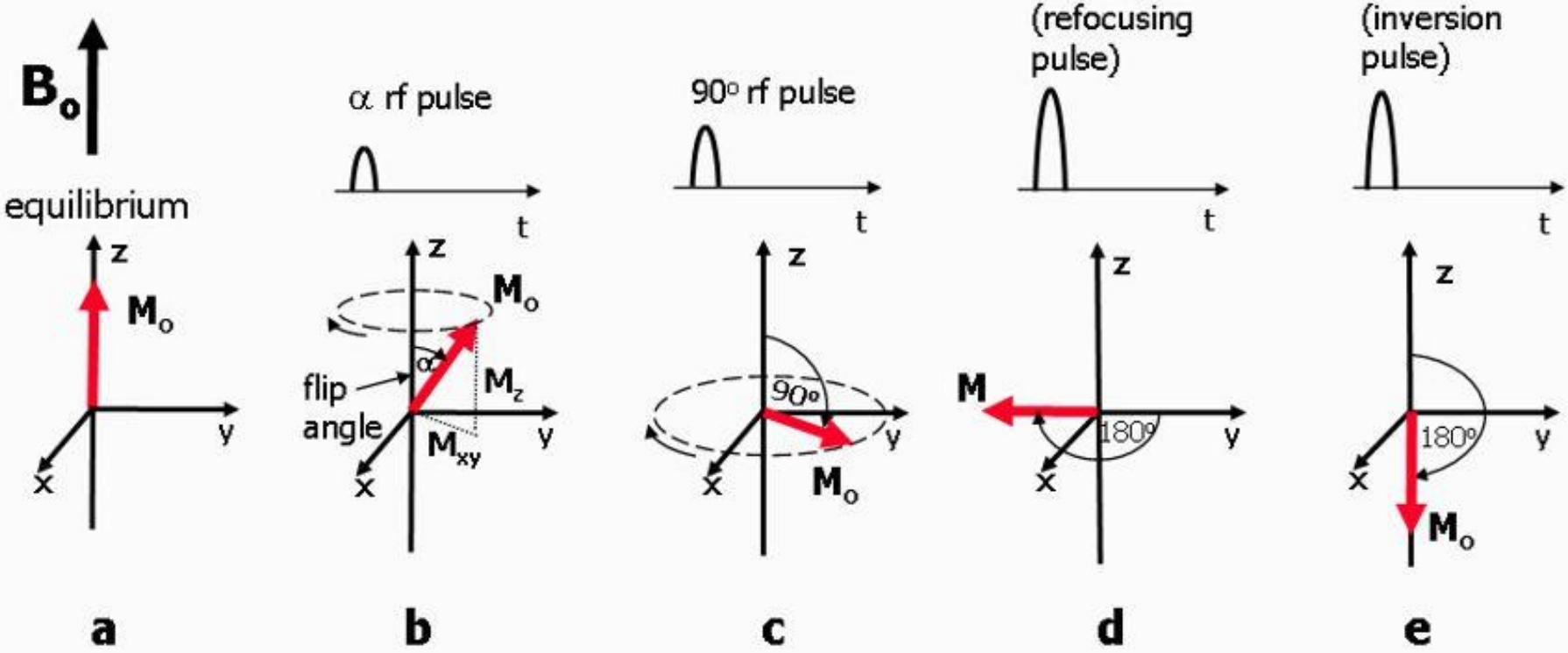

90 Degree RF pulse

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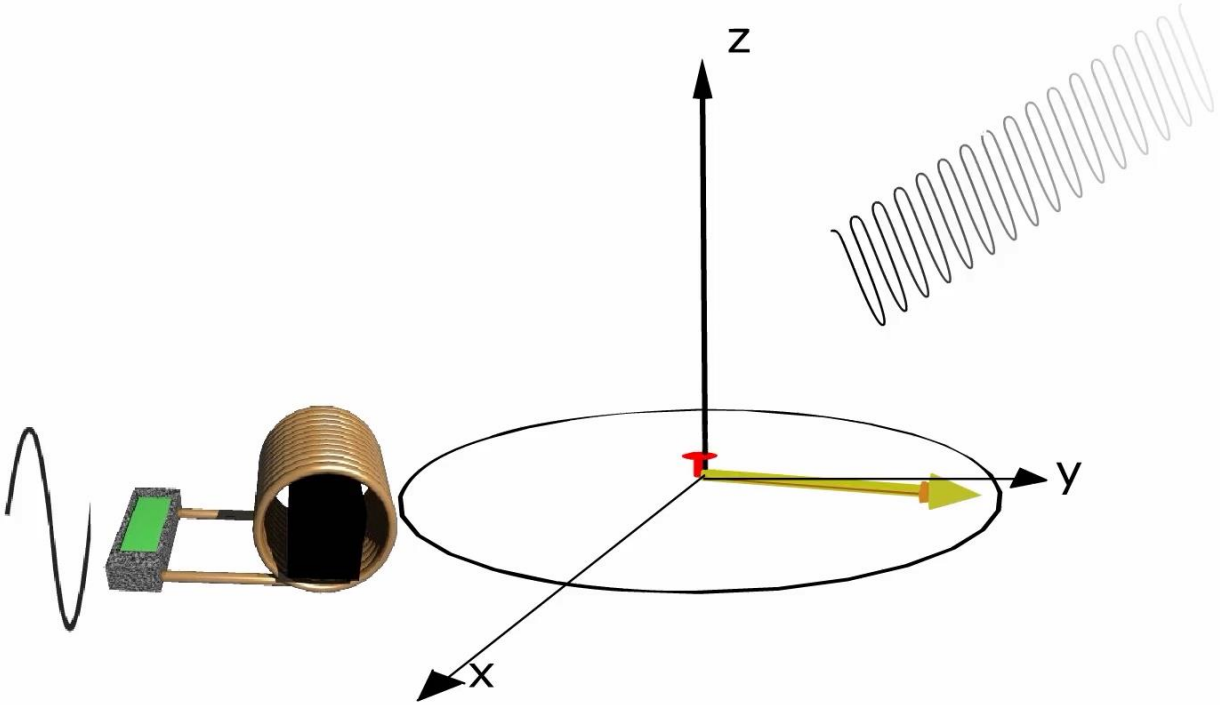

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90 degree RF pulse…

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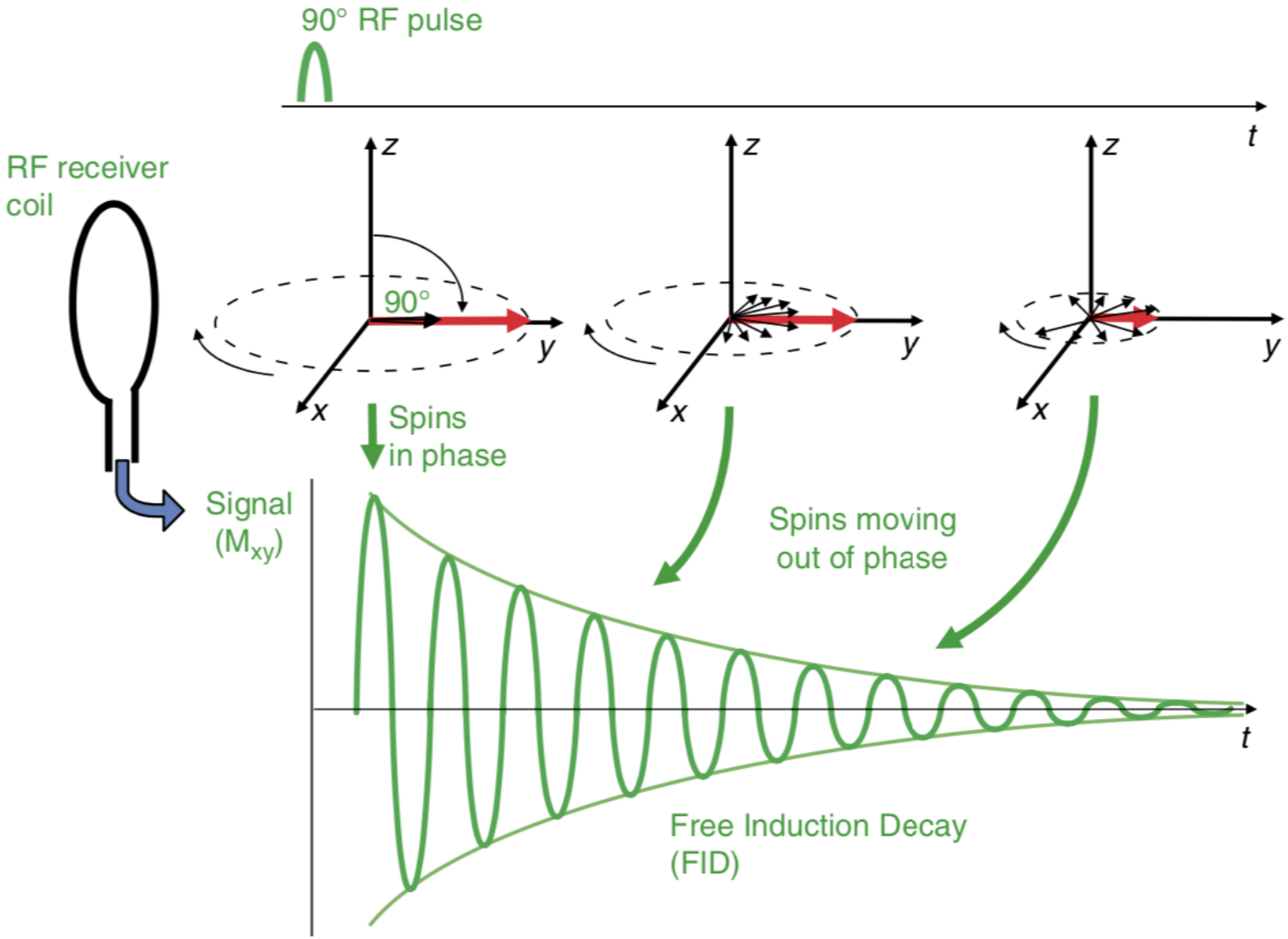

However,….

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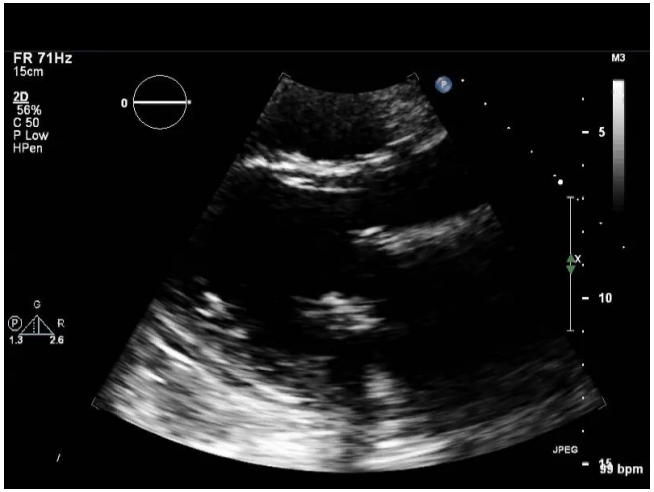
The magnetic field gradients used to localize and encode the MR signals in space cause additional de-phasing which disrupts the FID

so…

We use Echoes to generate images!



Gradient Echo

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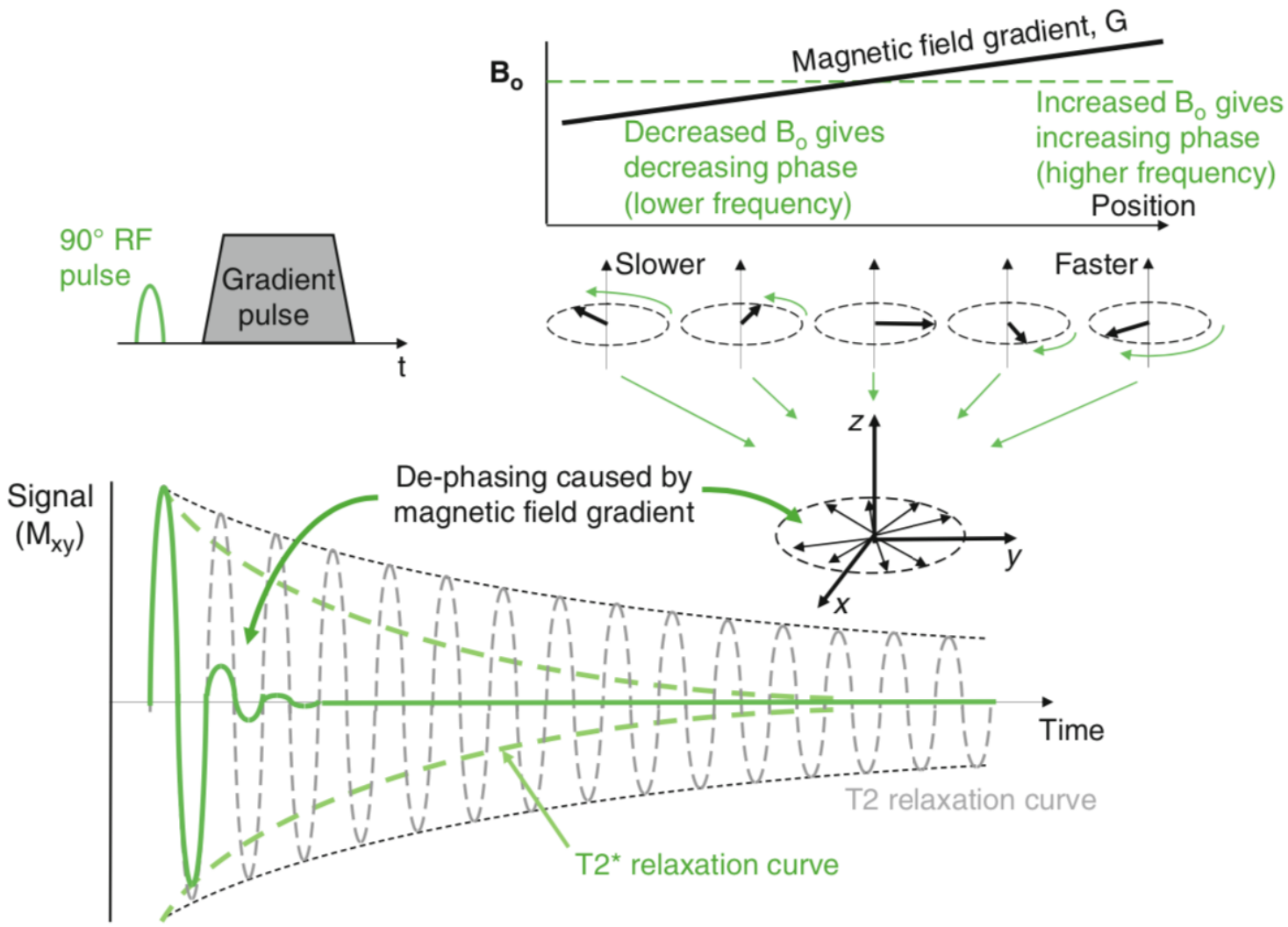

Gradient Echo

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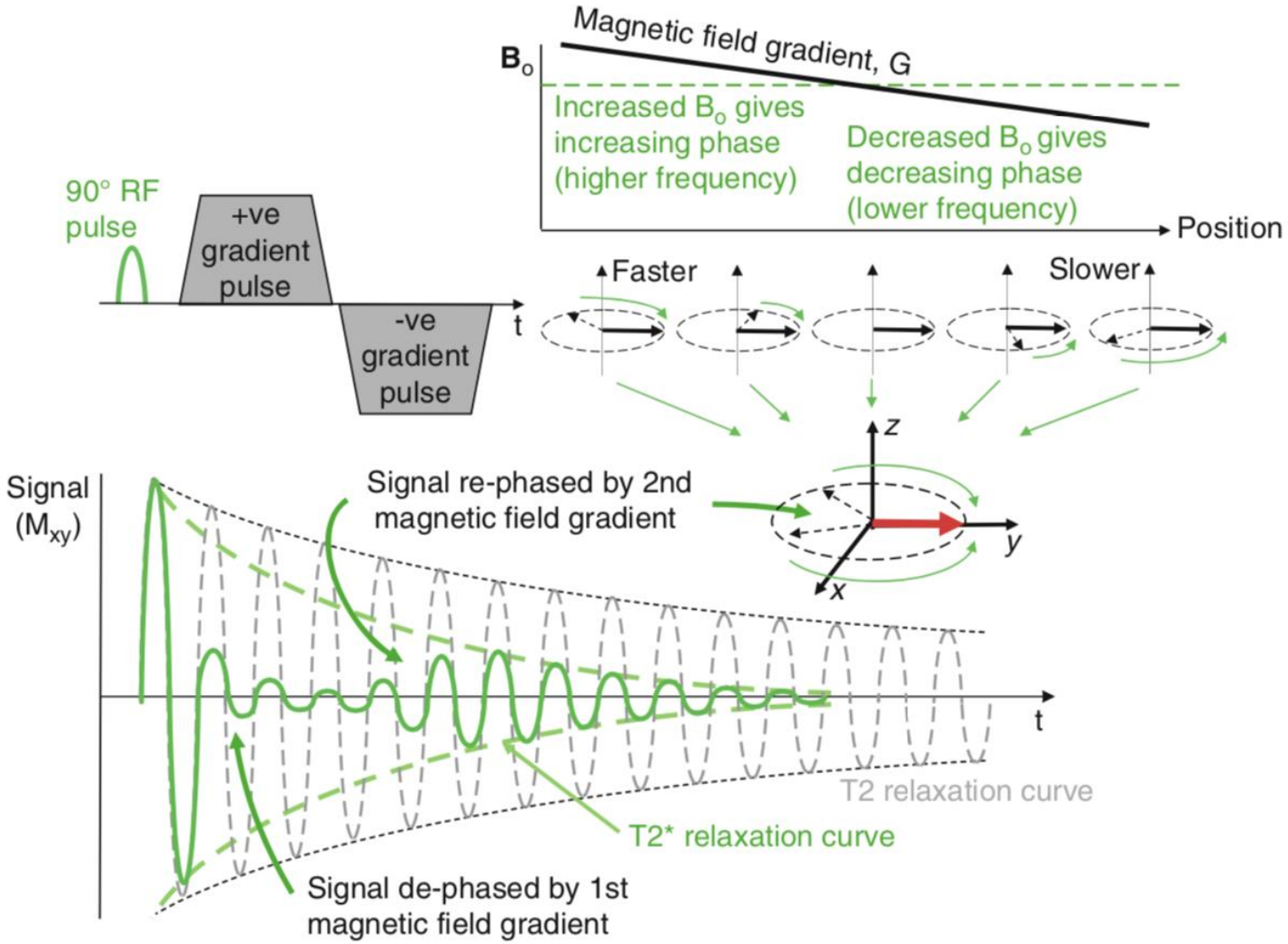

Gradient Echo

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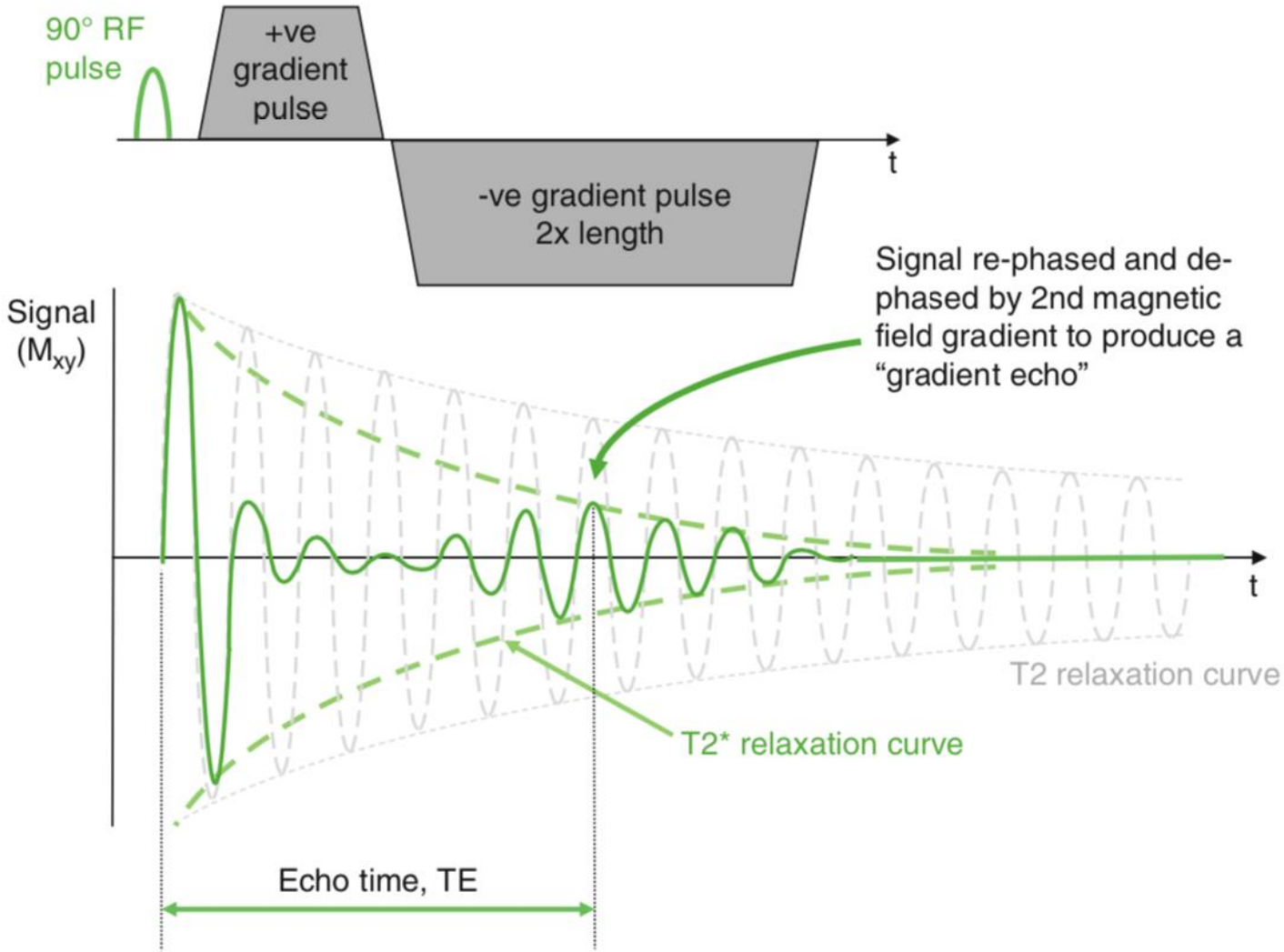

Spin Echo

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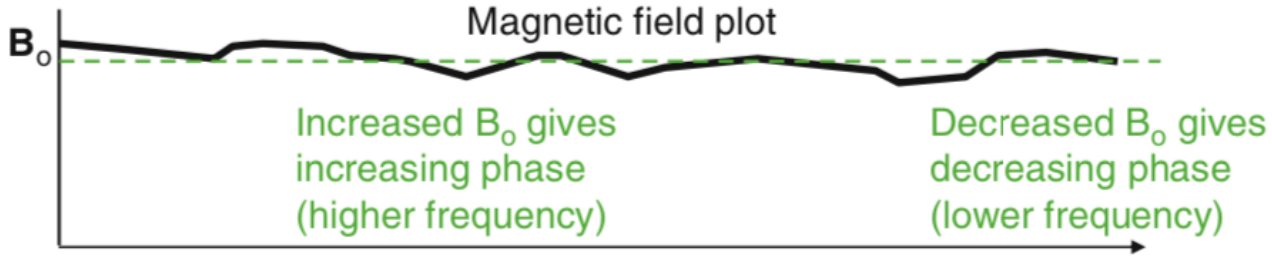
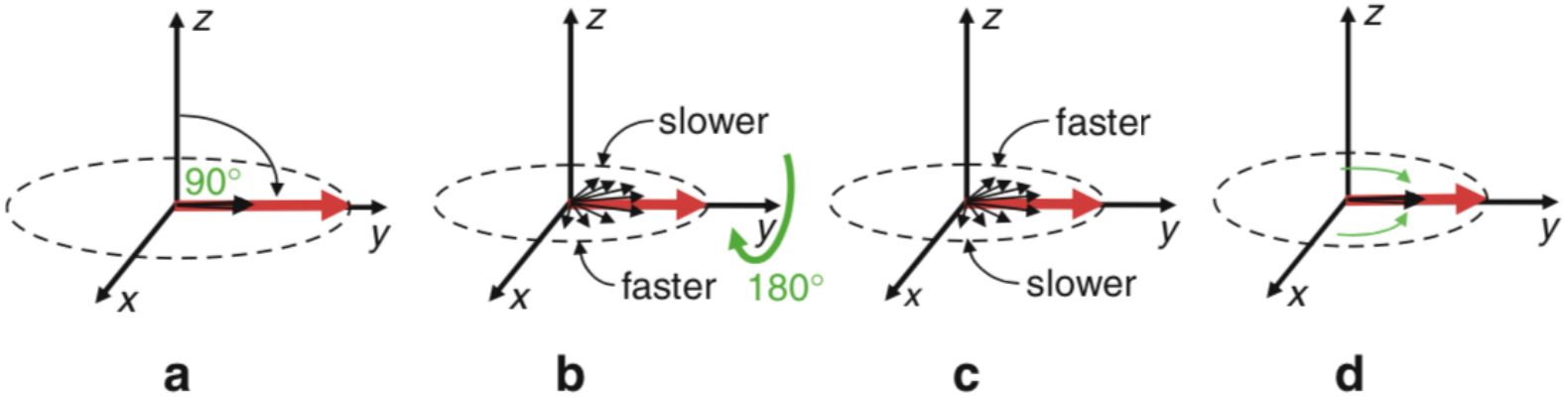
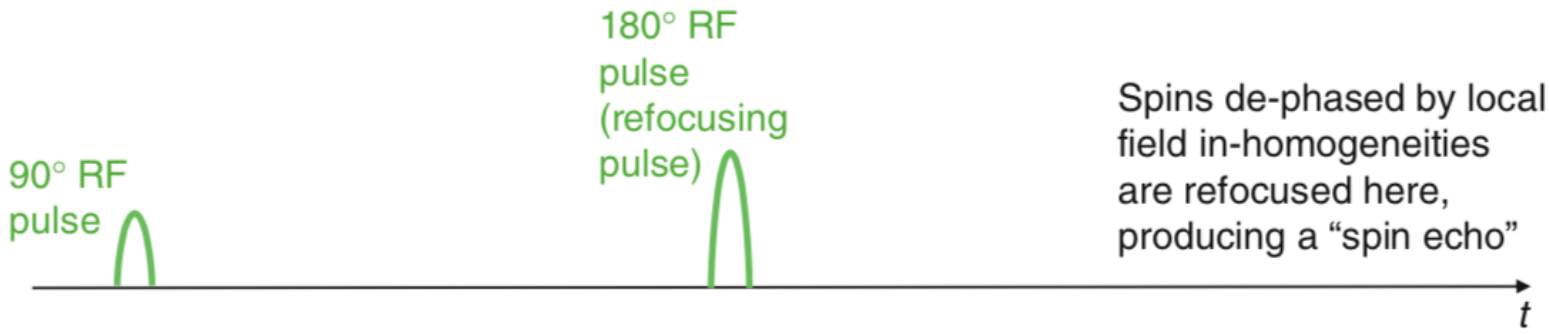
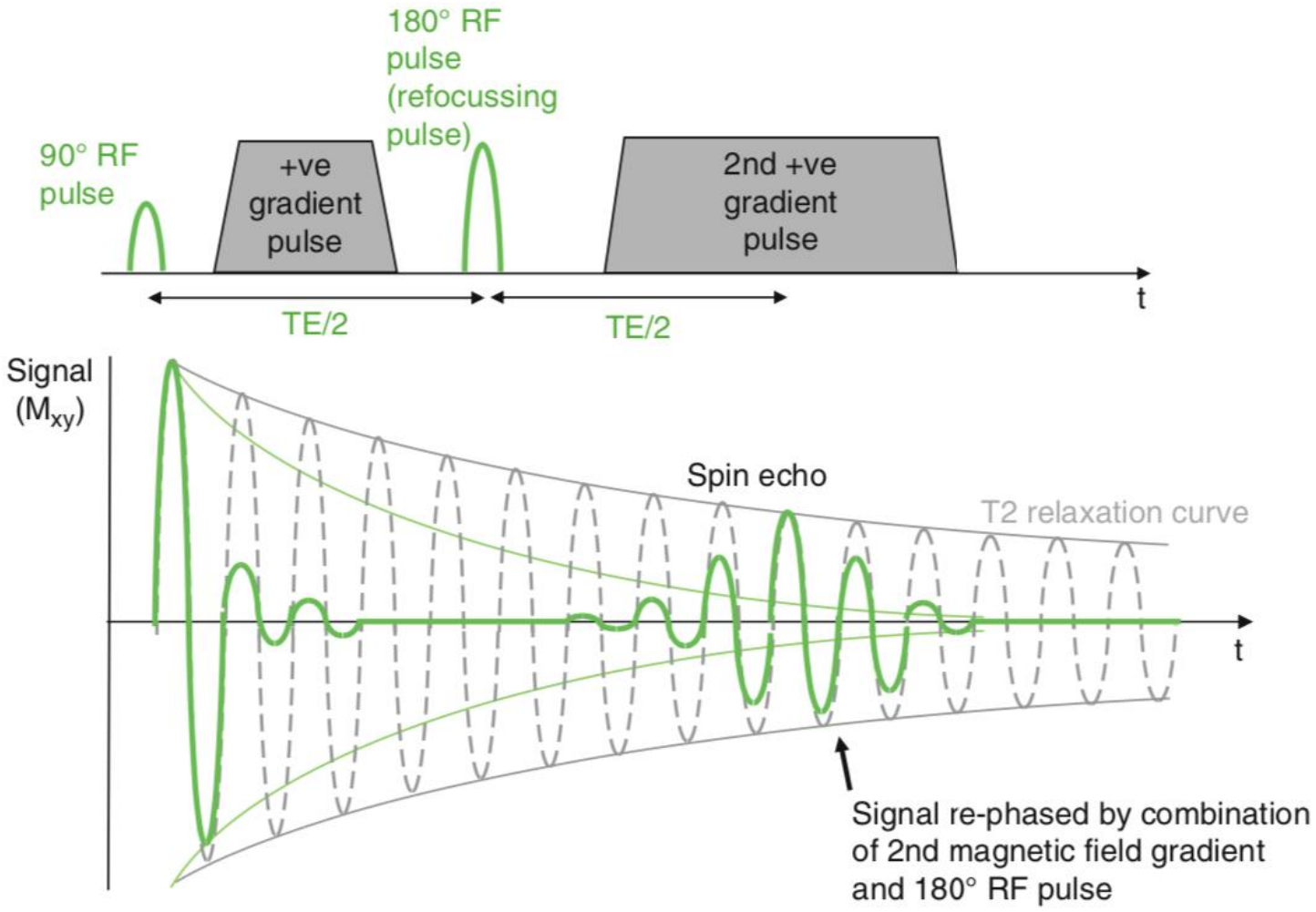






Spin Echo


180° RF pulse (refocussing pulse)
90° RF pulse
+ve gradient pulse
2nd +ve gradient pulse
t
TE/2
TE/2
Signal (M_{xy})
Spin echo
T2 relaxation curve
t
Signal re-phased by combination of 2nd magnetic field gradient and 180° RF pulse

180 degree refocus pulse

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180 Refocusing Pulse

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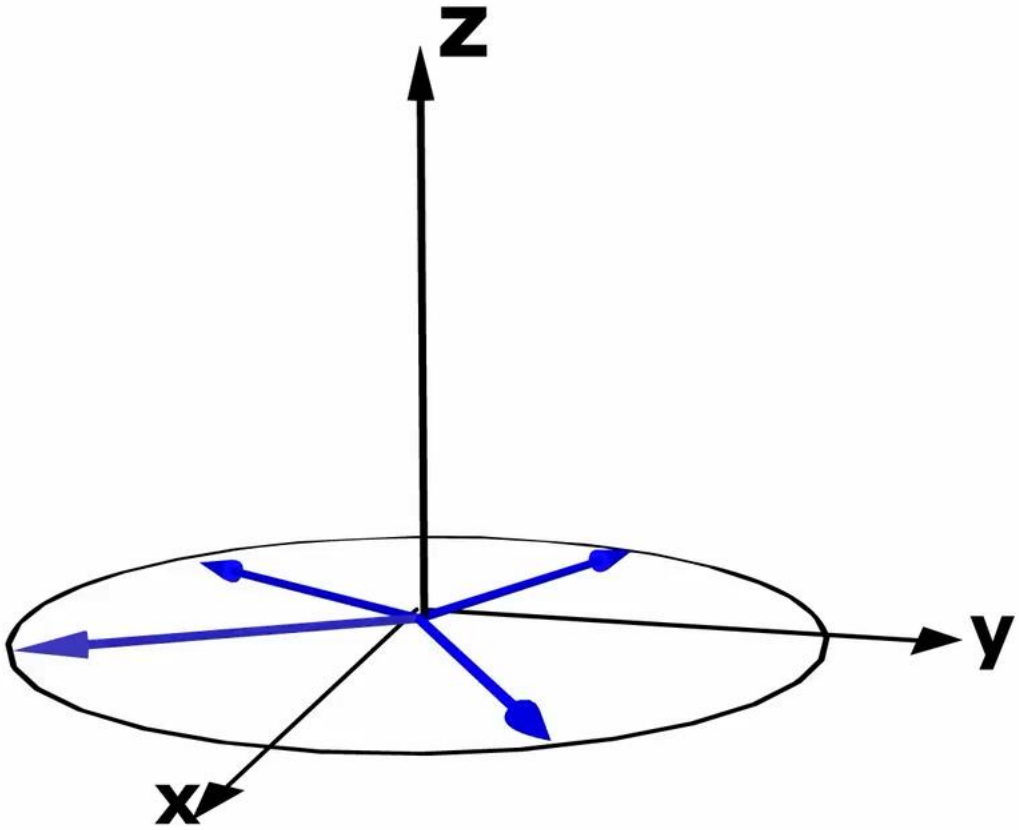

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Creating an image

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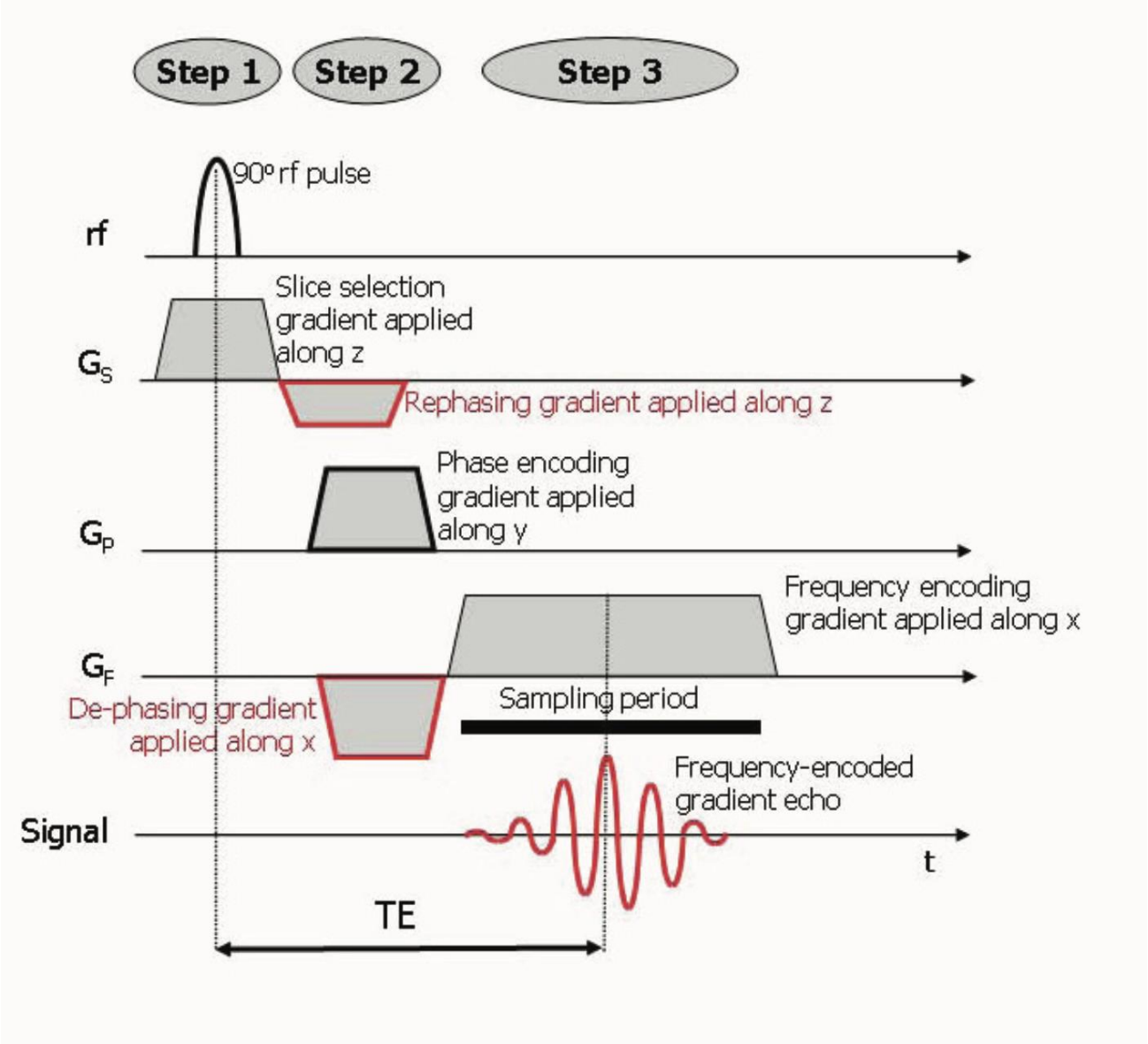

A key difference, with clinical implications

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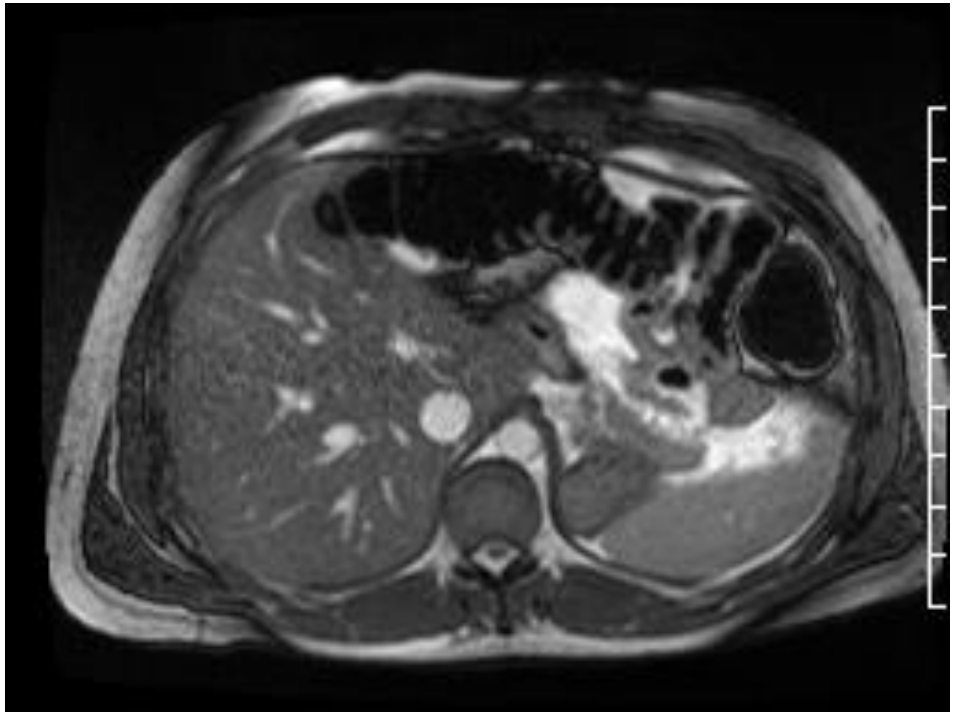
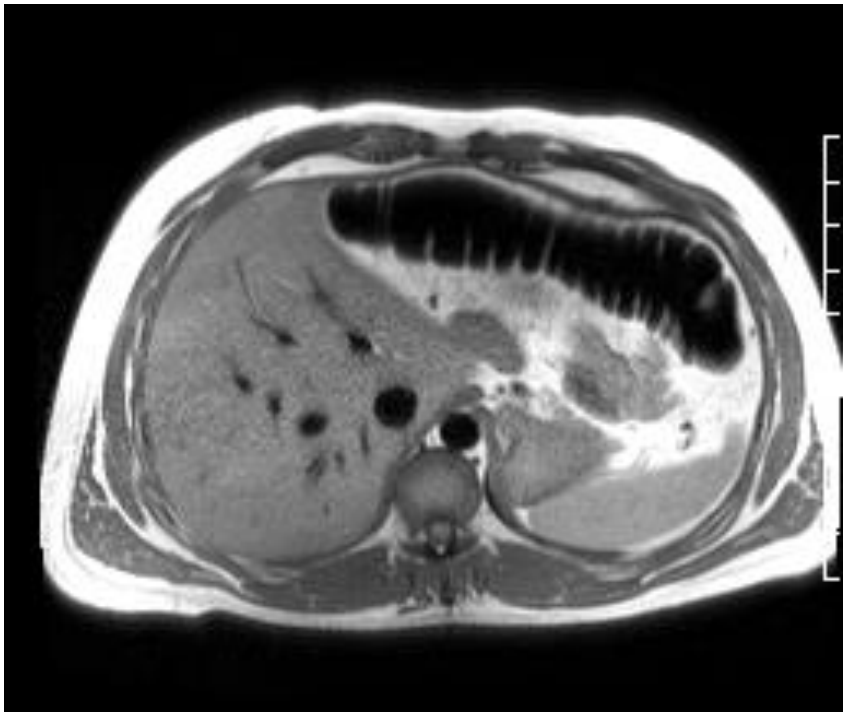
- In general, because of the 180° refocusing pulse of spin echo removes the de-phasing caused by magnetic field inhomogeneities, the amplitude of the spin echo signal is greater than the gradient echo signal (also, the initial flip angle is higher)

- Imaging based on spin echo is also less affected by the presence of field inhomogeneities caused by metallic artefacts (e.g. sternal wires or metal)

Morphology assessment in routine CMR



Gradient echo based sequence



Spin echo based sequence

Device artifacts on GRE vs spin echo

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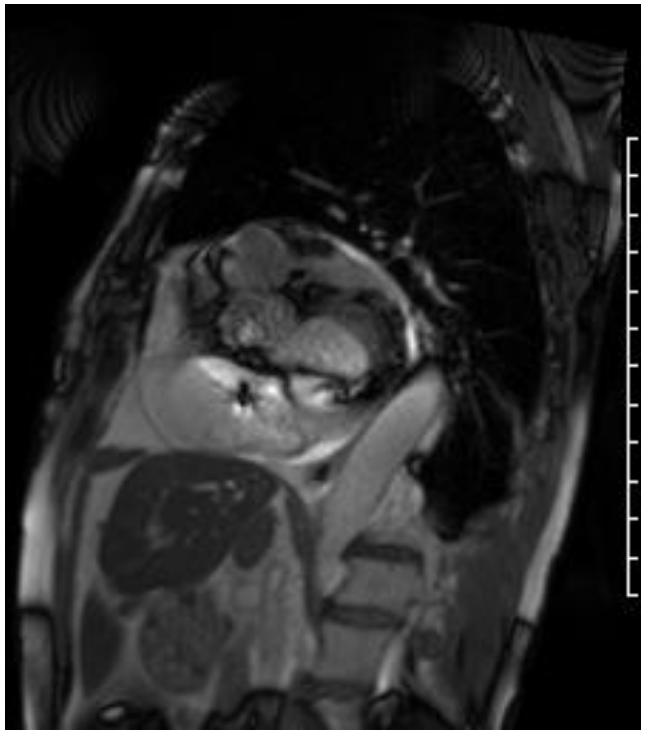

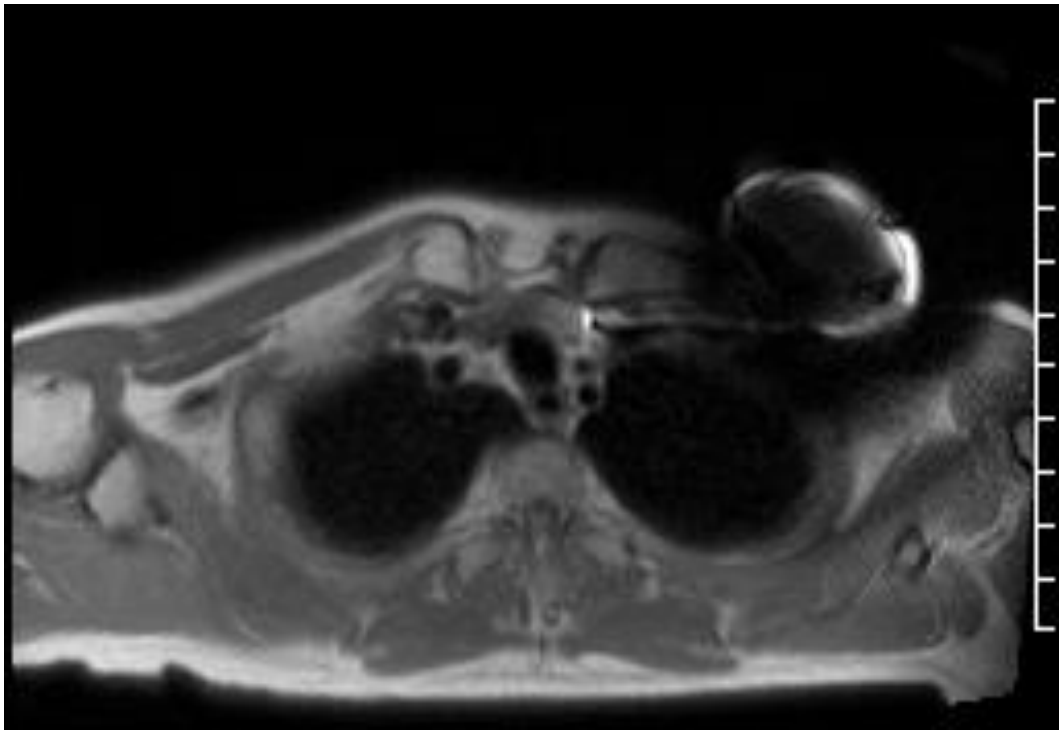

Why are blood vessels black in spin echo sequences

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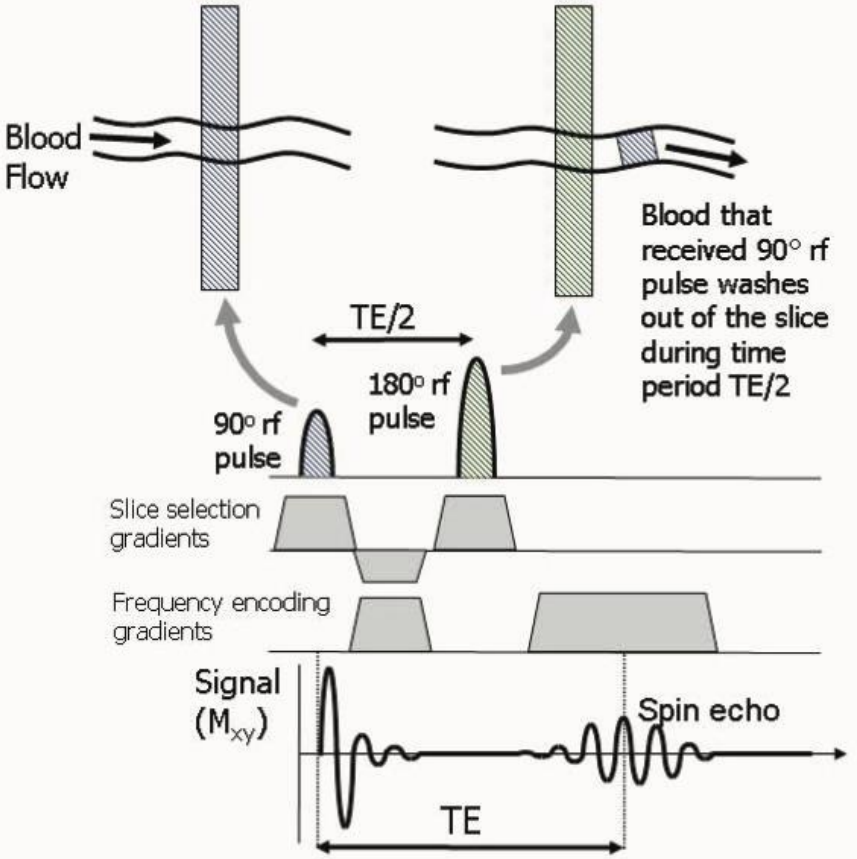

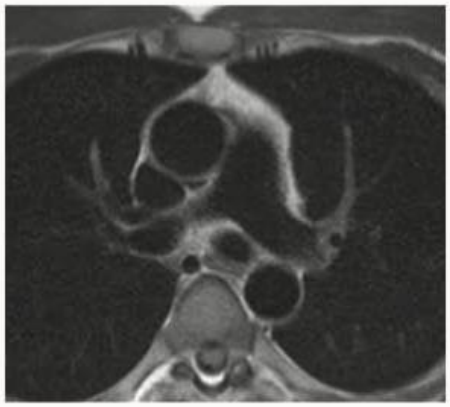

'Black blood' spin echo image

Black blood prep 2.0

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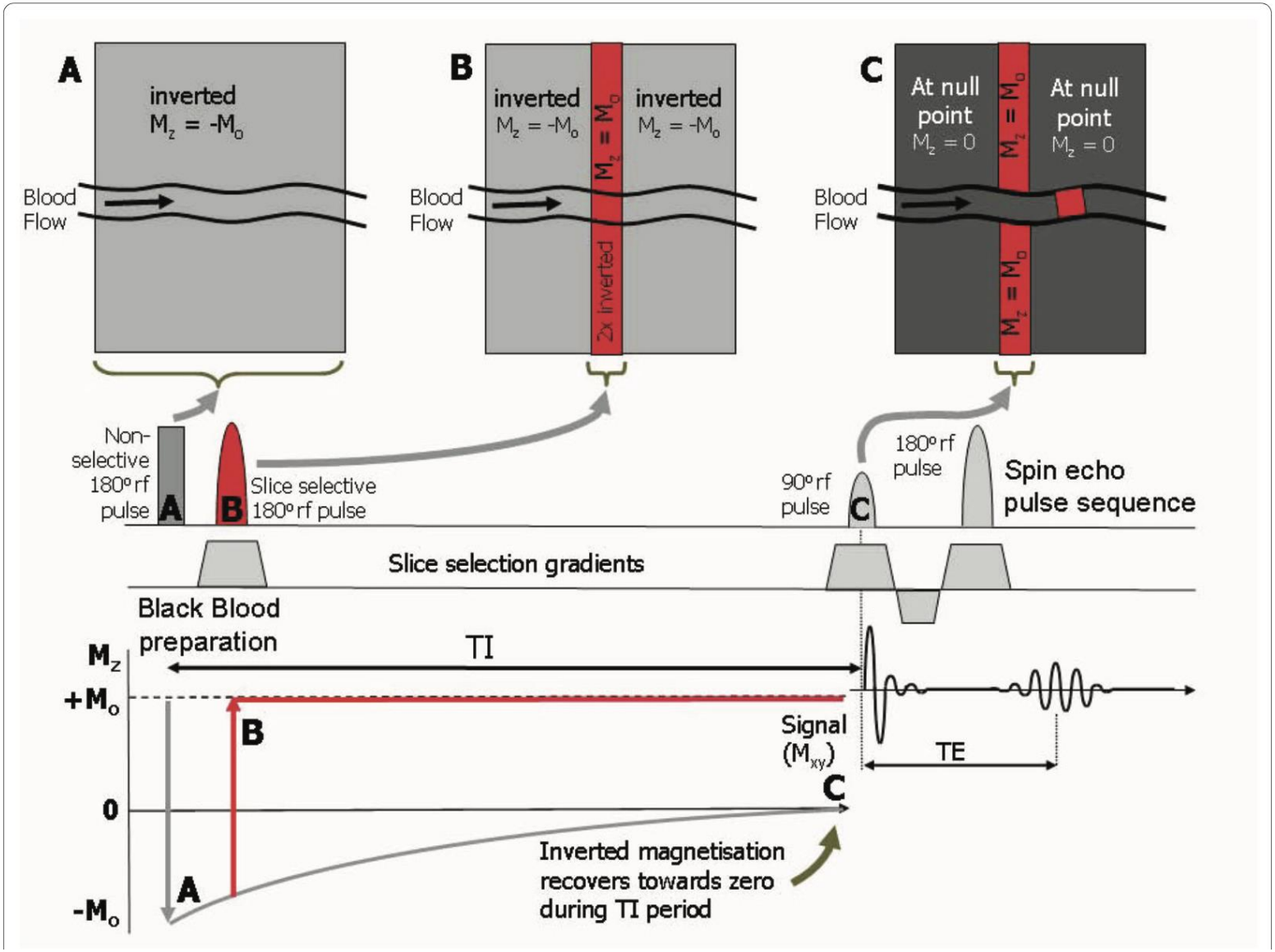

Why are blood vessels bright in gradient echo sequences? (hence the name bright blood)

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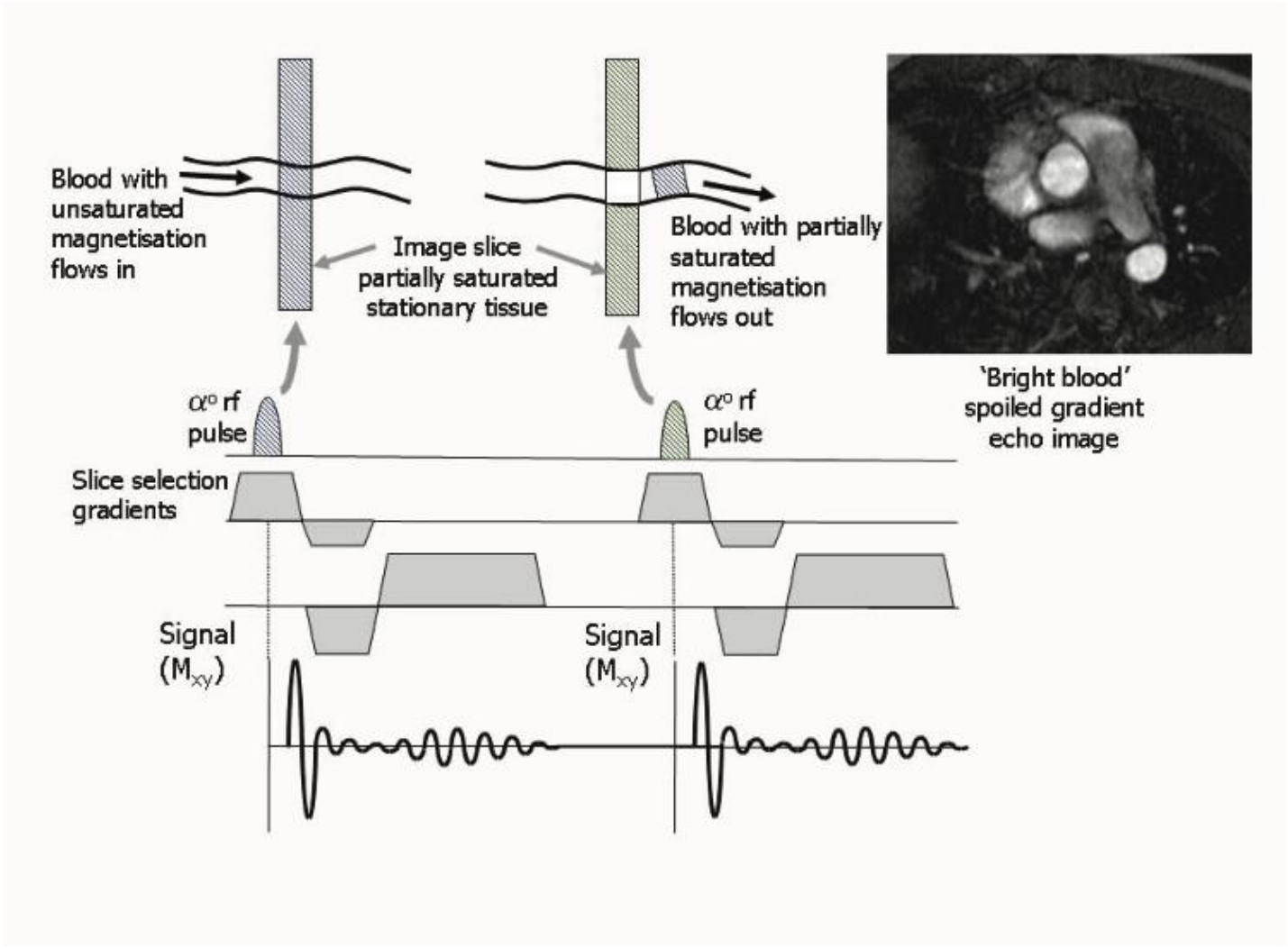

Subtypes of gradient echo sequences, cines

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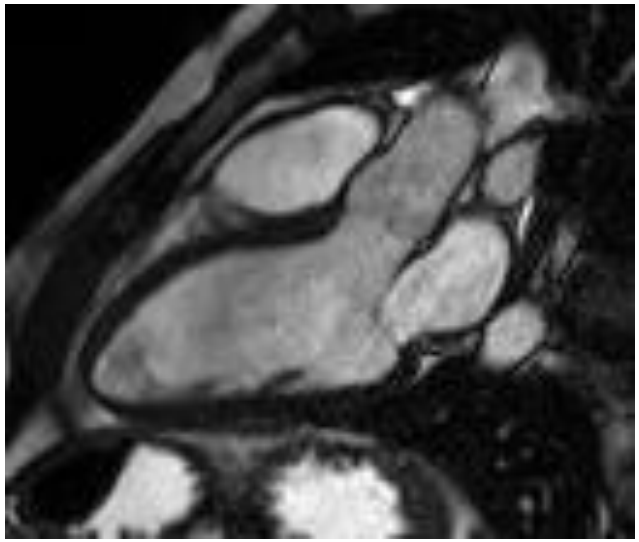
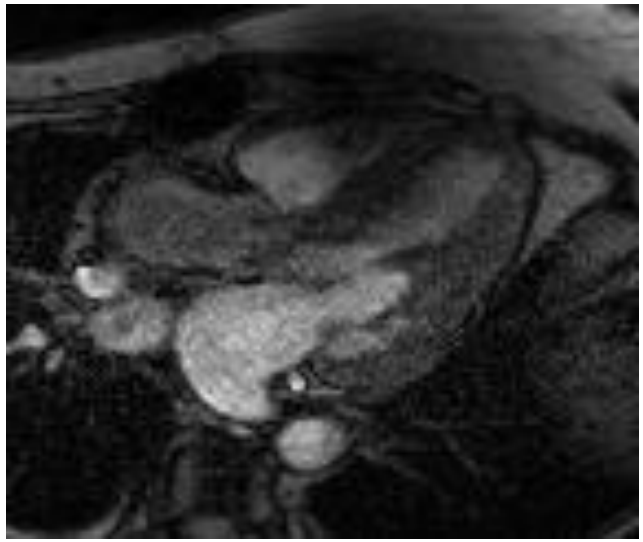




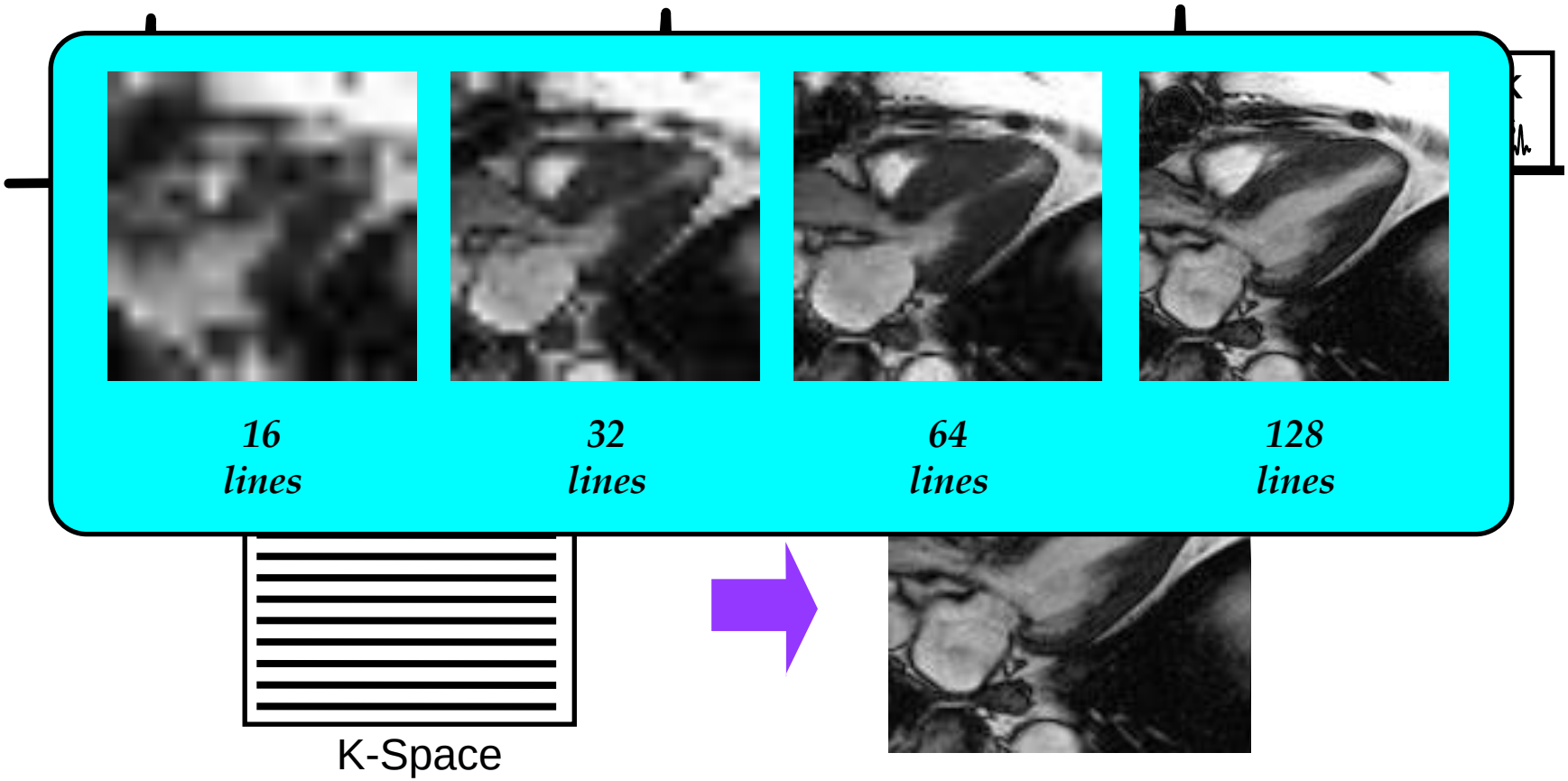
Steady State Free Precession (SSFP)

- Have become the main sequences of cardiac imaging, higher angle, and high SNR/CNR
- Transverse magnetization is brought back with balancing gradients, rather than spoiled
- More sensitive to artifacts esp with non-uniform magnet
- Contrast is T2/T1 weighted (fluid and fat are bright)

Spoiled Gradient echo

- Low flip angle
- Spoiling gradients to allow short TR
- Short TR/TE to allow T1 weighting
- Less susceptible to artifacts
- Able to see flow jets better
- Relies to on blood flow to give contrast

How to get a Cine done



- Entire image is completed after 4 heart beats

Courtesy of Dipan Shah, MD

Techniques of CMR Acquisition
ECG gating with Segmentation

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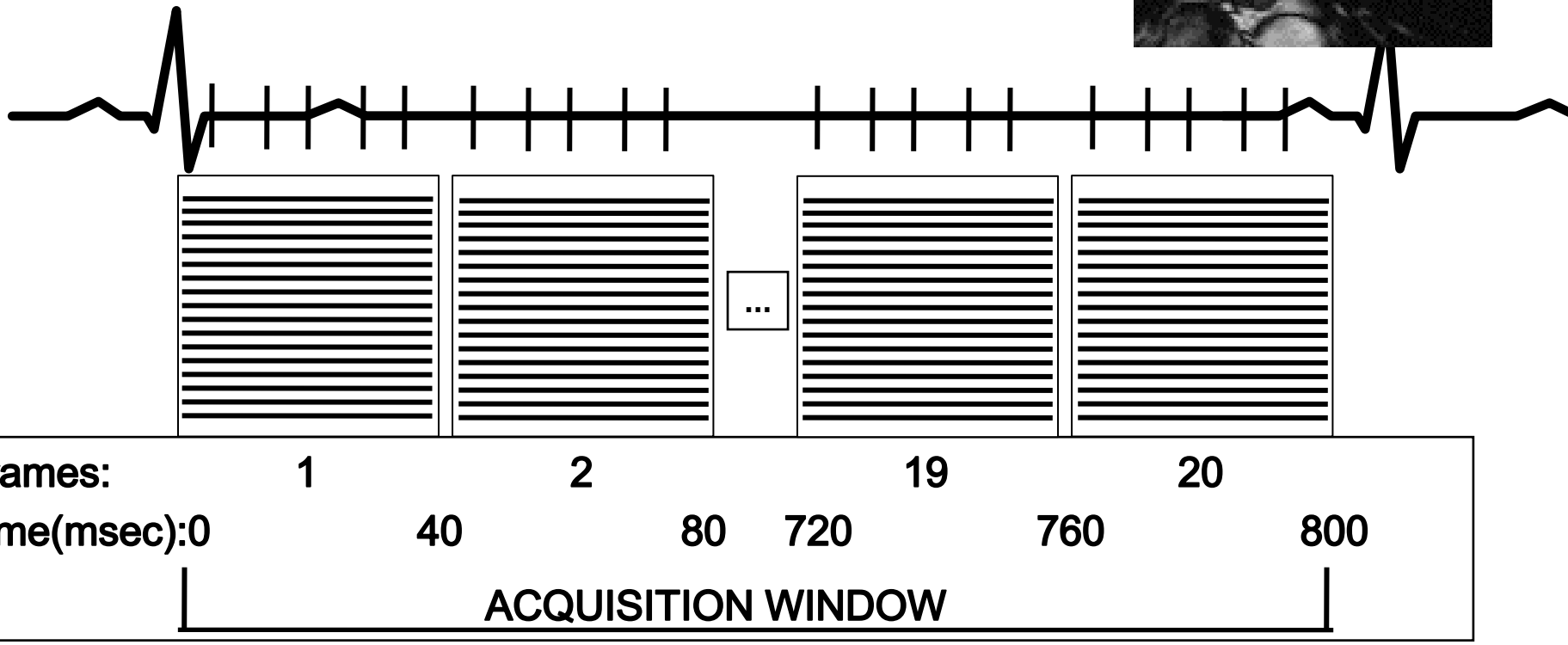
- Cine image is a series of 20-25 image frames at different points in the cardiac cycle that are played one after another to create a "movie"



Courtesy of Dipan Shah, MD

What about flow and velocity assessment? Flow velocity mapping: Intrinsic flow sensitivity of pulse sequences

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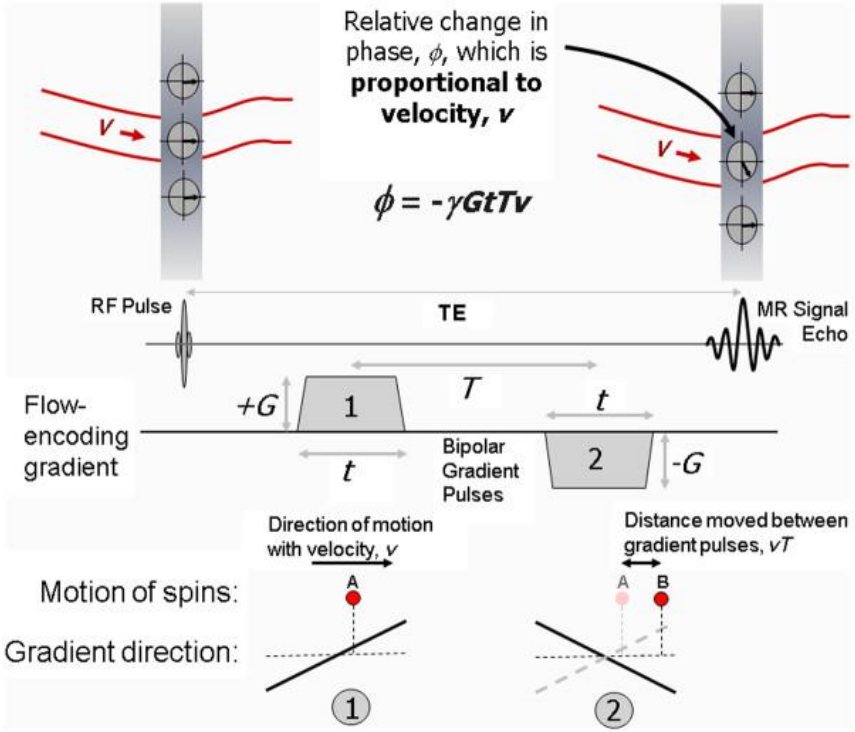
- Bipolar gradient pulse pair
  - Reverses magnetization de-phasing at TE (slice select, freq encode)
  - Same direction, opposite signs
  - 2nd gradient re-phases everything still in-slice



Phase contrast imaging, through plane

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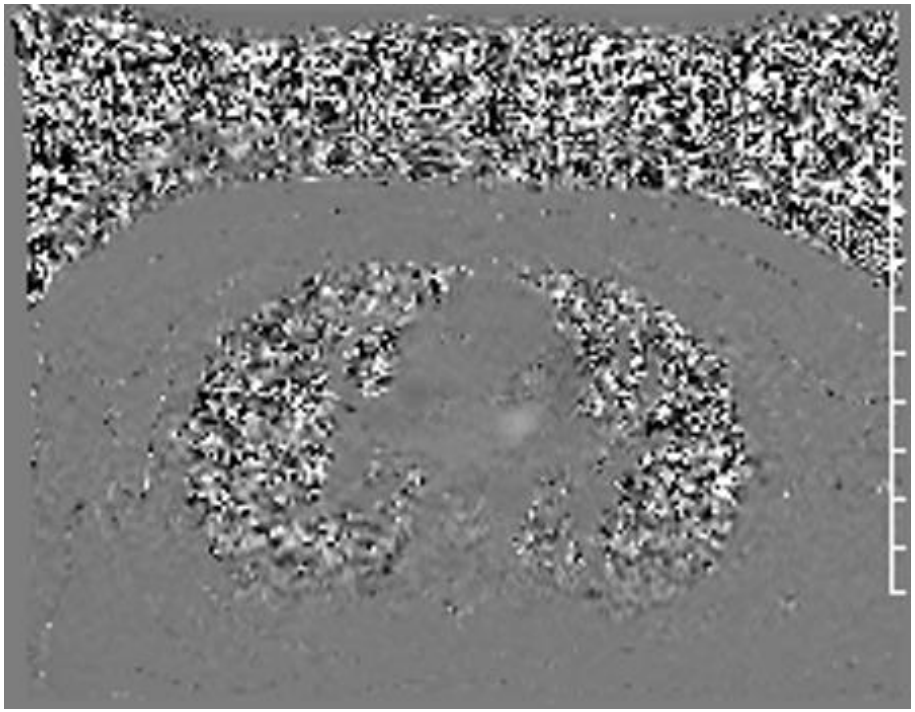

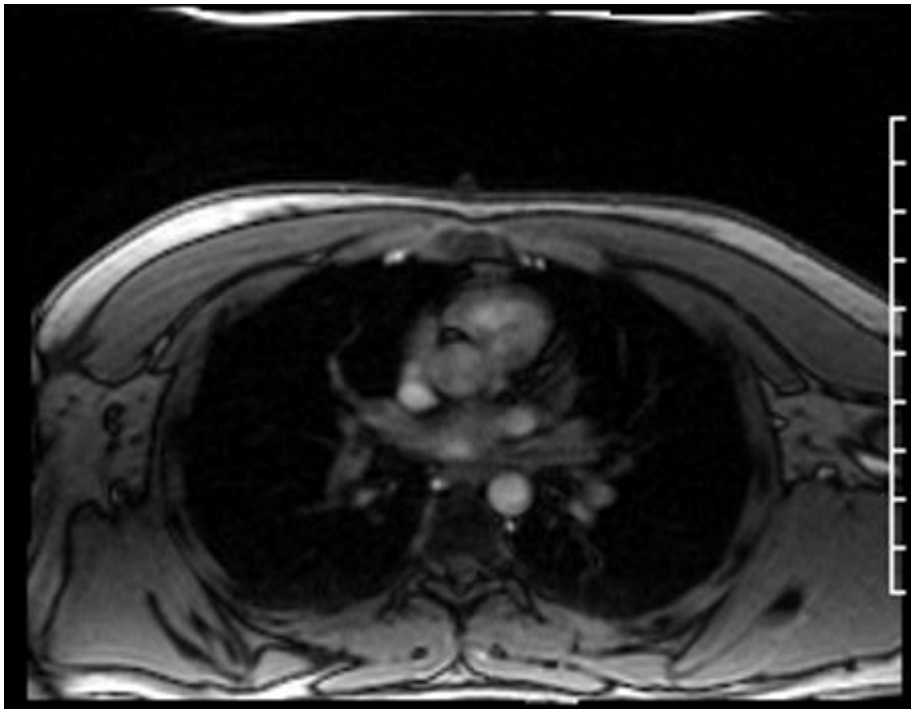

Phase contrast imaging, in-plane

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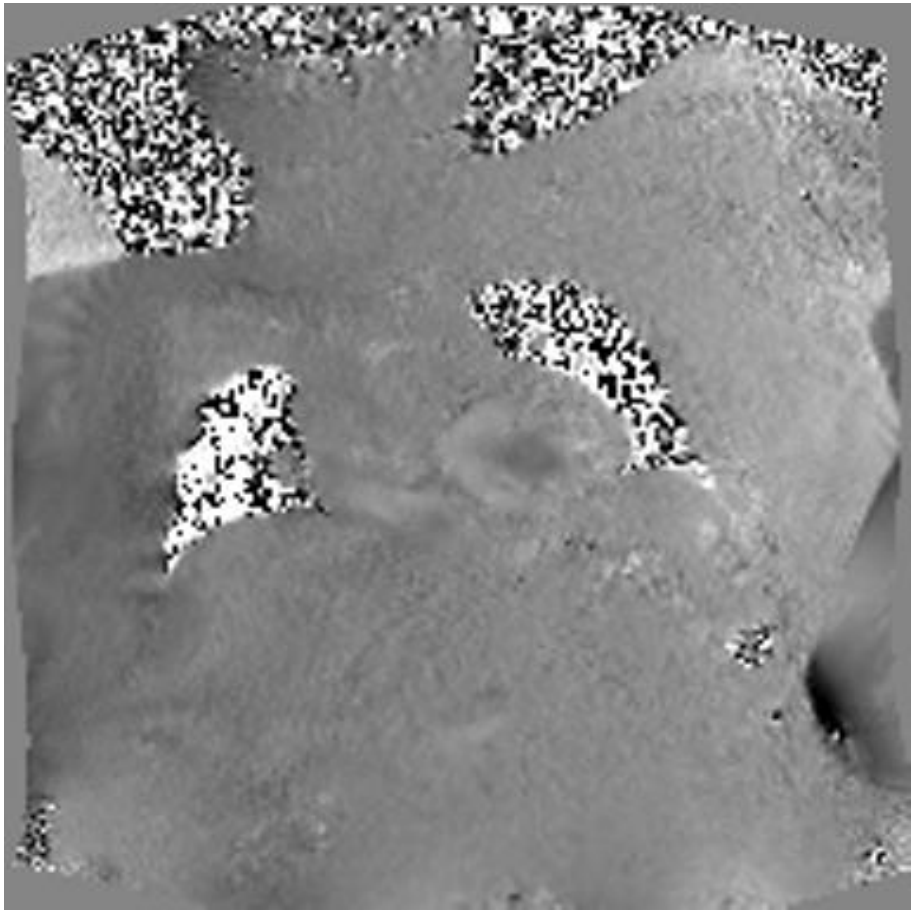

Example of PC utilization

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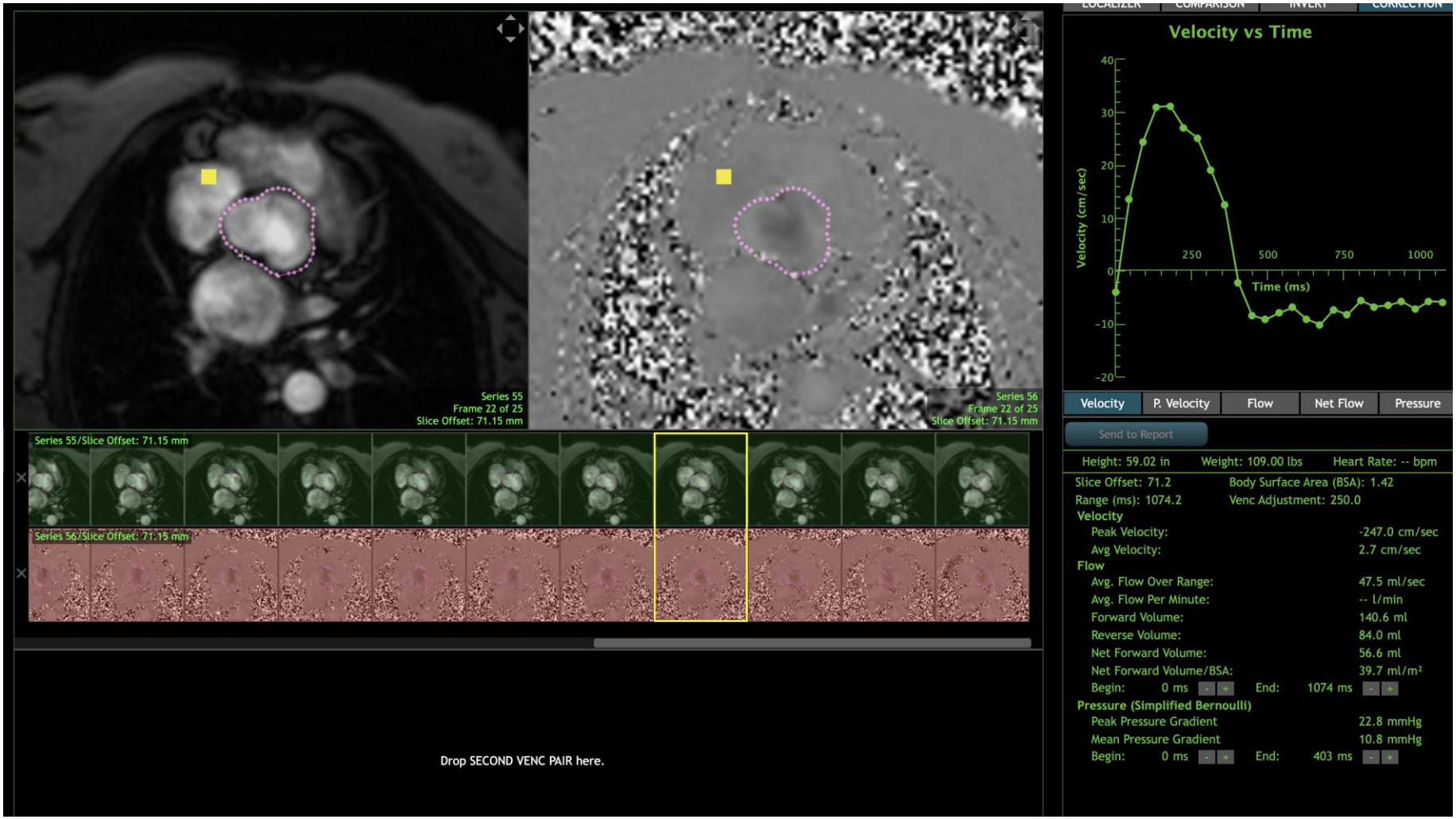

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