

Physics 1

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EACVI
European Association of
Cardiovascular Imaging

Resonance tip NMV into x-y



Resonance tip NMV into x-y



Impart energy

Resonance tip NMV into x-y



Impart energy

EM radiation at Larmor

Resonance tip NMV into x-y



Impart energy

EM radiation at Larmor

63 MHz - radio waves

Resonance tip NMV into x-y

Why is this useful



Impart energy

EM radiation at Larmor

63 MHz - radio waves

Resonance tip NMV into x-y



Why is this useful



Impart energy

EM radiation at Larmor

63 MHz - radio waves

Induces current in antenna

Resonance tip NMV into x-y



Why is this useful

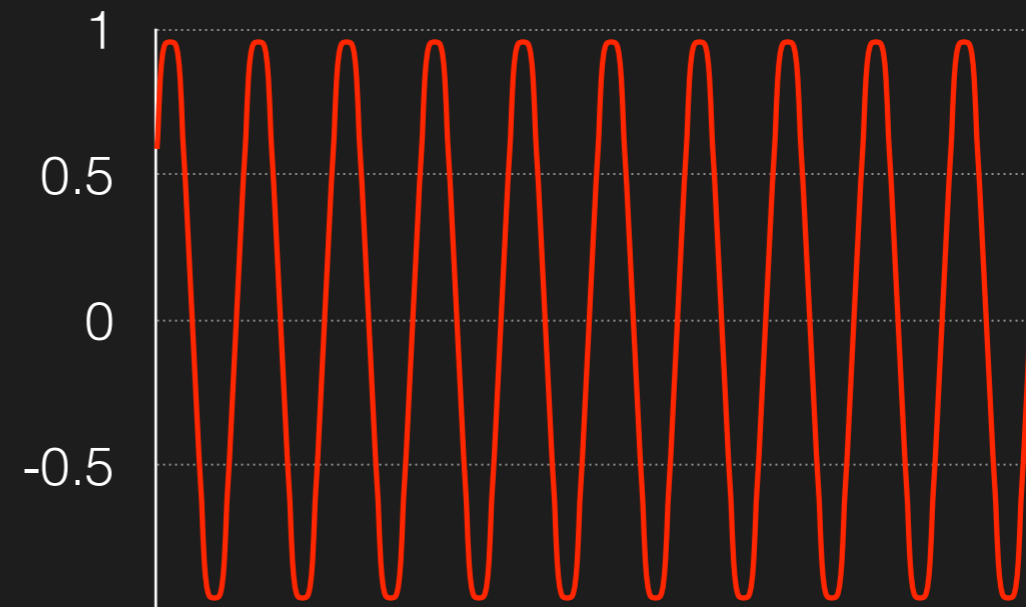


Impart energy

EM radiation at Larmor

63 MHz - radio waves

Induces current in antenna



RF -----

Slice -----

Phase -----

Freq -----

k-space filling



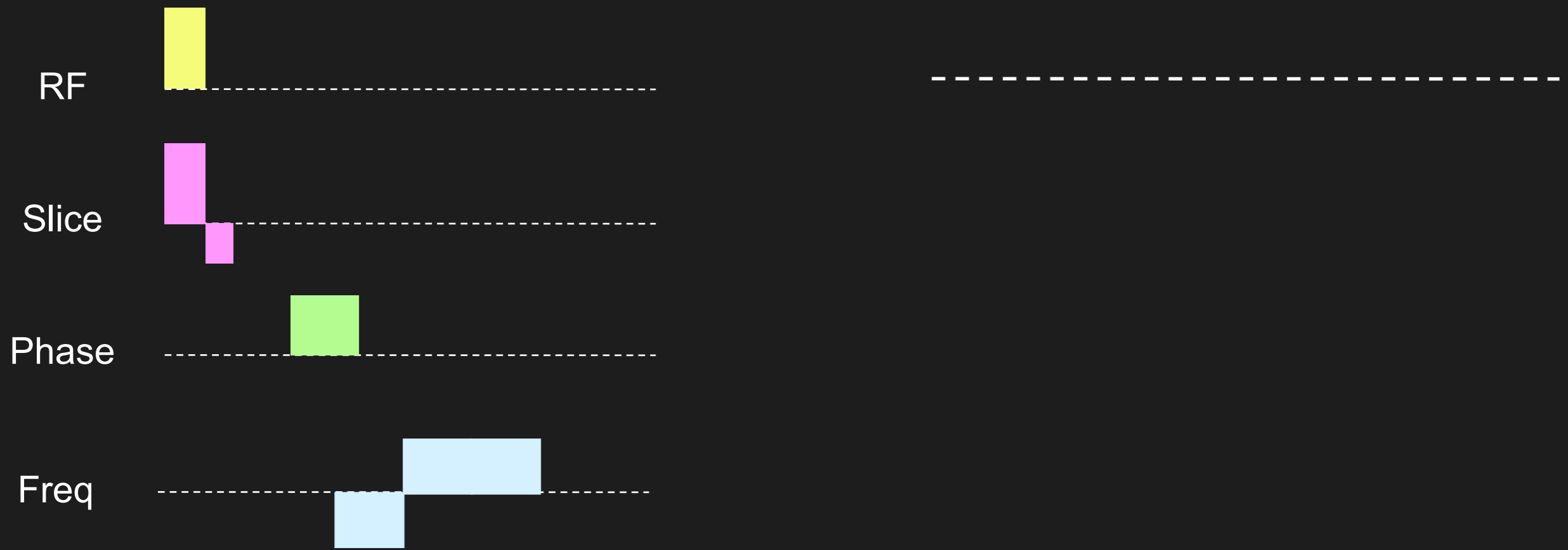
k-space filling



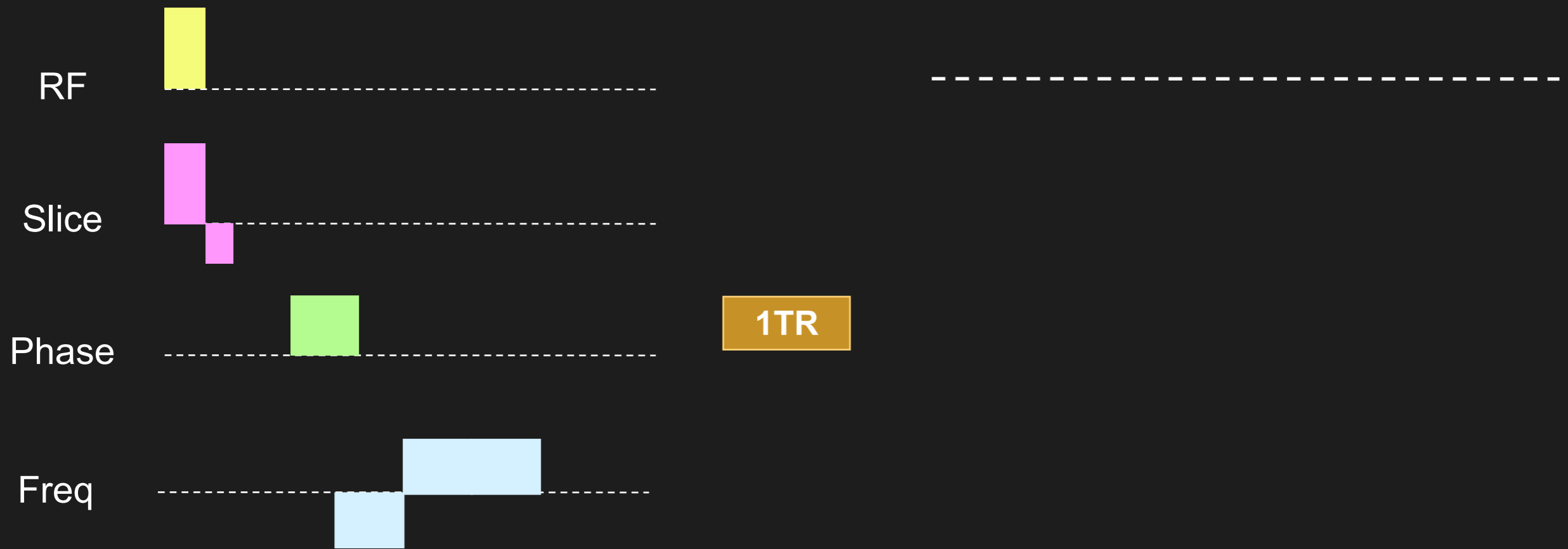
k-space filling



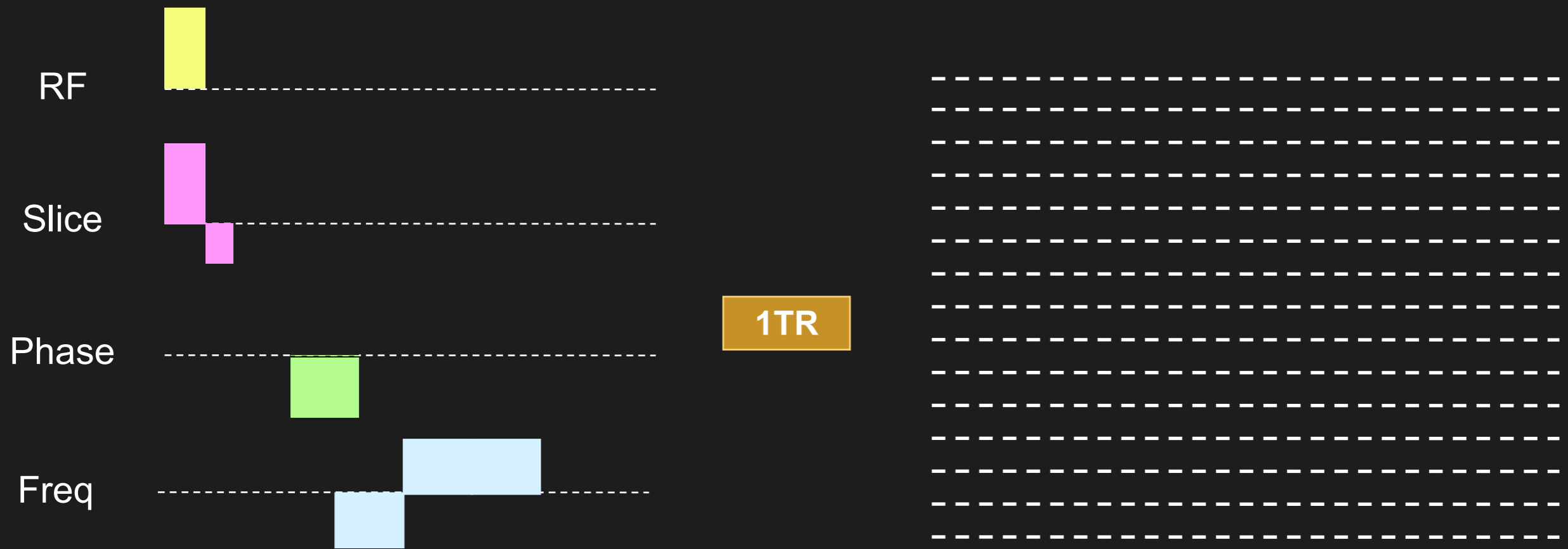
k-space filling



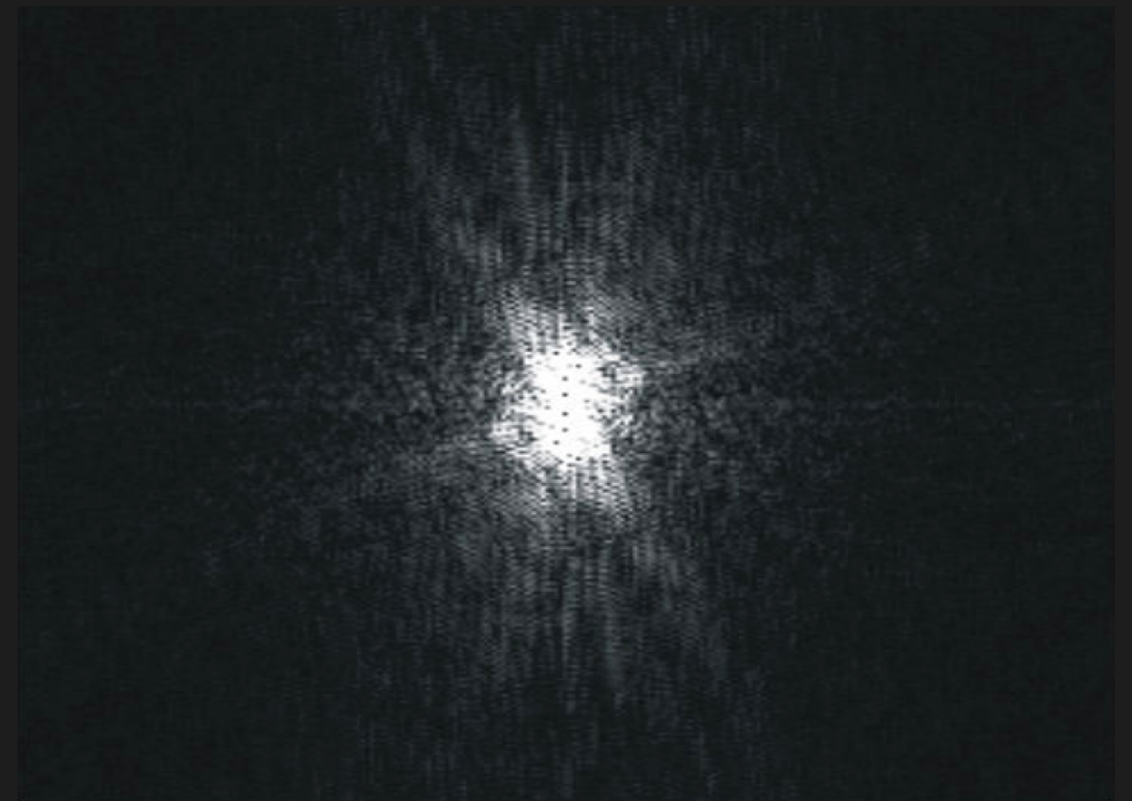
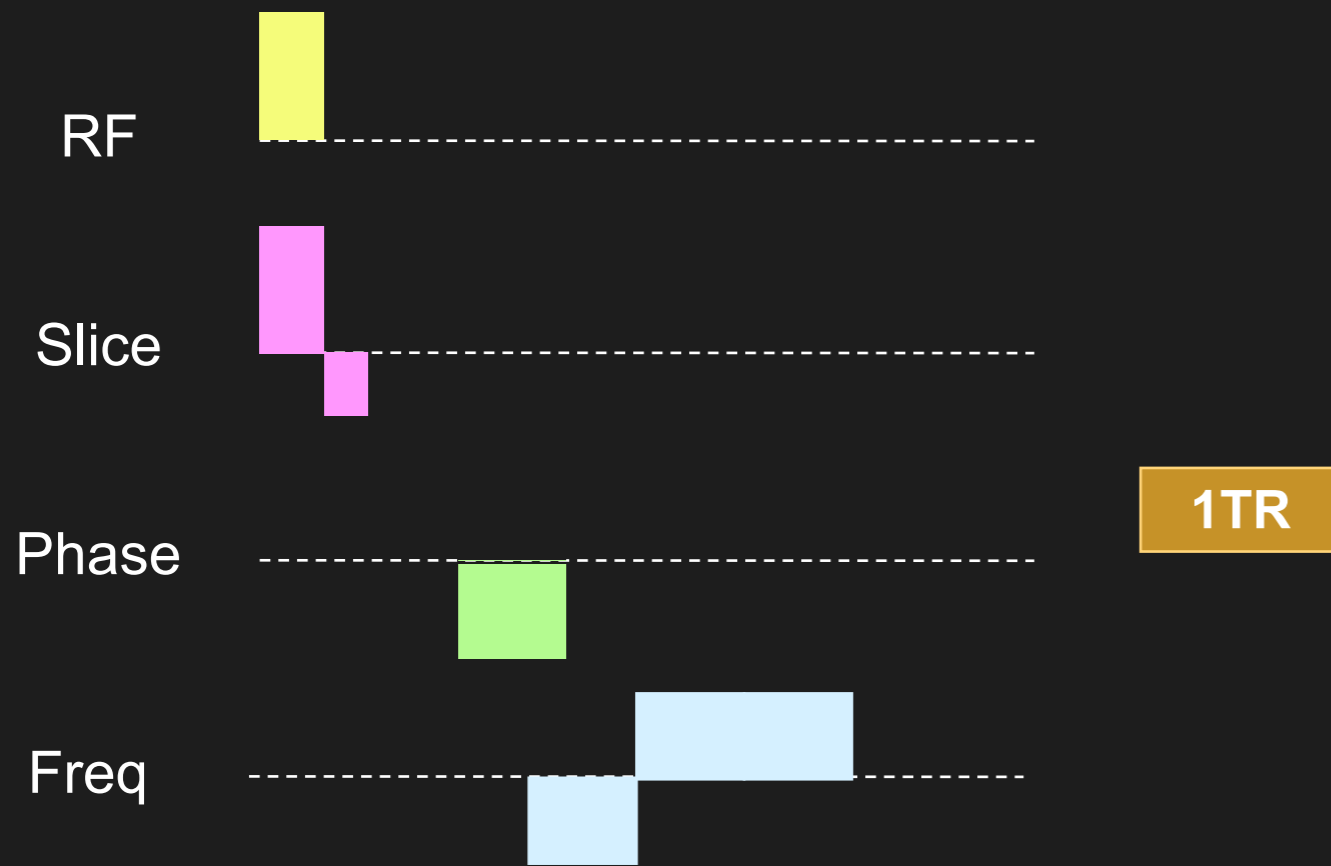
k-space filling



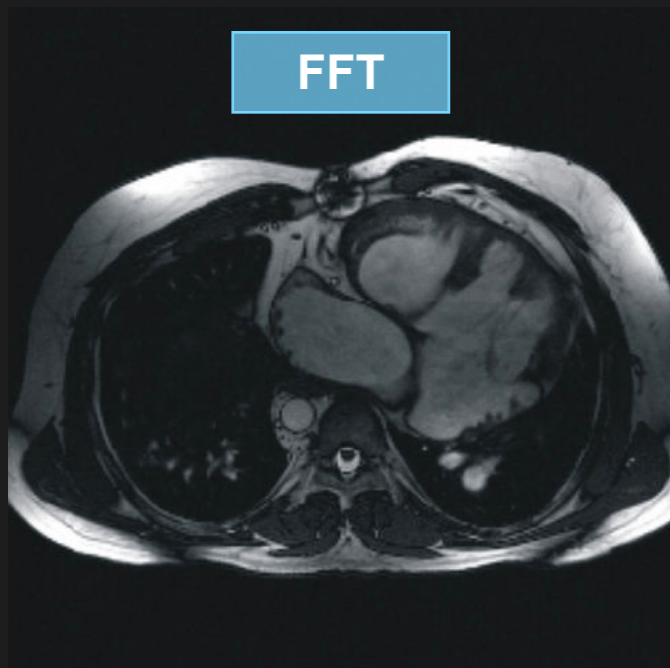
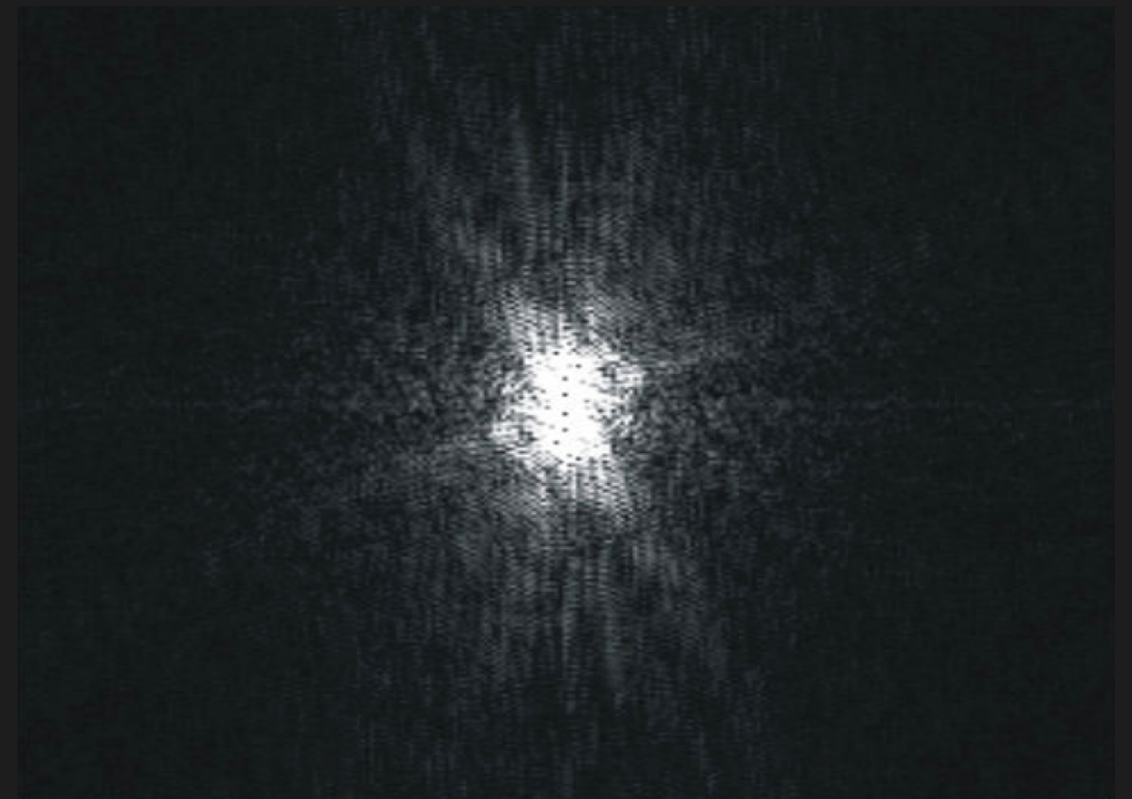
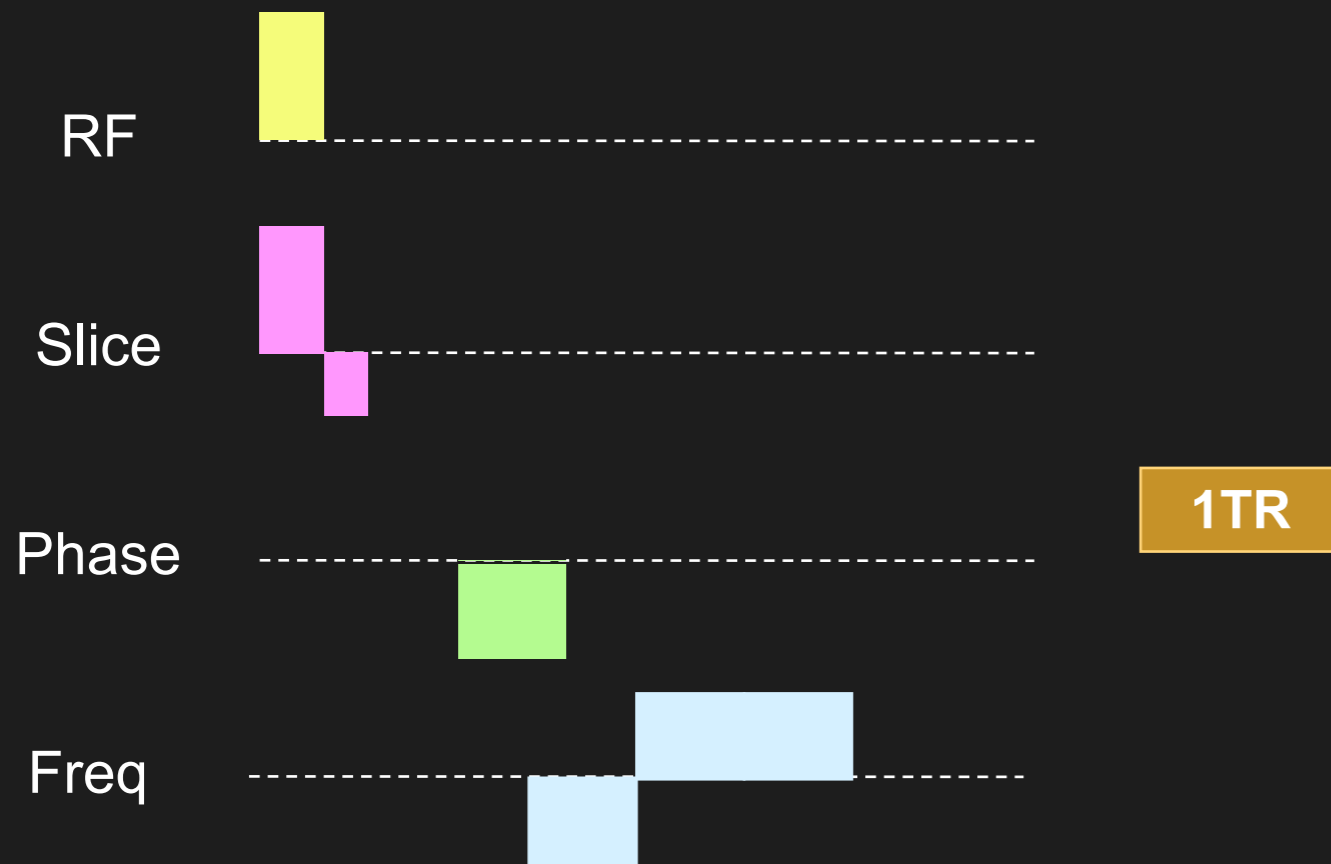
k-space filling



k-space filling



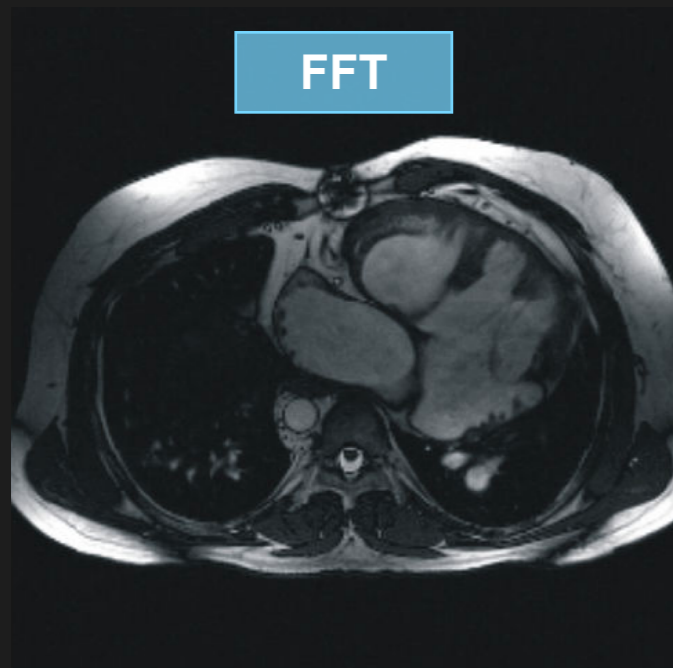
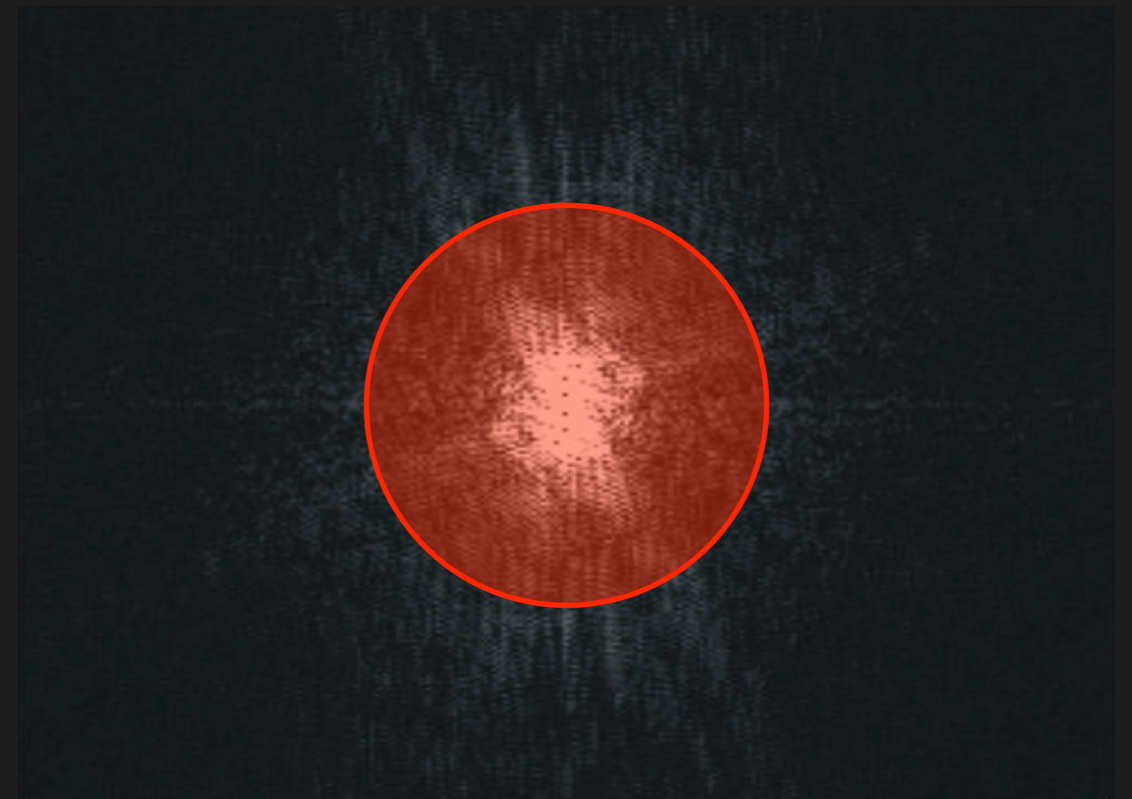
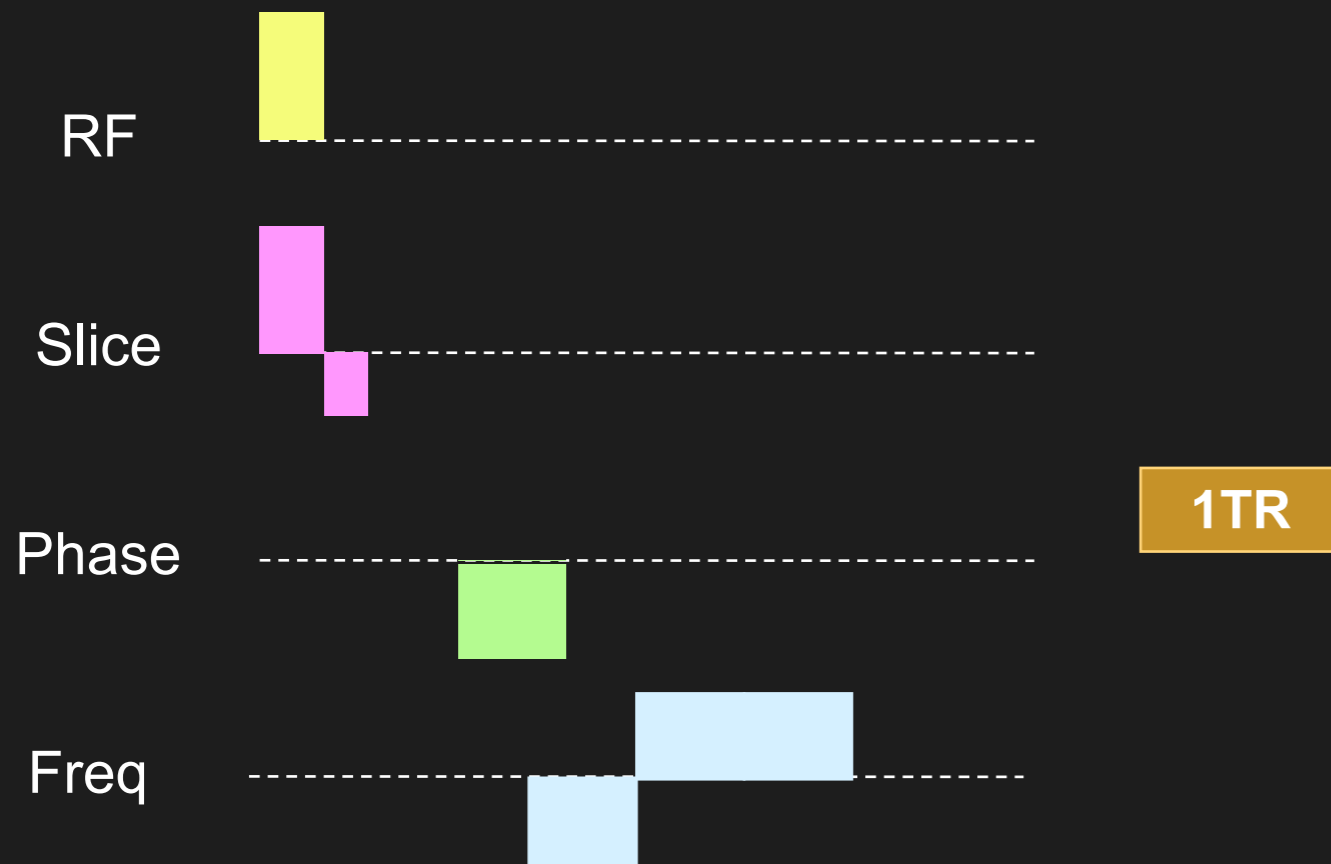
k-space filling



FFT

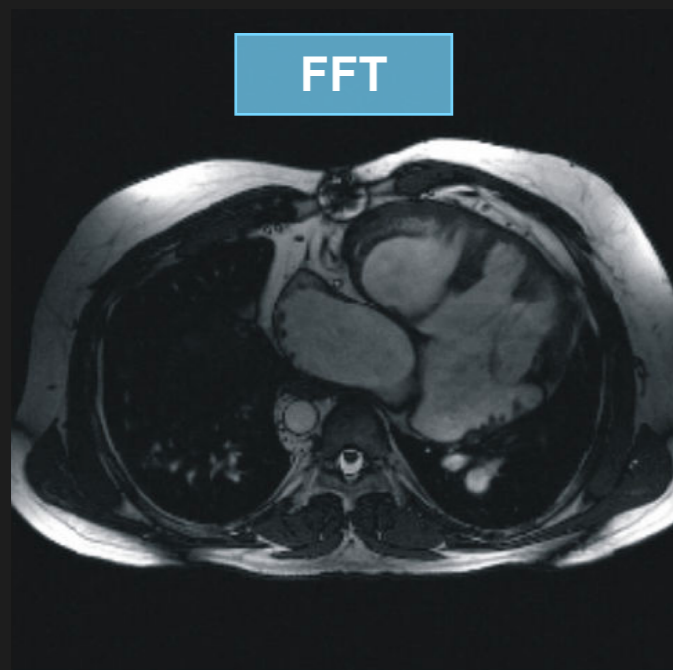
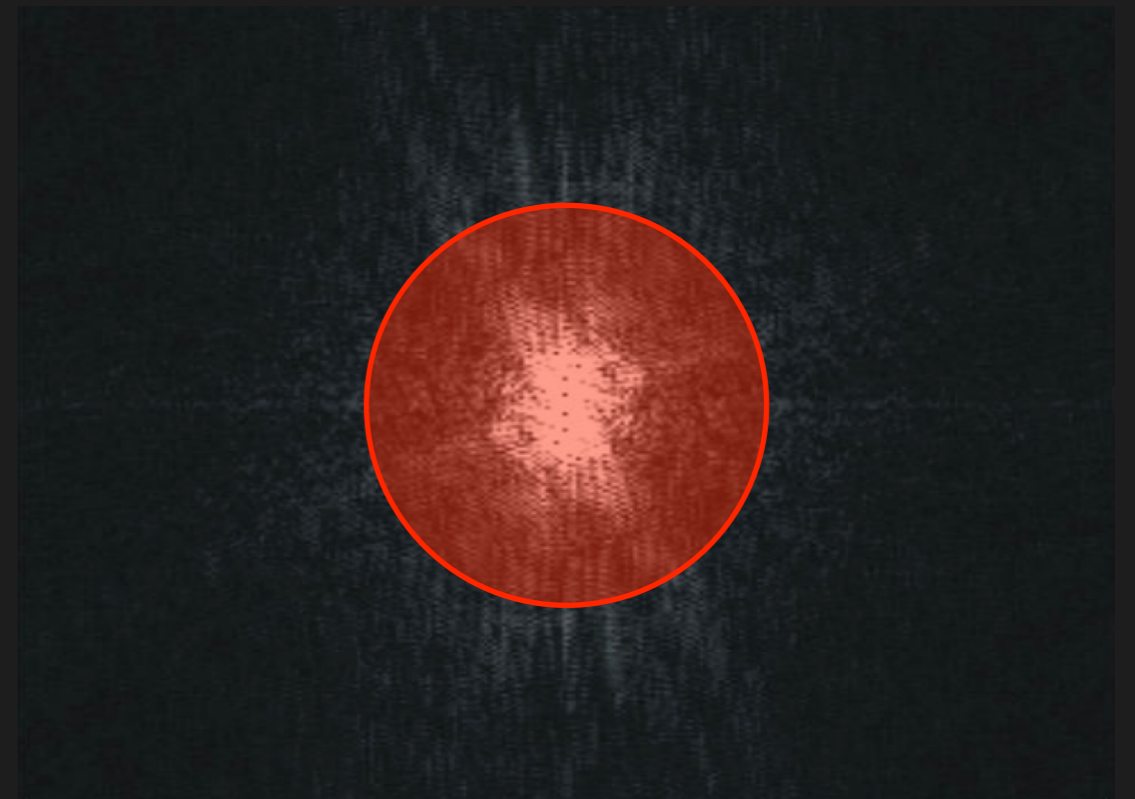
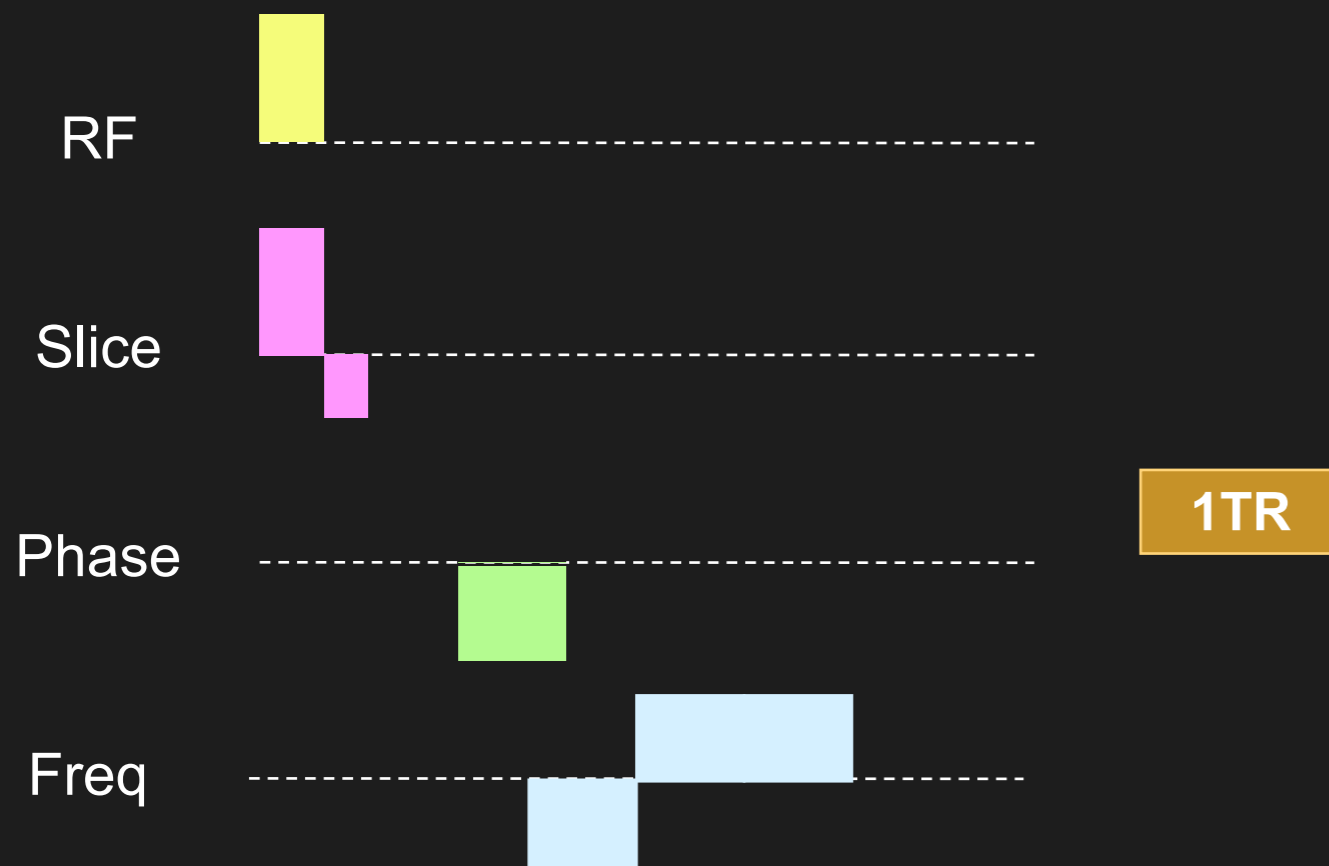
Full image

k-space filling

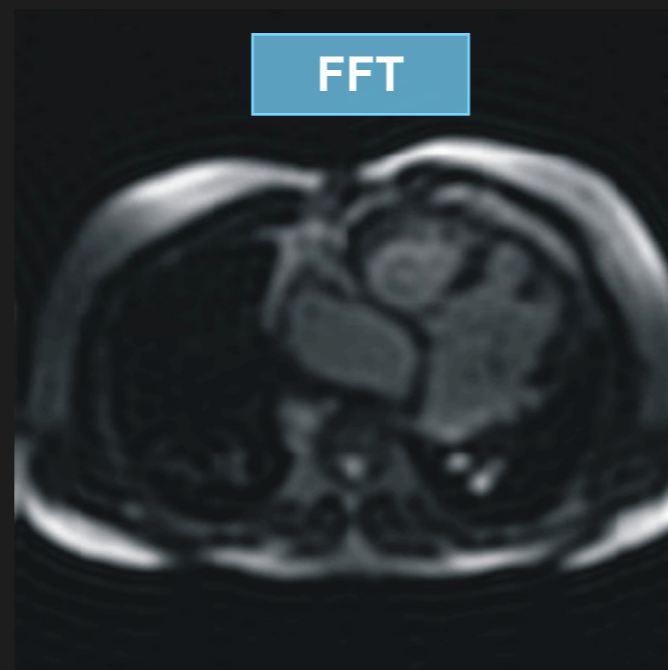


Full image

k-space filling

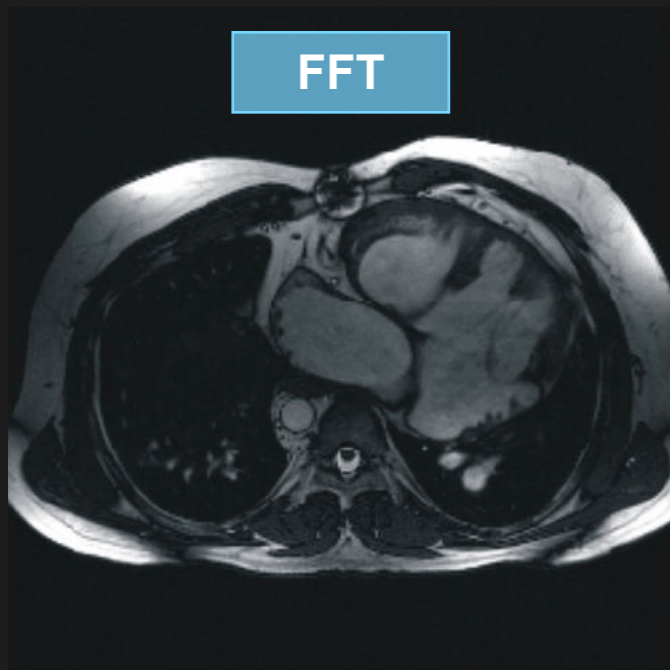
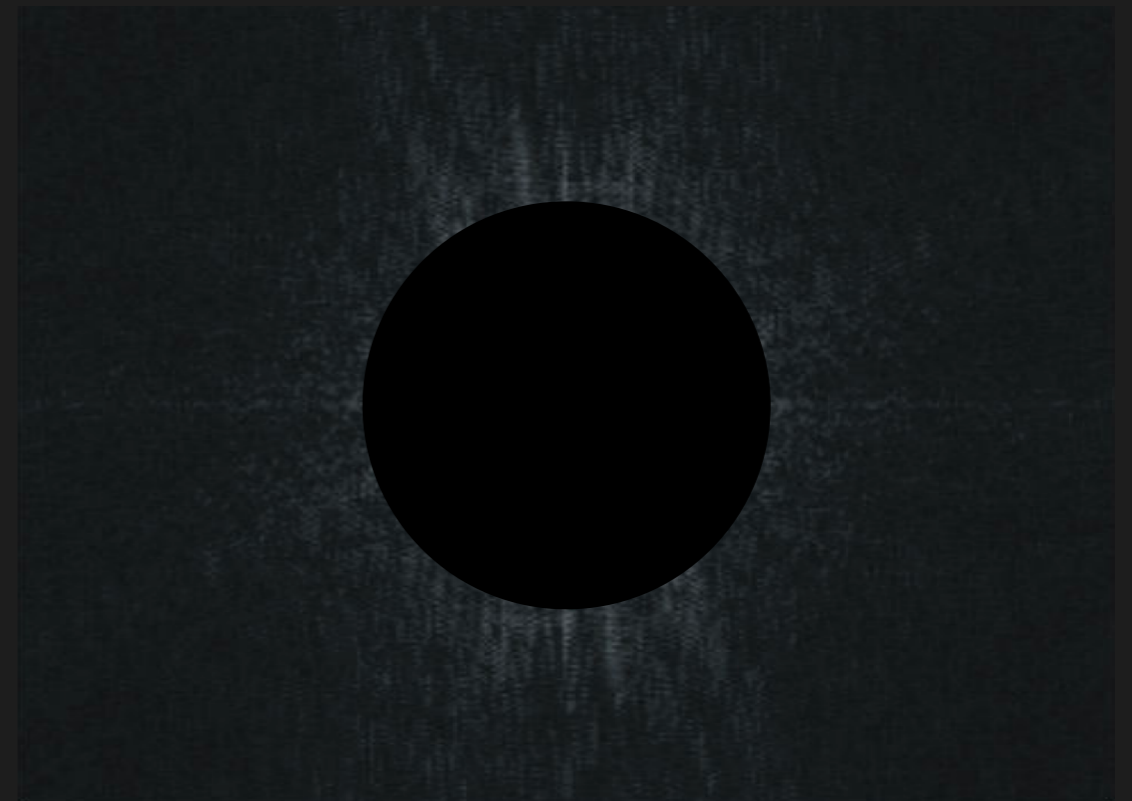
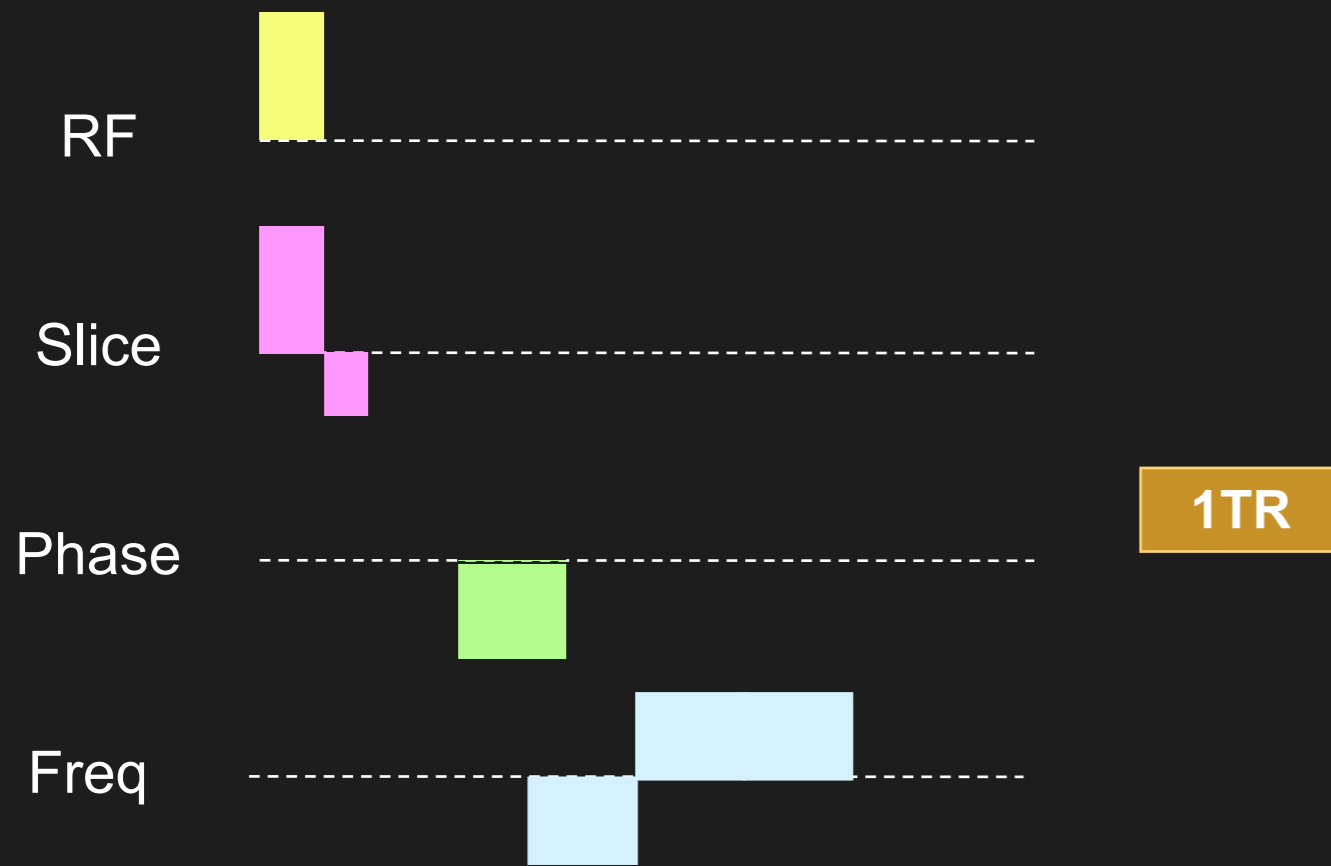


Full image

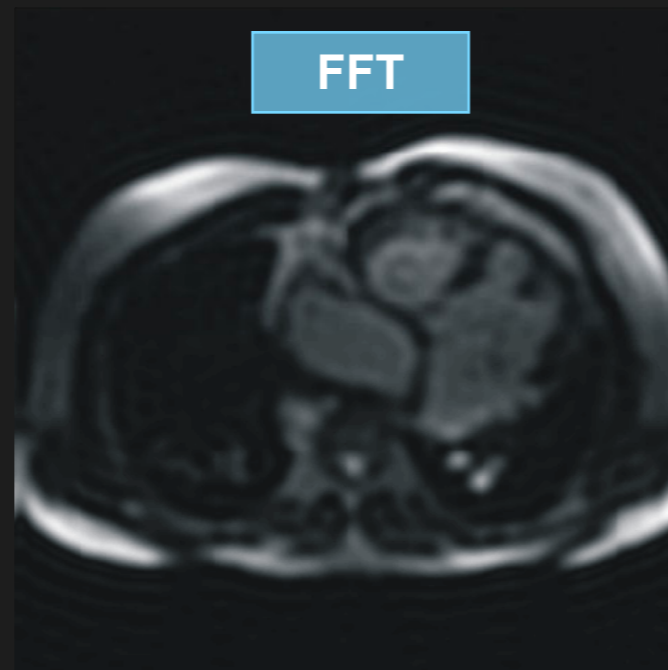


Low resolution - contrast

k-space filling

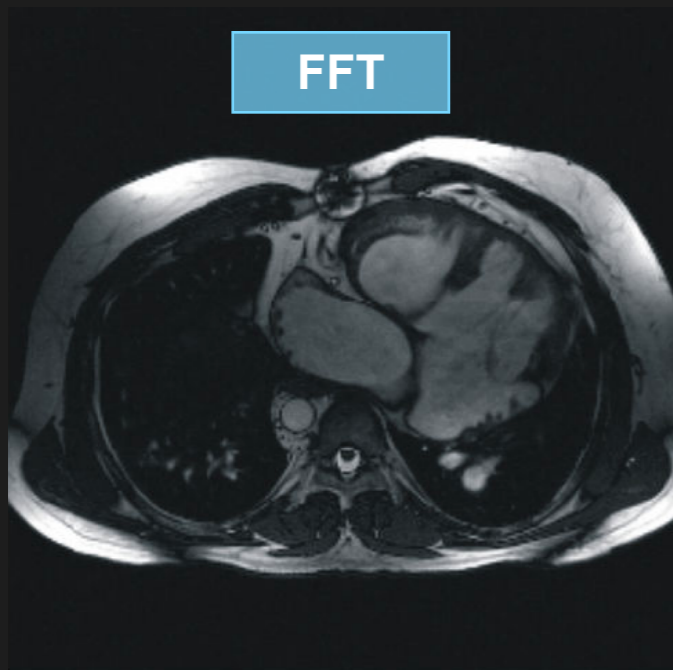
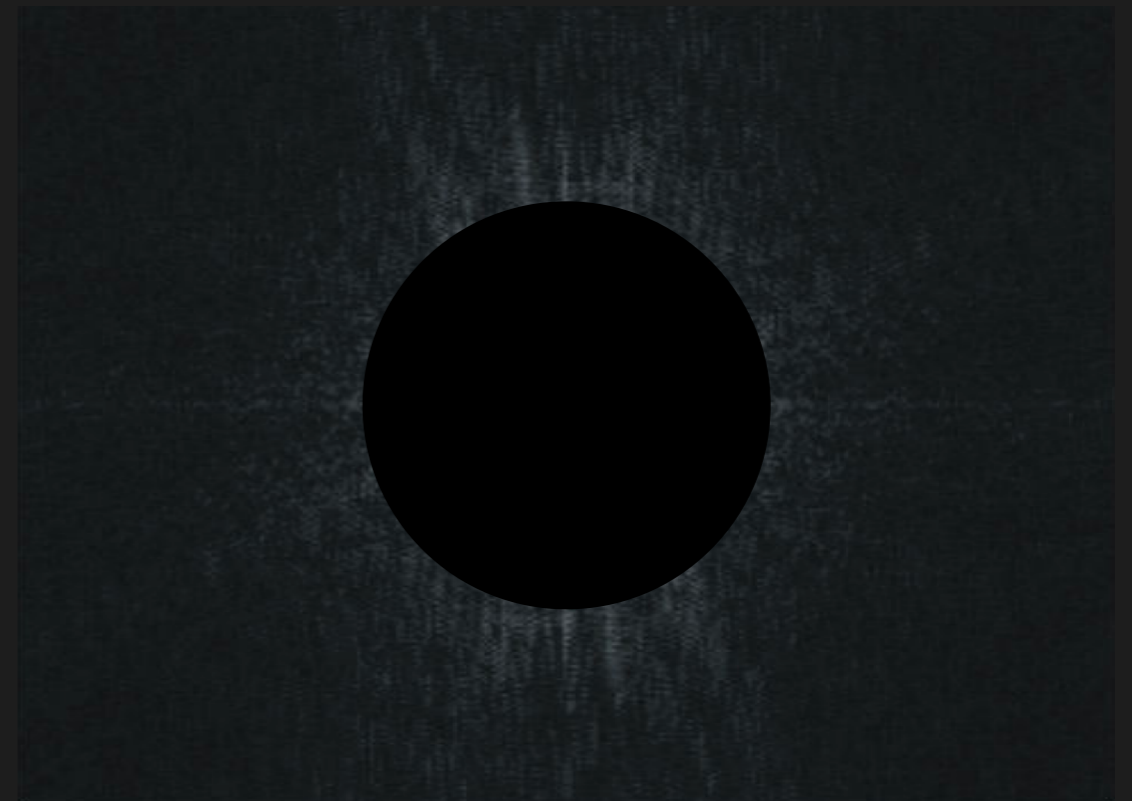
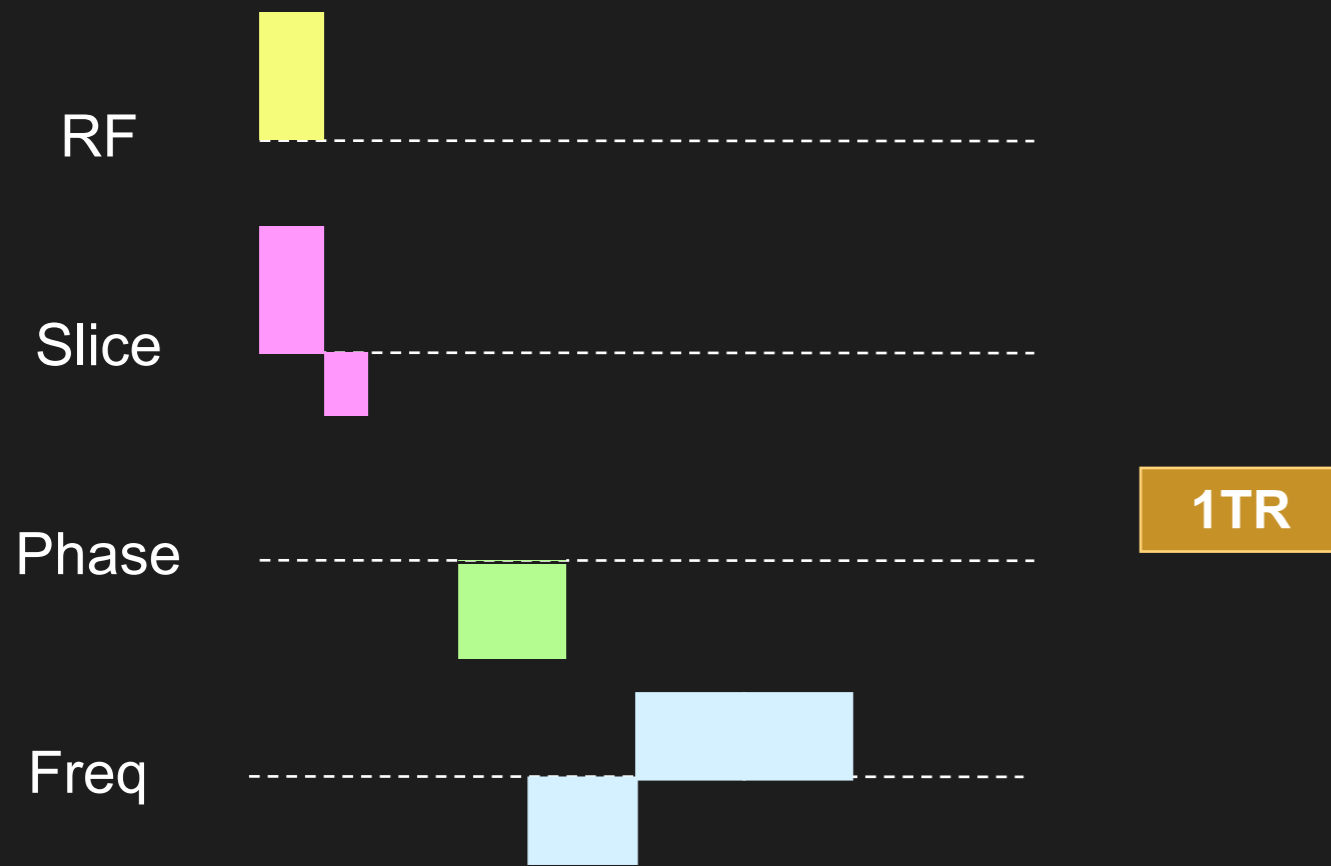


Full image

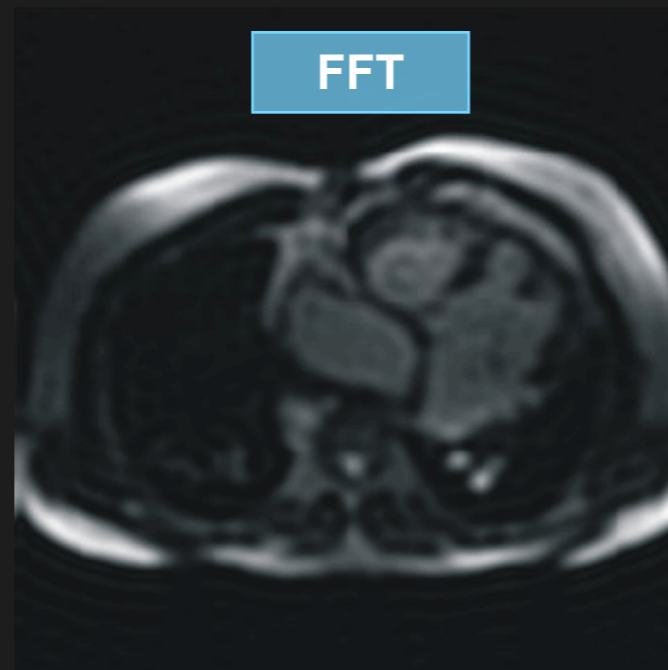


Low resolution - contrast

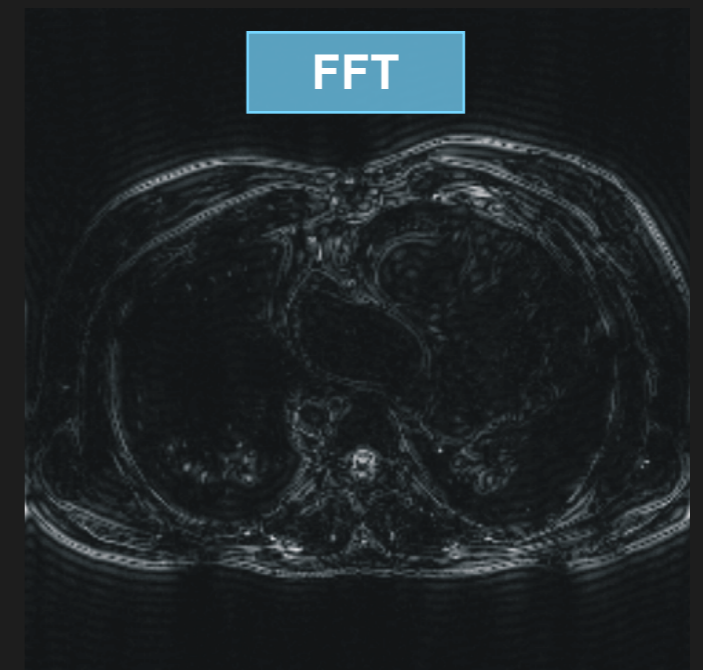
k-space filling



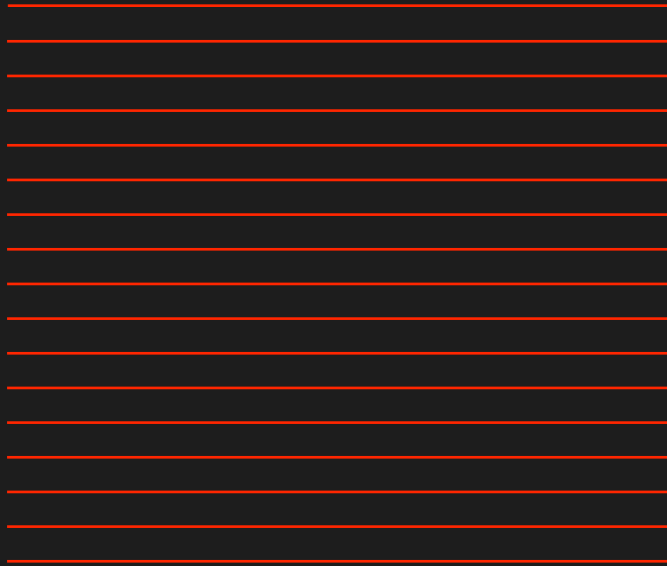
Full image

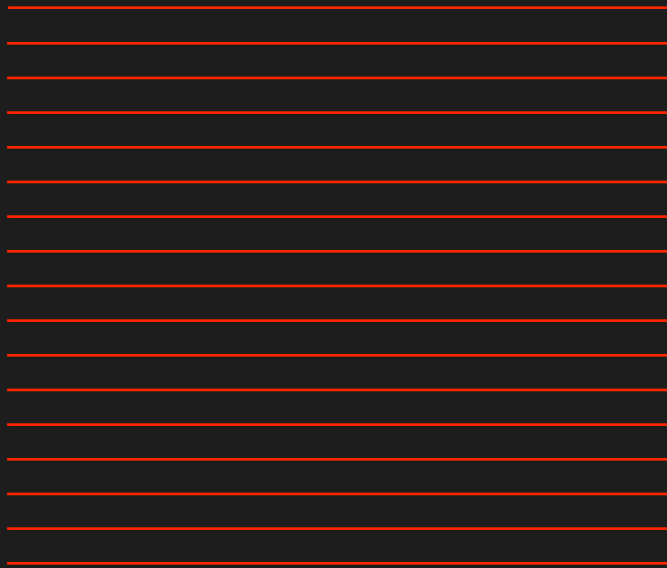


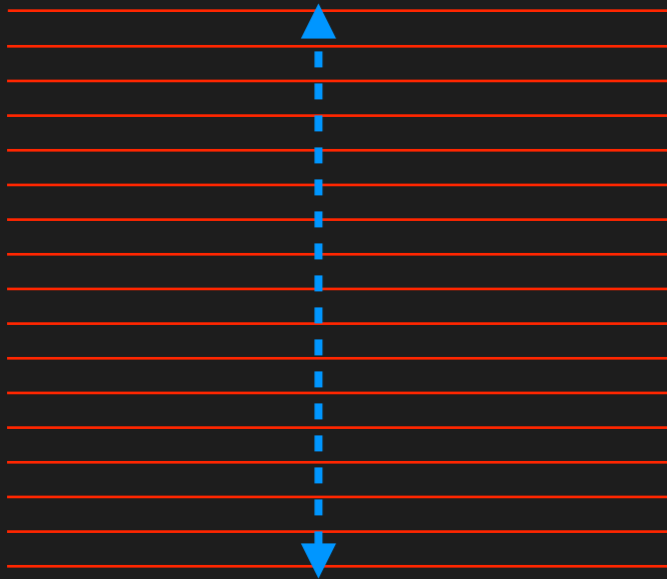
Low resolution - contrast



High resolution - edges





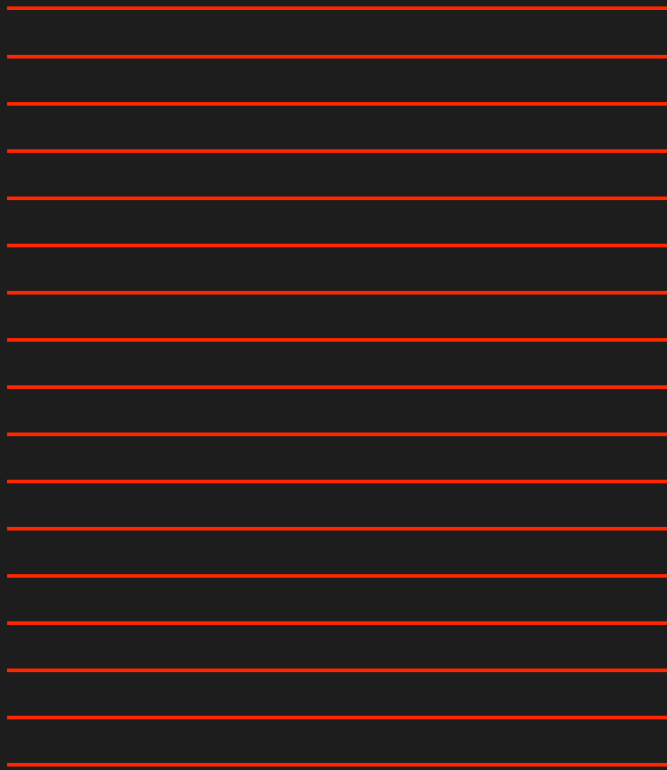


Resolution - size of K-space



Resolution - size of K-space

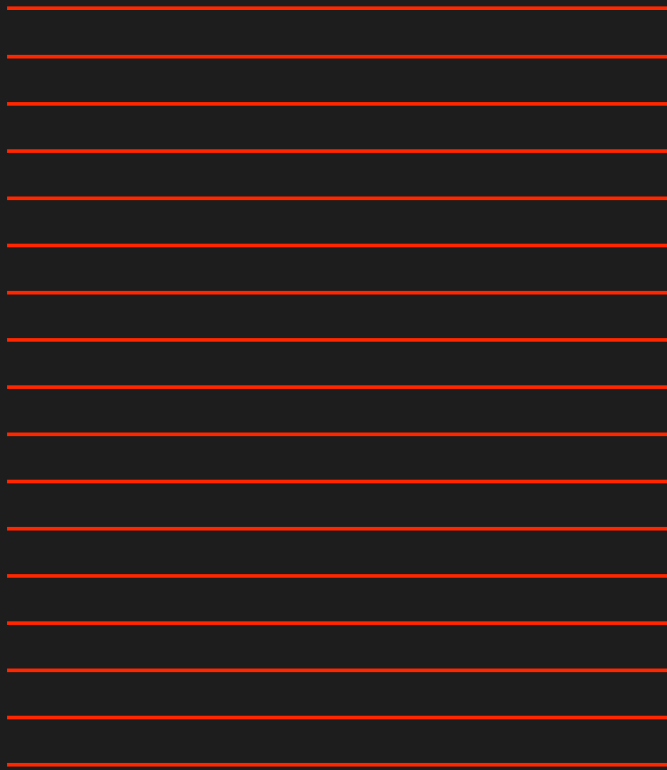
Increase line spacing



Resolution - size of K-space

Increase line spacing

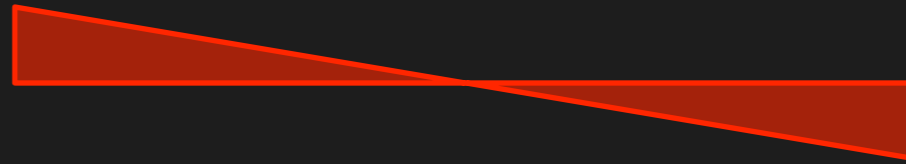
How do we do that?



Resolution - size of K-space

Increase line spacing

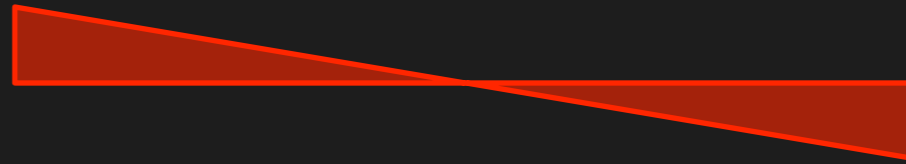
How do we do that?



Resolution - size of K-space

Increase line spacing

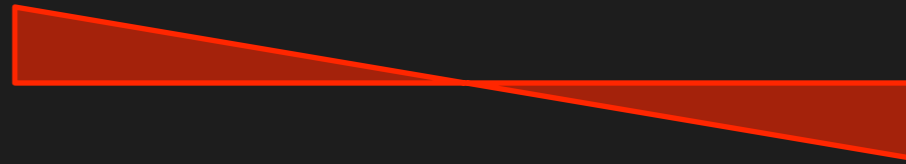
How do we do that?



Resolution - size of K-space

Increase line spacing

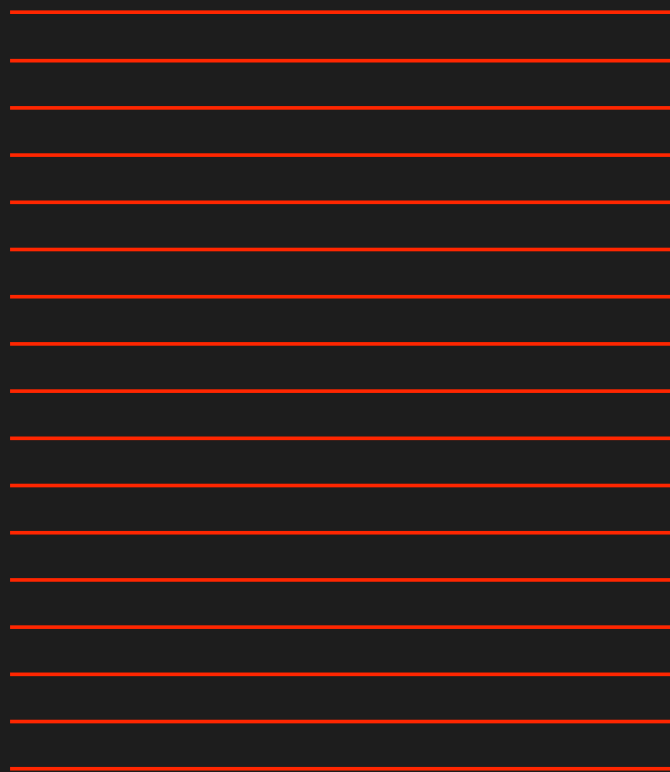
How do we do that?



Resolution - size of K-space

Increase line spacing

How do we do that?

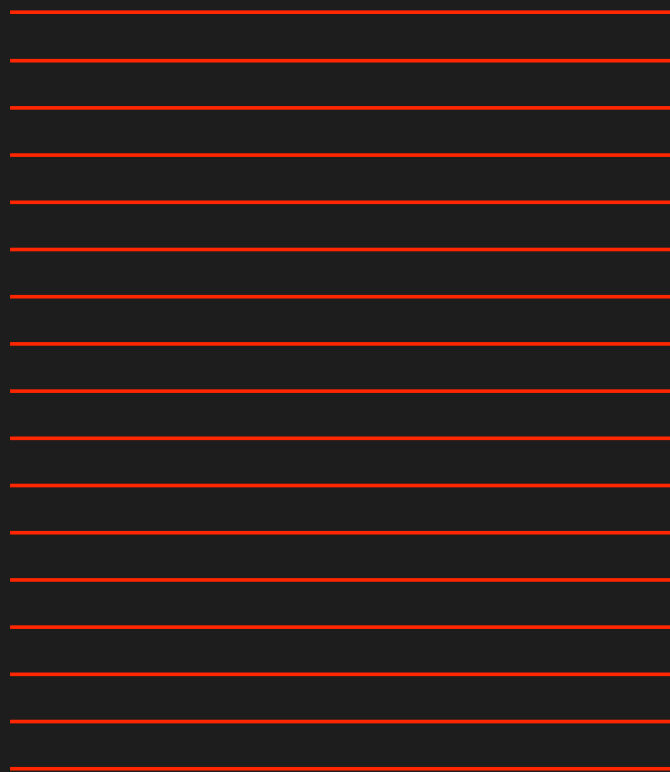


Larger gradient more dephasing

Resolution - size of K-space

Increase line spacing

How do we do that?



Larger gradient more dephasing

Resolution - size of K-space

Increase line spacing

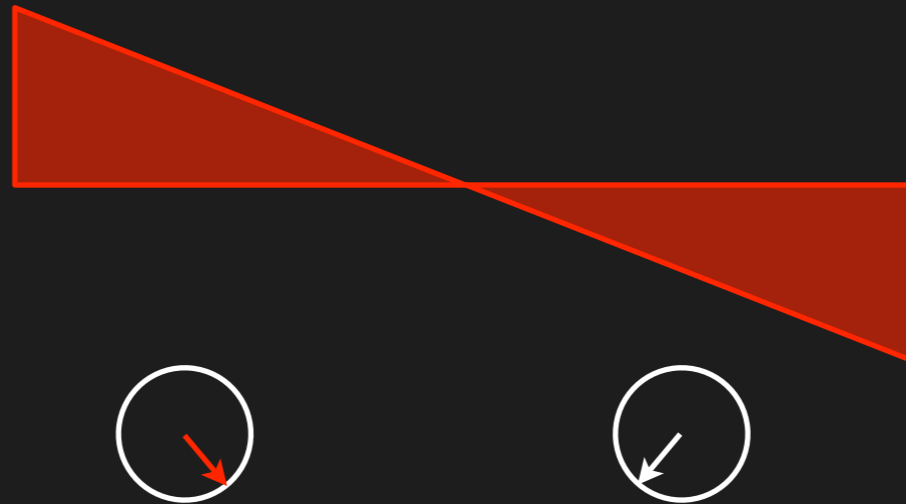
How do we do that?



Resolution - size of K-space

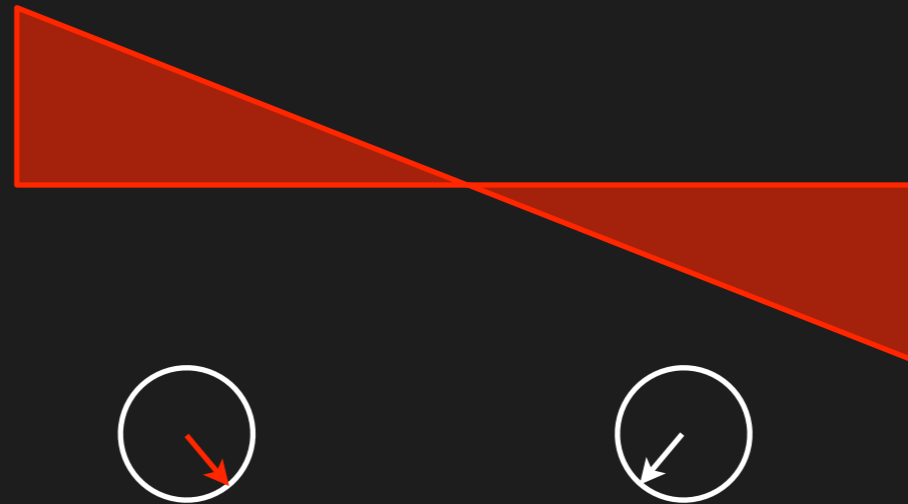
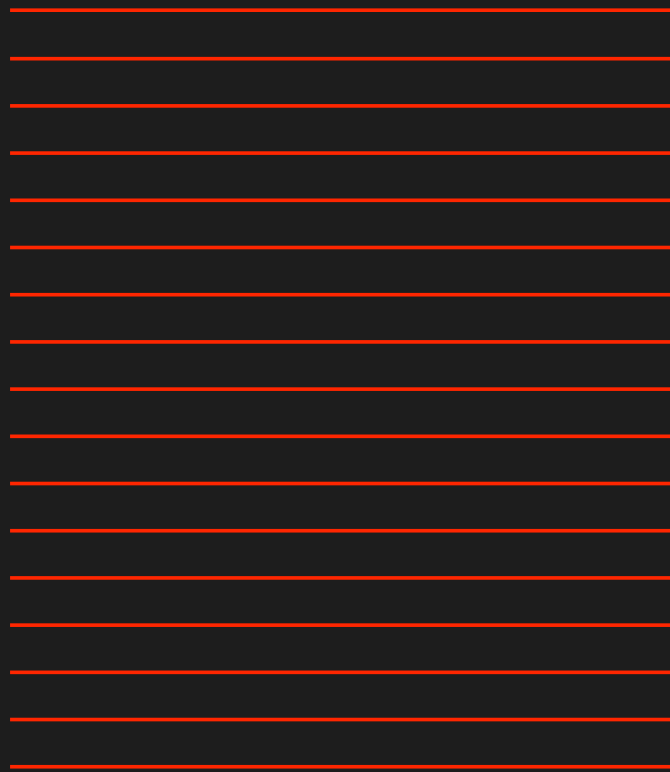
Increase line spacing

How do we do that?



Larger gradient more dephasing

Limited by aliasing - 360 phase



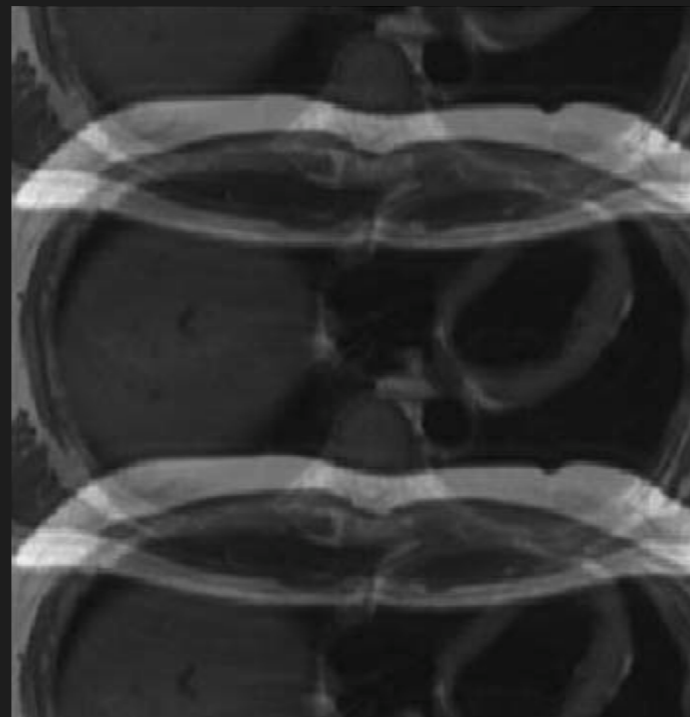
Larger gradient more dephasing

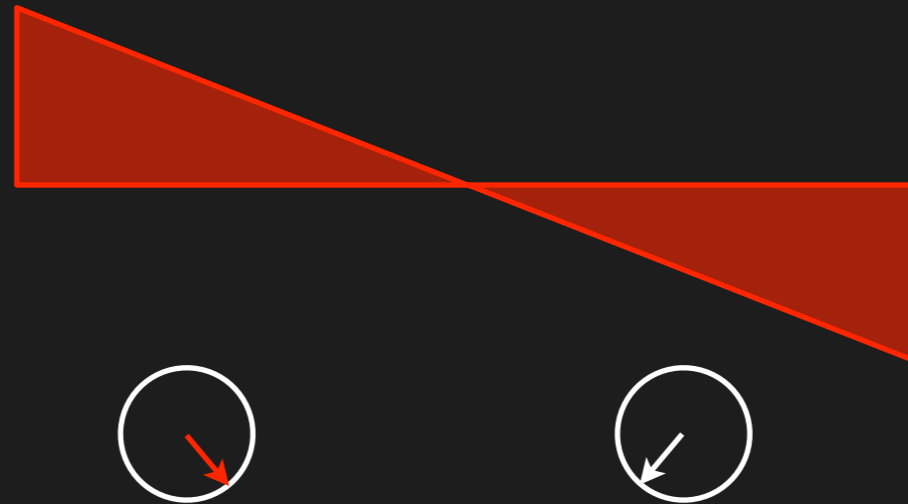
Limited by aliasing - 360 phase

Resolution - size of K-space

Increase line spacing

How do we do that?





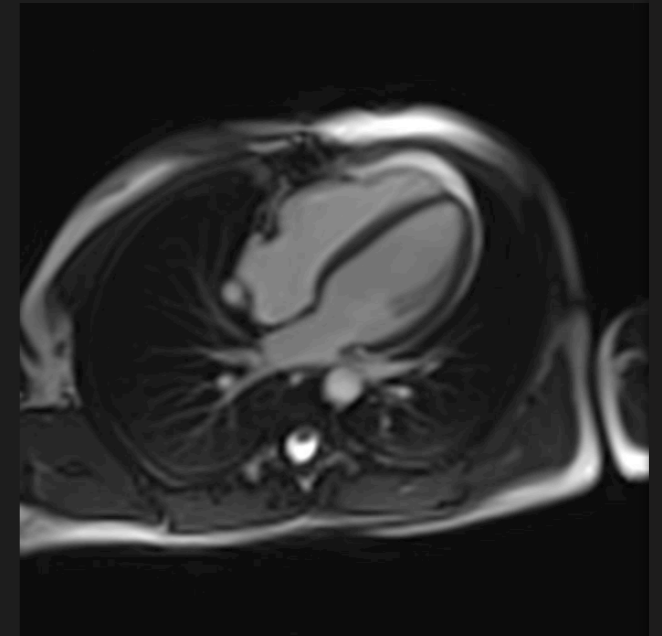
Larger gradient more dephasing

Limited by aliasing - 360 phase

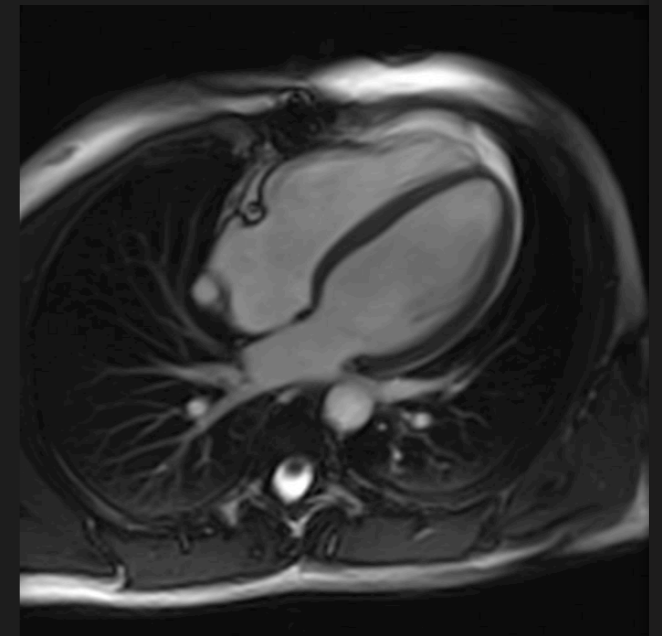
Resolution - size of K-space

Increase line spacing

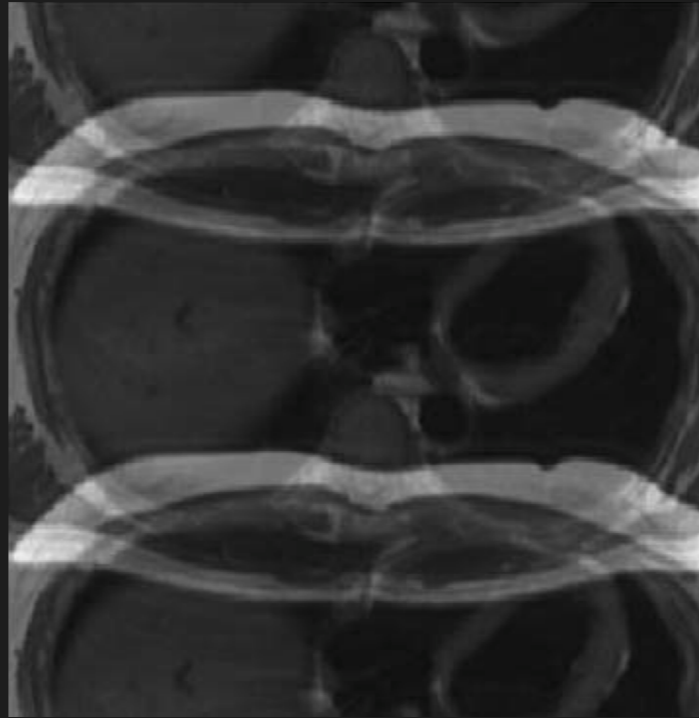
How do we do that?

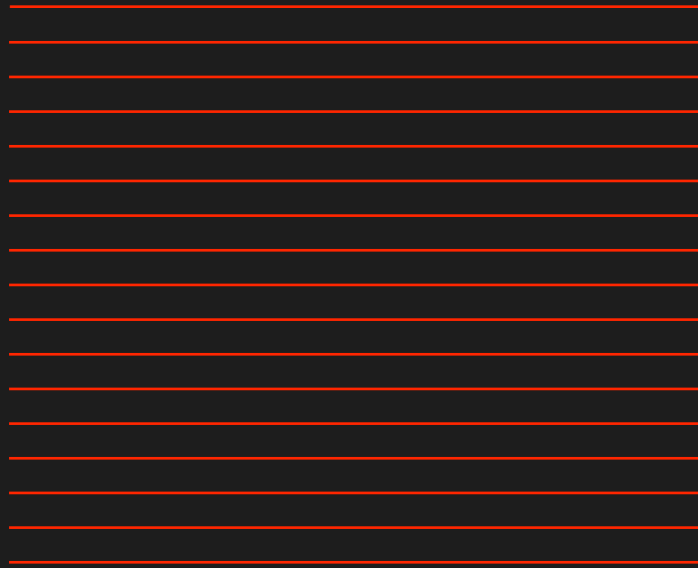


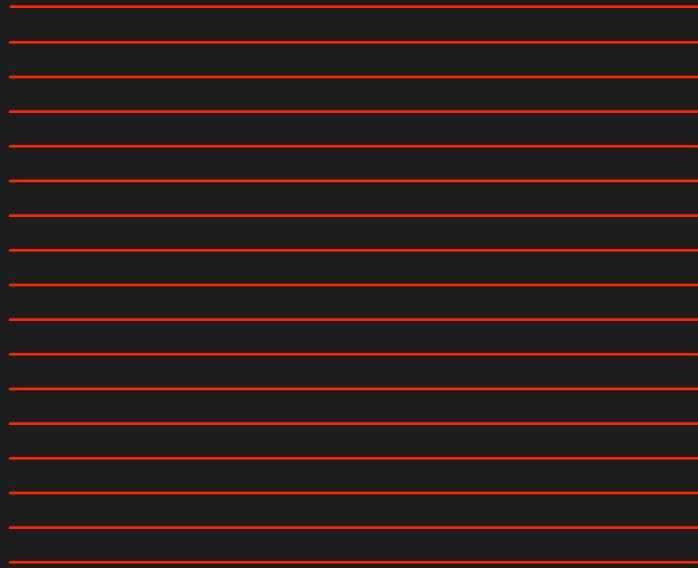
FOV = 500mm
Matrix = 176*176
Scan time = 15s

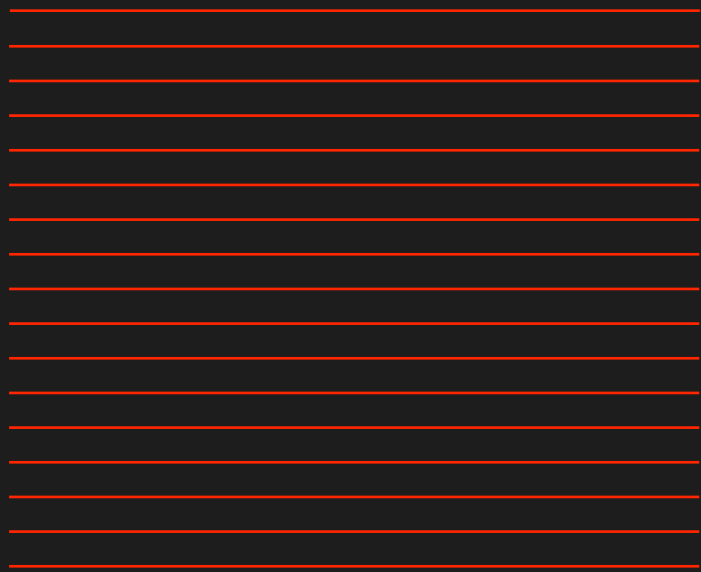


FOV = 300mm
Matrix = 176*176
Scan time = 15s

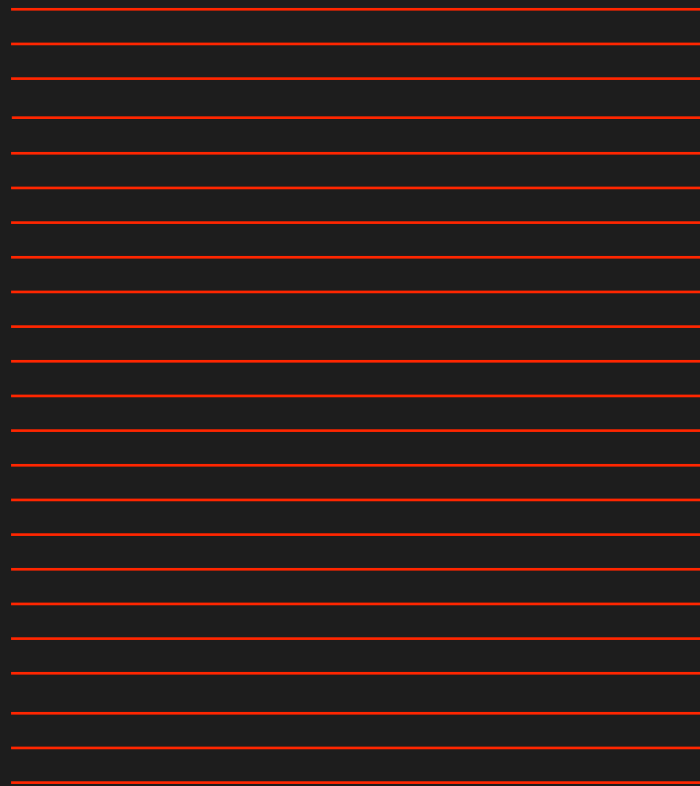






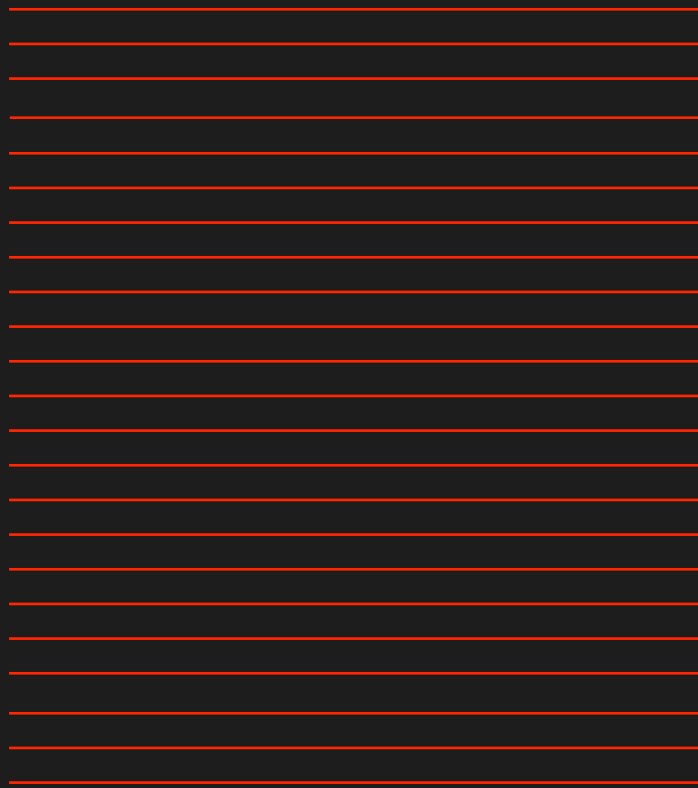


Resolution - size of K-space



Resolution - size of K-space

Increase number of lines

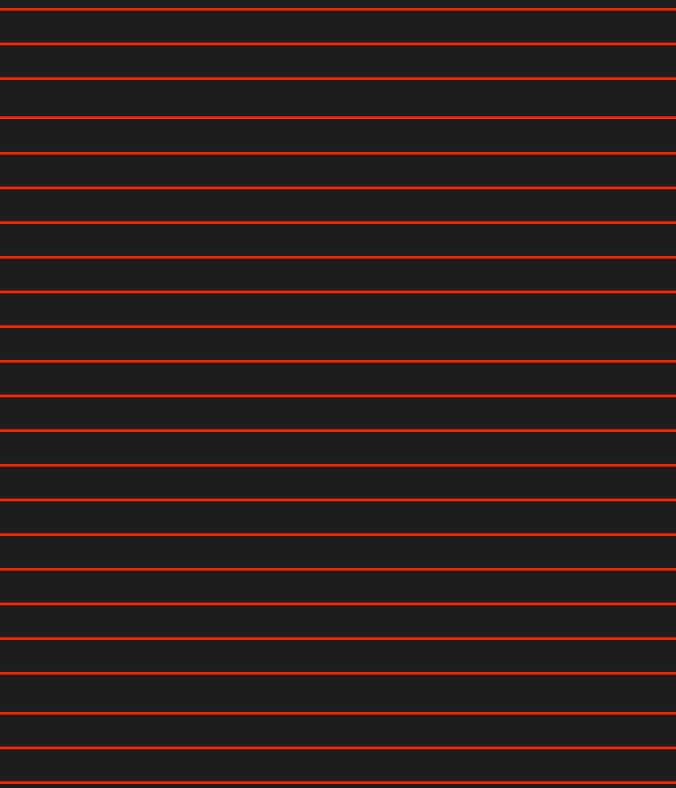


Resolution - size of K-space

Increase number of lines

How do we do that?

Increase matrix



Resolution - size of K-space

Increase number of lines

How do we do that?



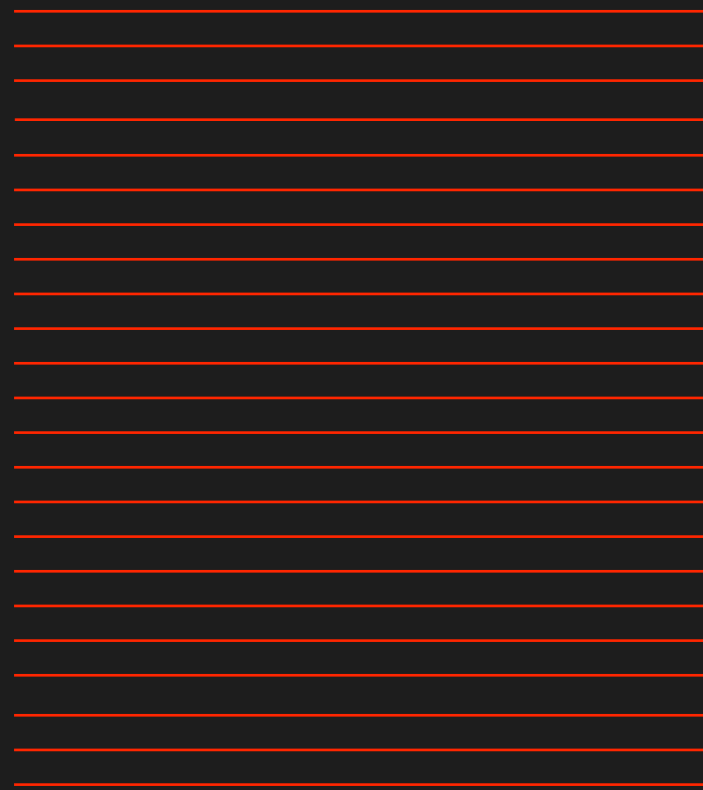
Increase matrix

Increased time

Resolution - size of K-space

Increase number of lines

How do we do that?



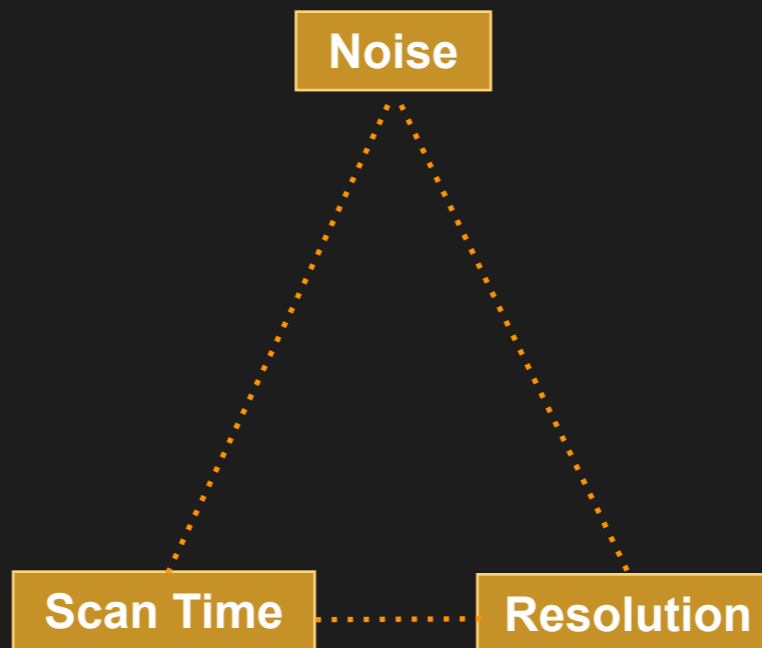
Increase matrix

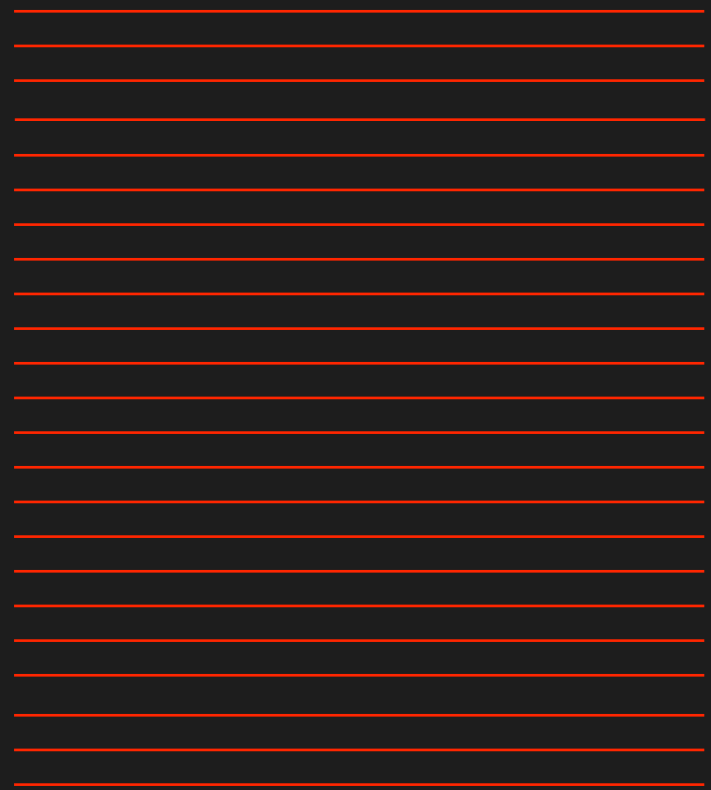
Increased time

Resolution - size of K-space

Increase number of lines

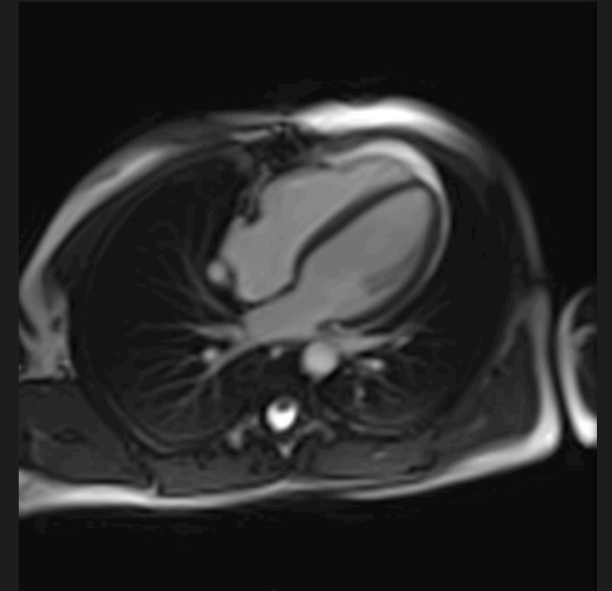
How do we do that?





Increase matrix

Increased time



FOV = 500mm
Matrix = 176*176
Scan time = 15s

Noise

Resolution - size of K-space

Increase number of lines

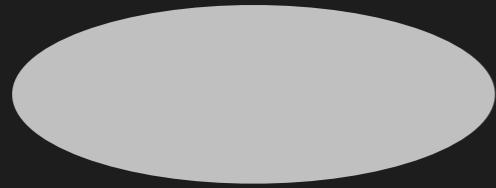
Scan Time

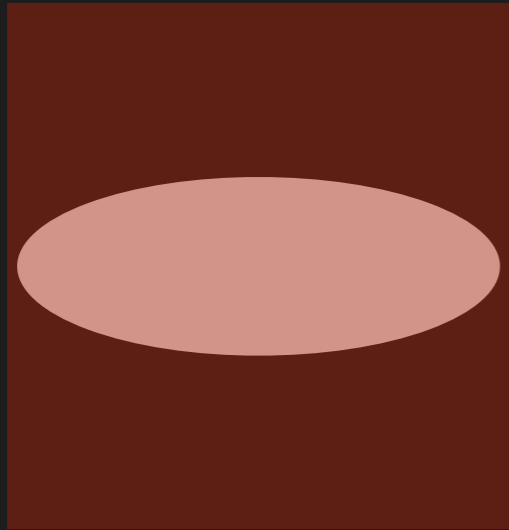
Resolution



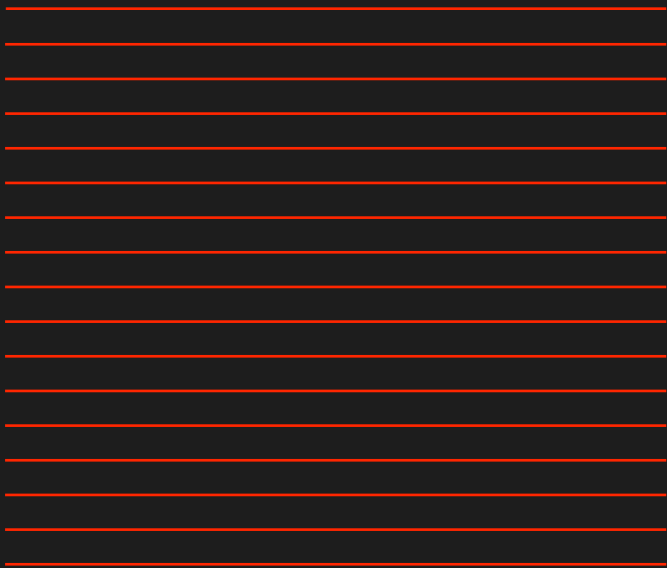
FOV = 500mm
Matrix = 240*240
Scan time = 20s

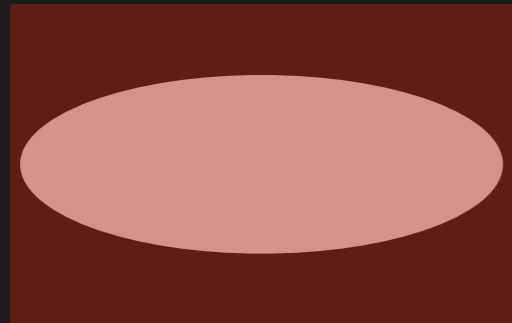
How do we do that?





Square FOV

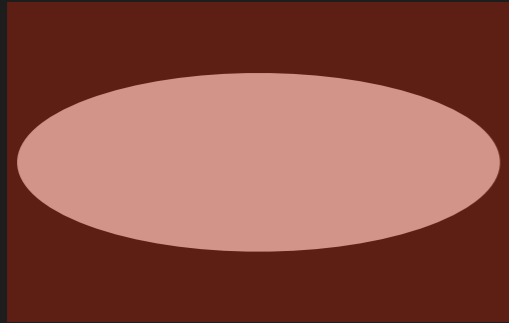




Square FOV

Smaller FOV - PE direction



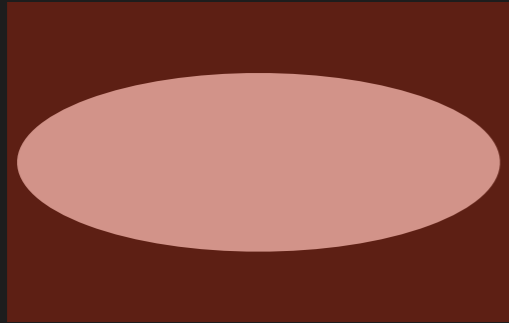


Square FOV

Smaller FOV - PE direction

Increase resolution



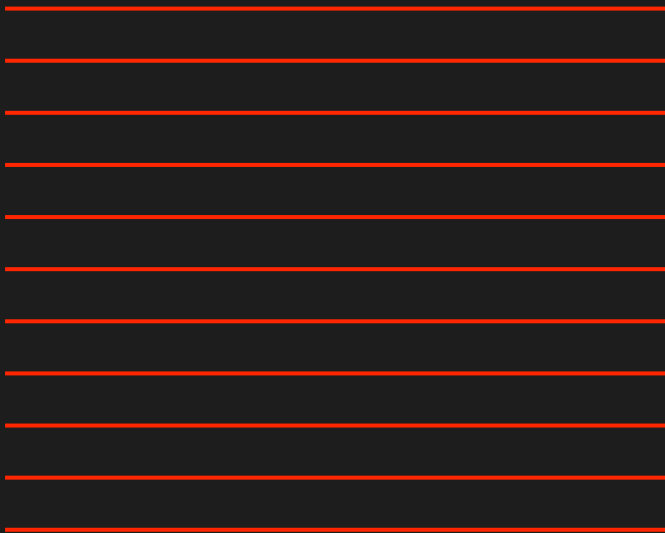


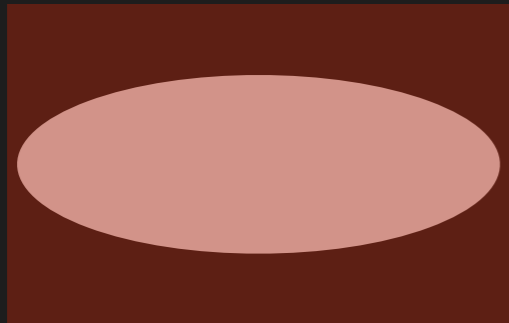
Square FOV

Smaller FOV - PE direction

Increase resolution

Lose lines





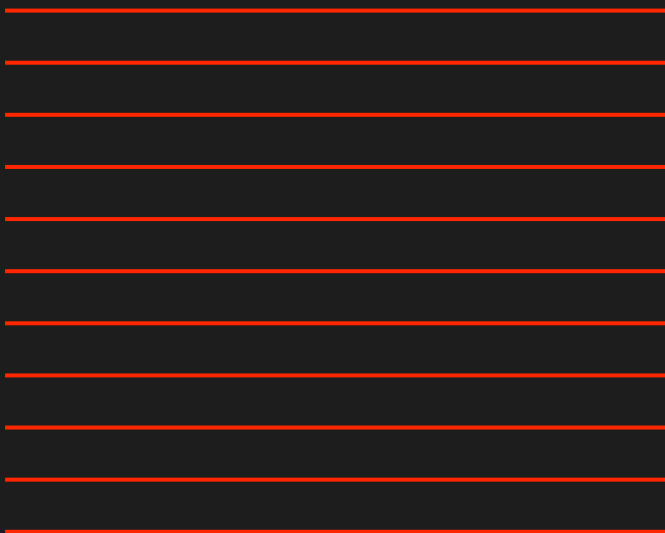
Square FOV

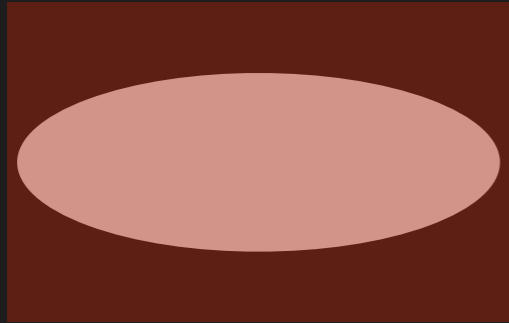
Smaller FOV - PE direction

Increase resolution

Lose lines

Same resolution





Square FOV

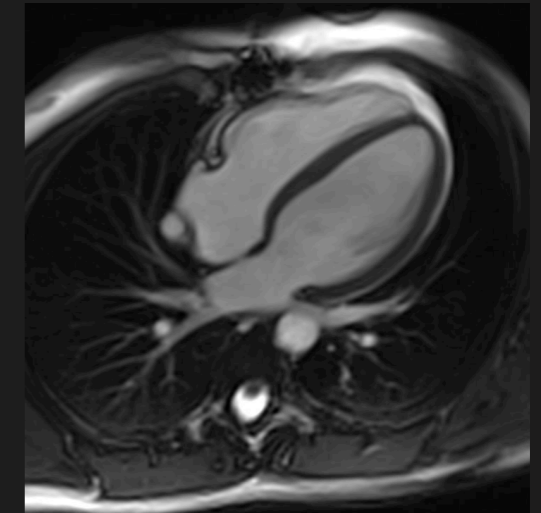
Smaller FOV - PE direction

Increase resolution

Lose lines

Same resolution

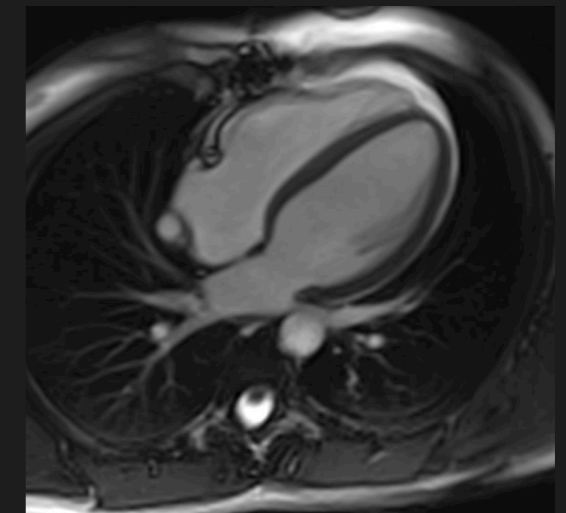
Shorter time - loss of SNR



FOV = 350mm

Matrix = 192*192

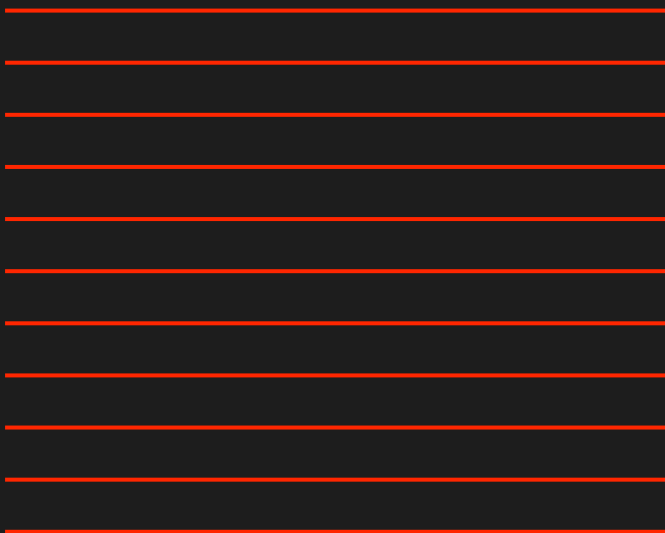
Scan time = 16s

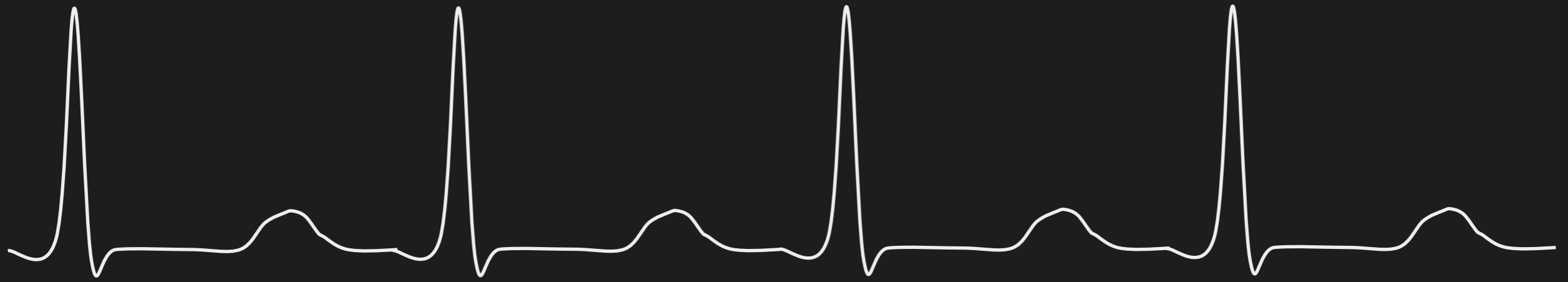


FOV = 350mm

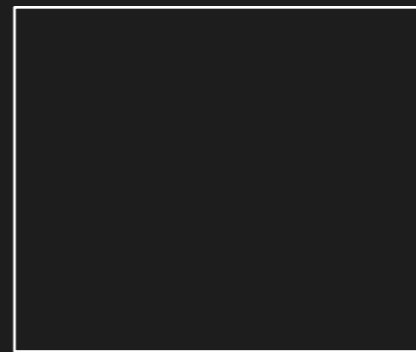
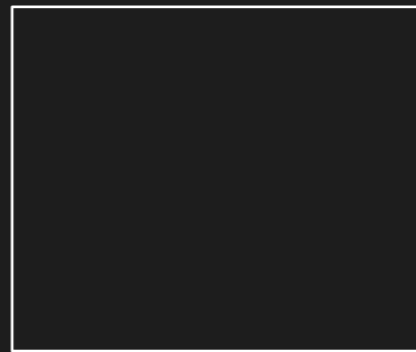
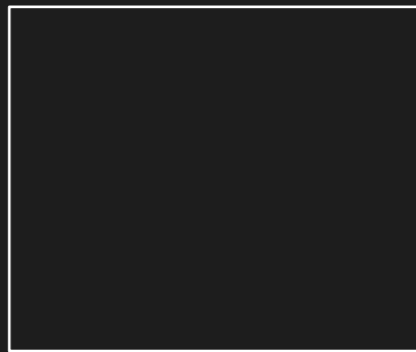
Matrix = 144*192

Scan time = 12s

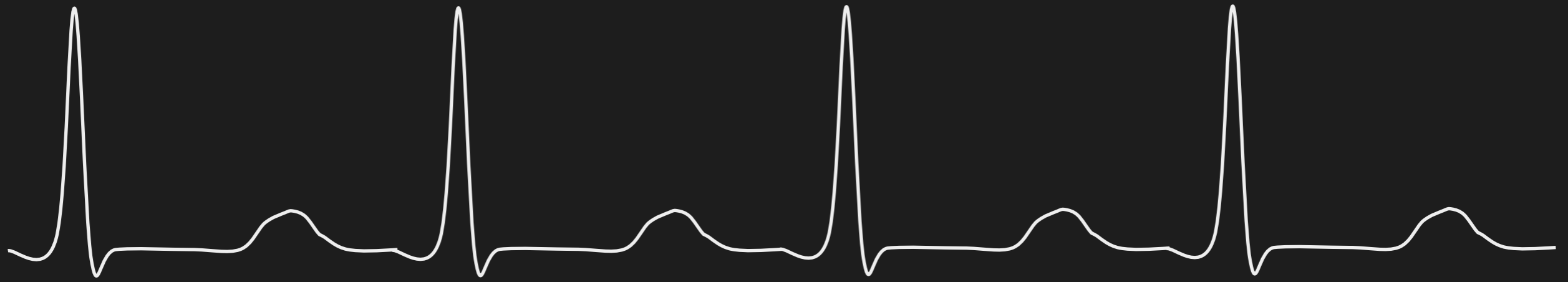




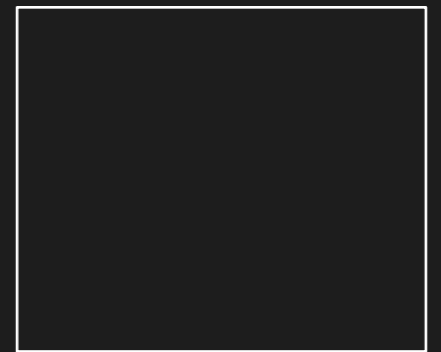
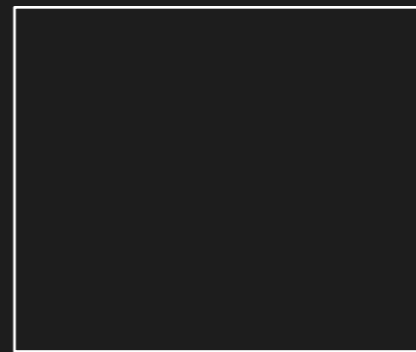
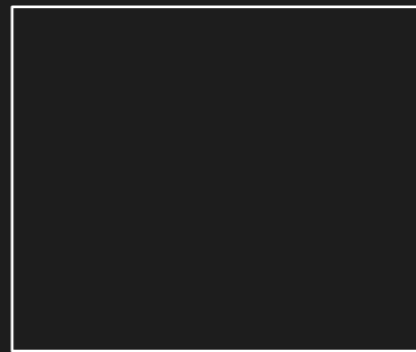
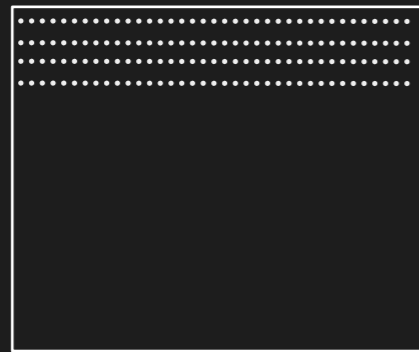
Signal



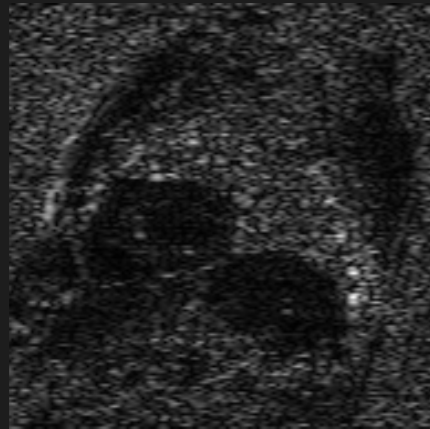
Images

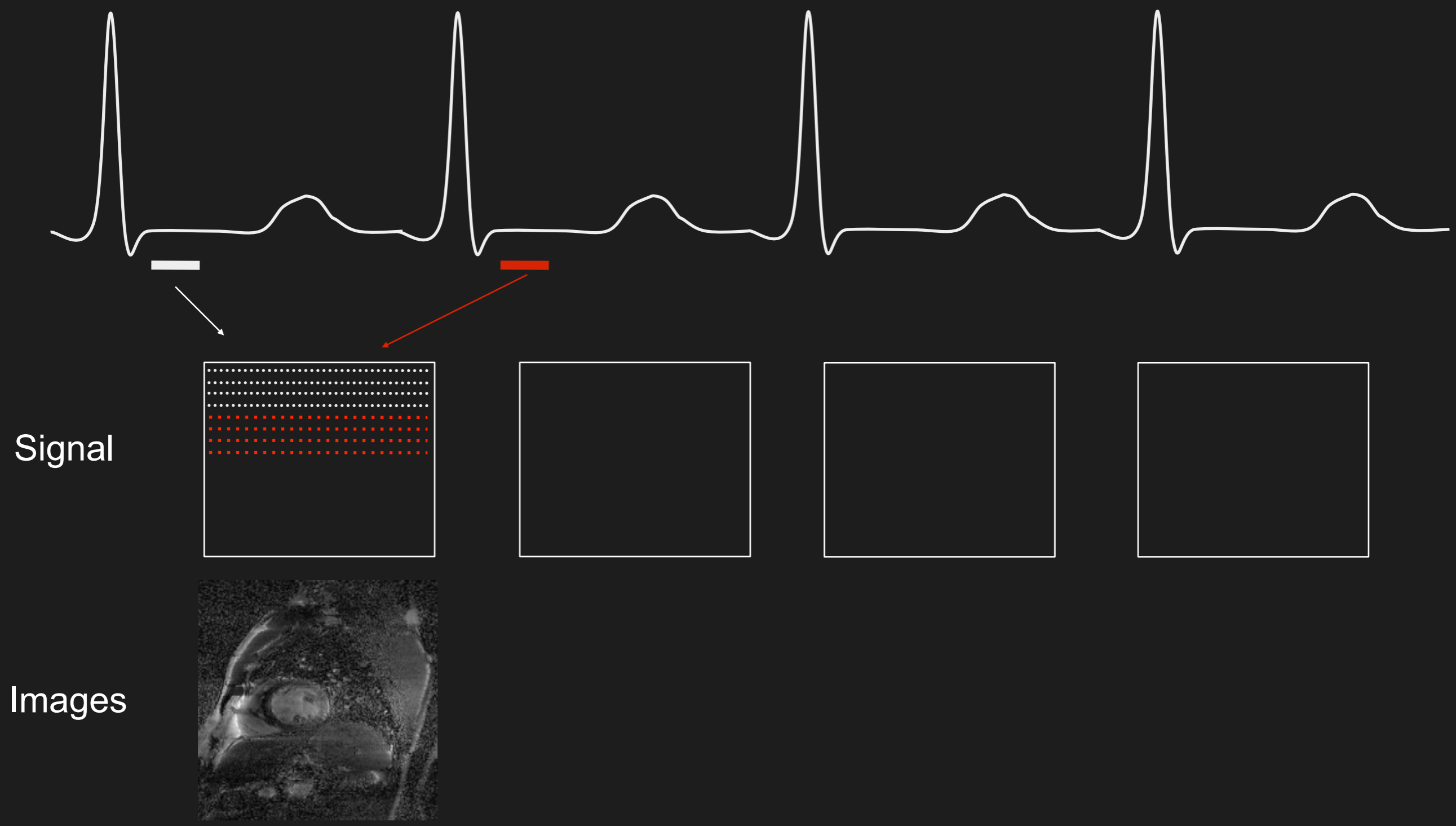


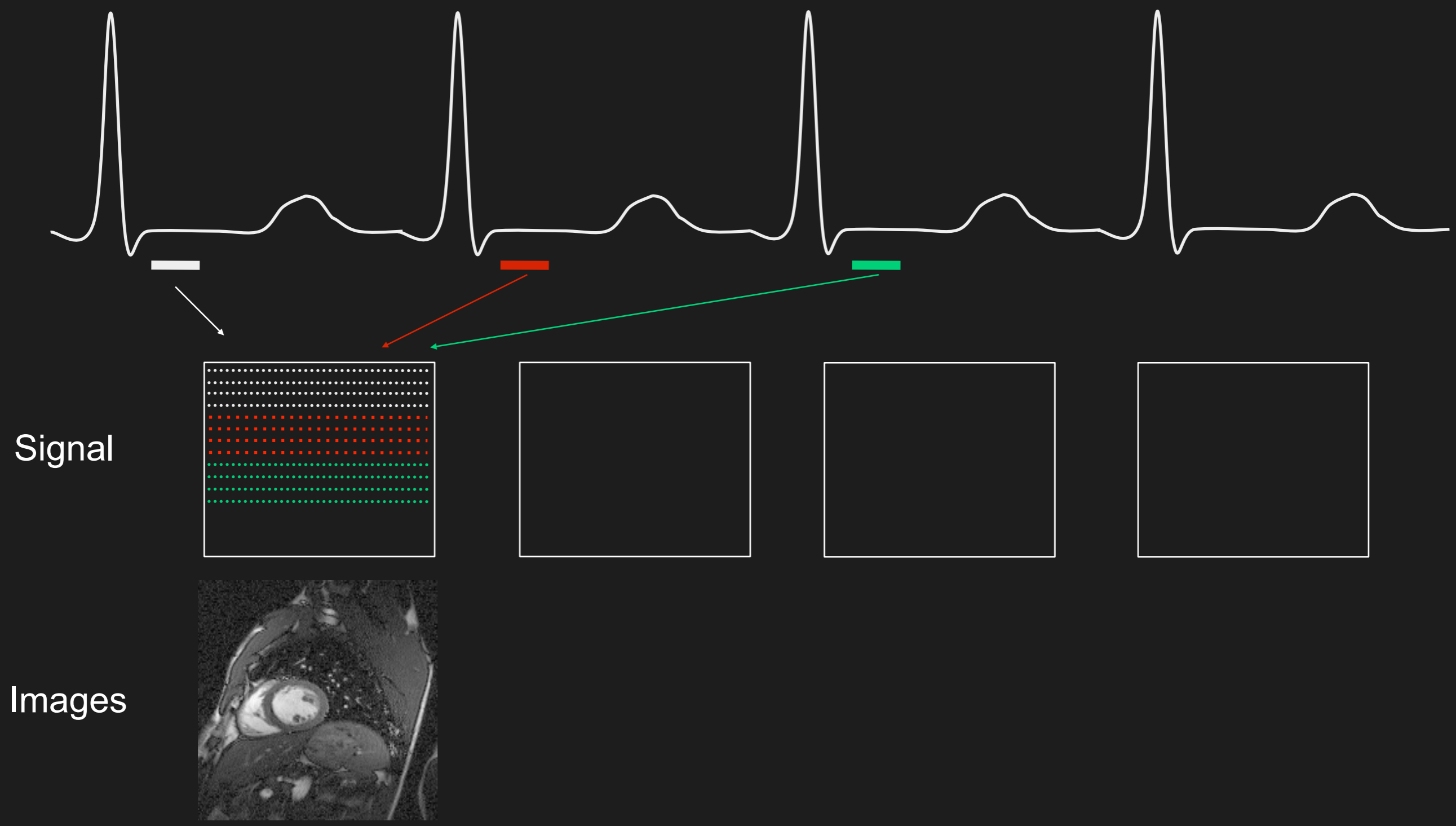
Signal

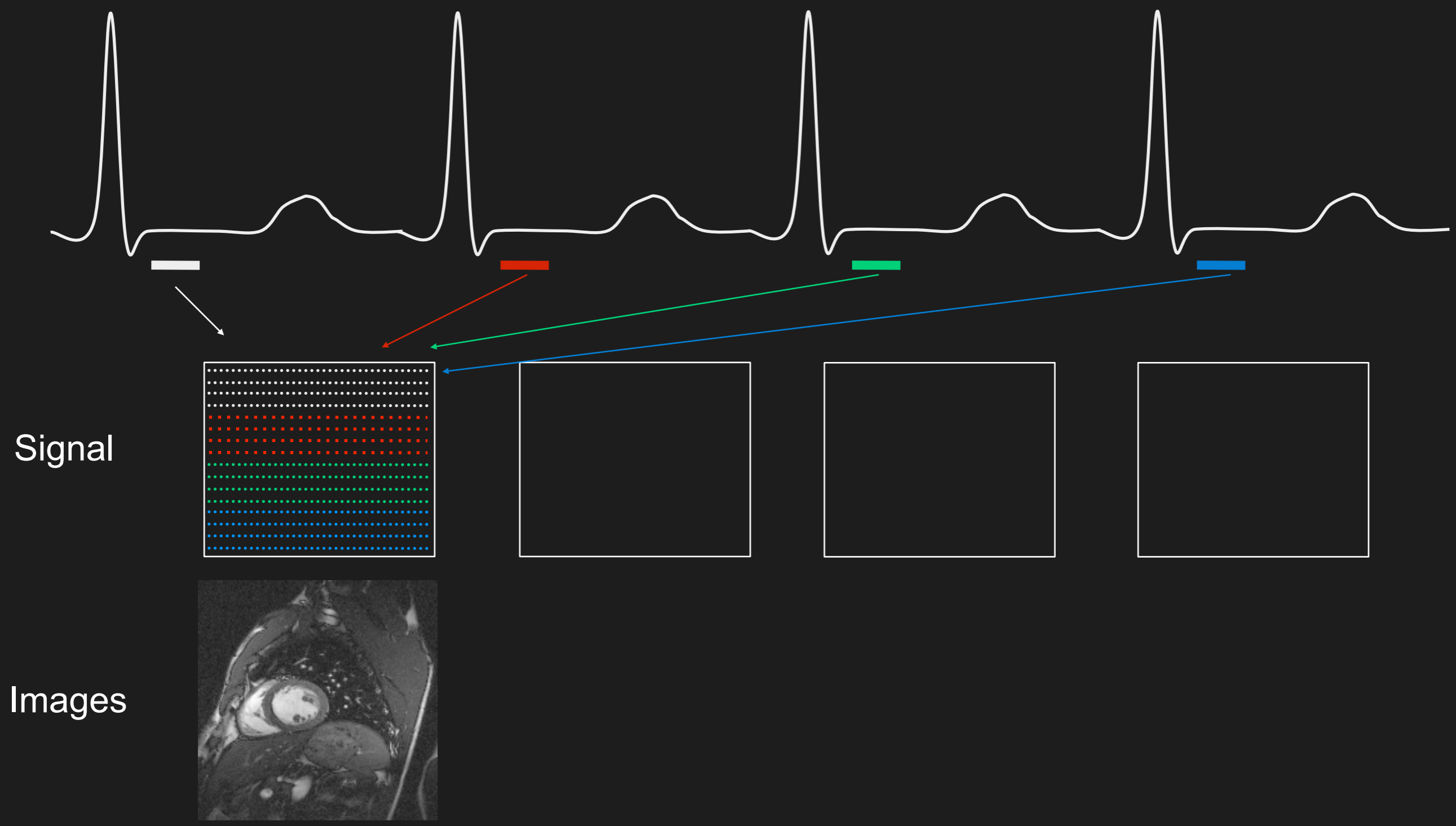


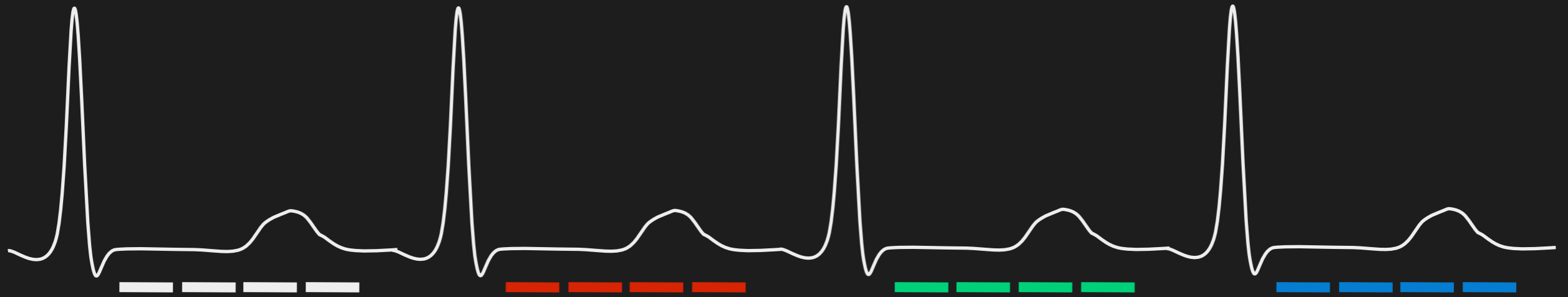
Images



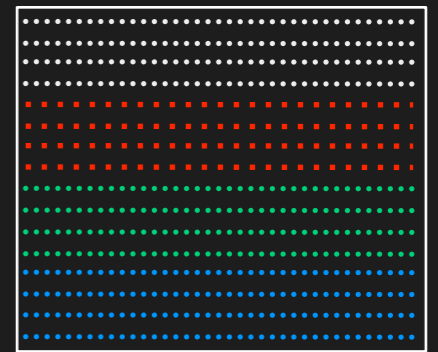
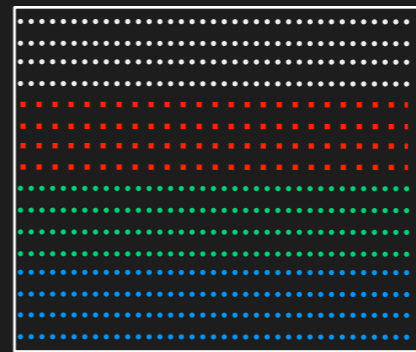
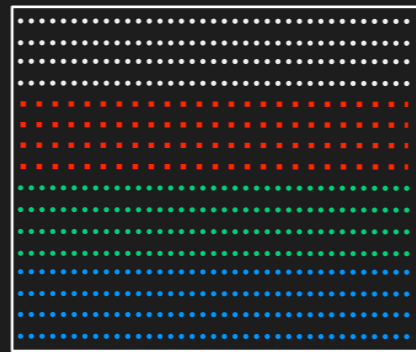
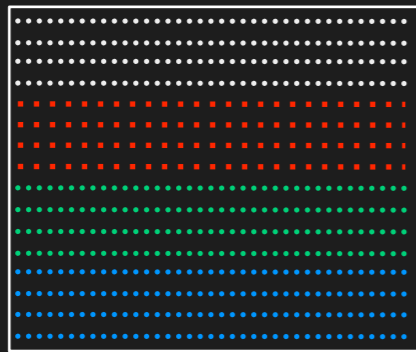




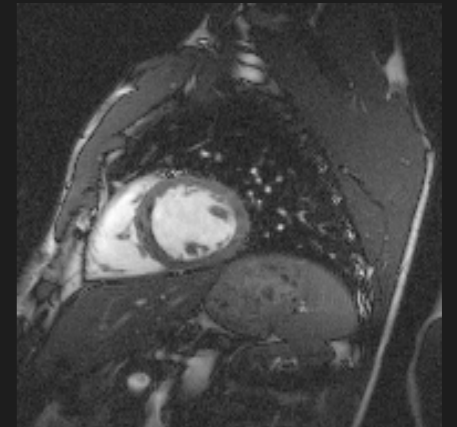
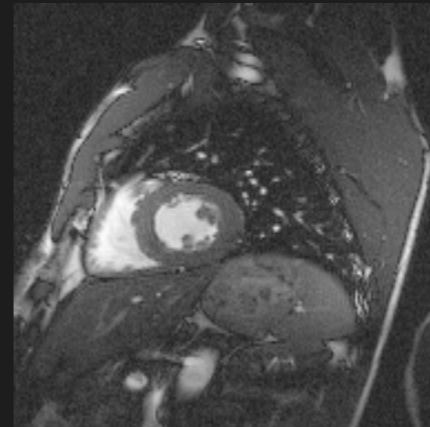
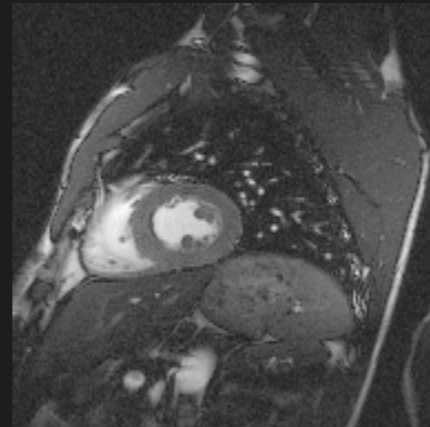
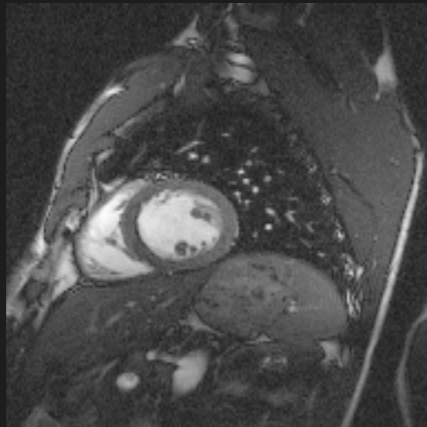




Signal

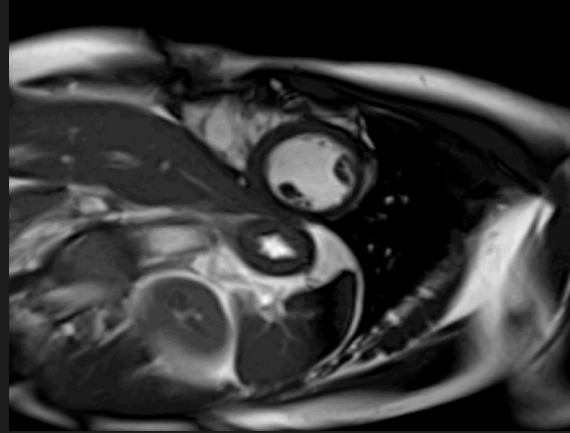


Images

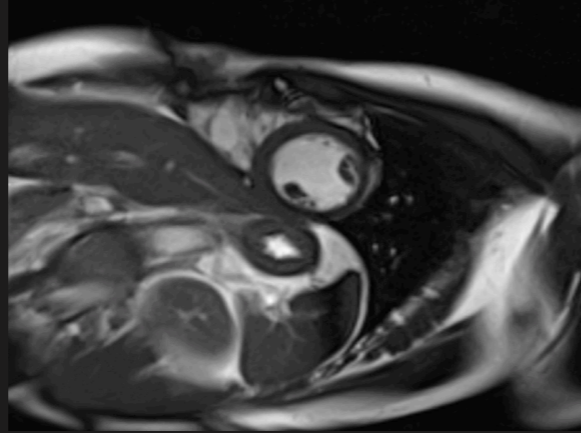


Temporal resolution

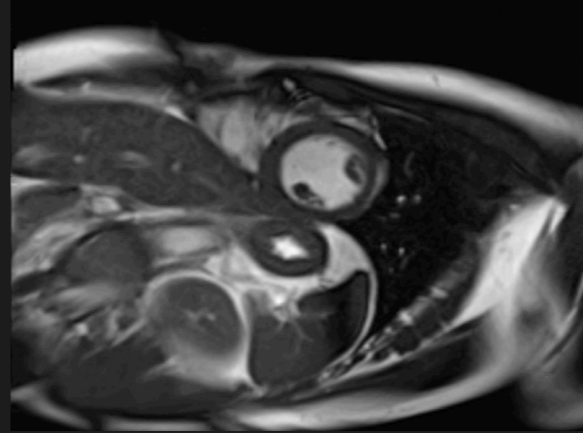
100 fps



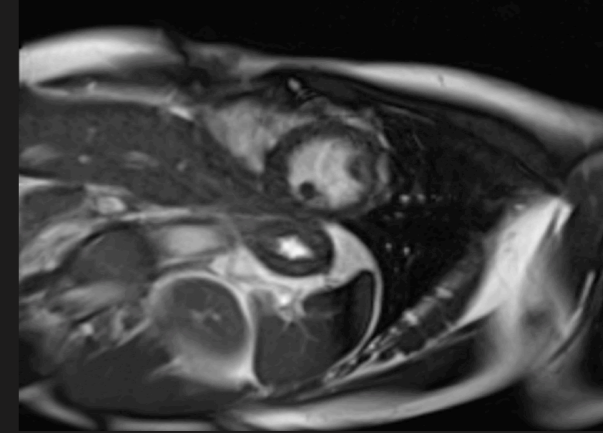
50 fps



10 fps

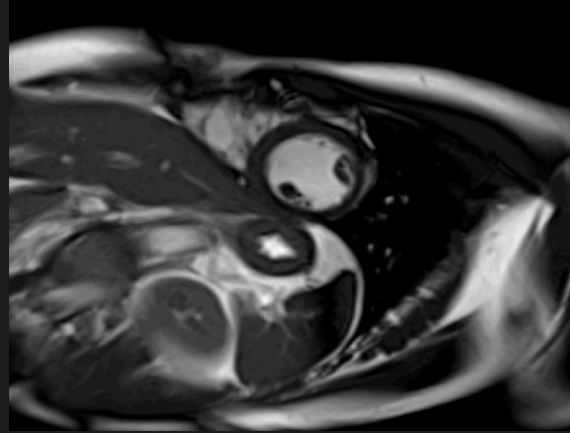


5 fps

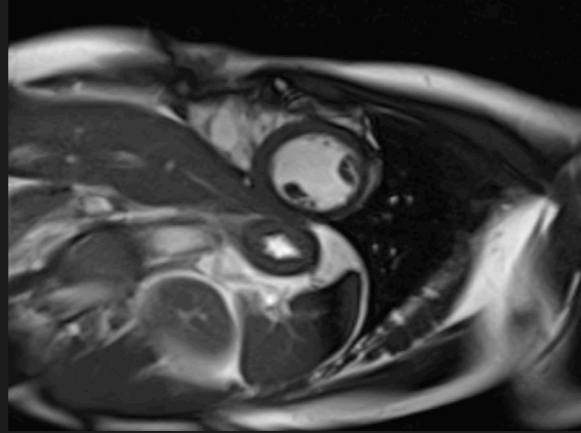


Temporal resolution

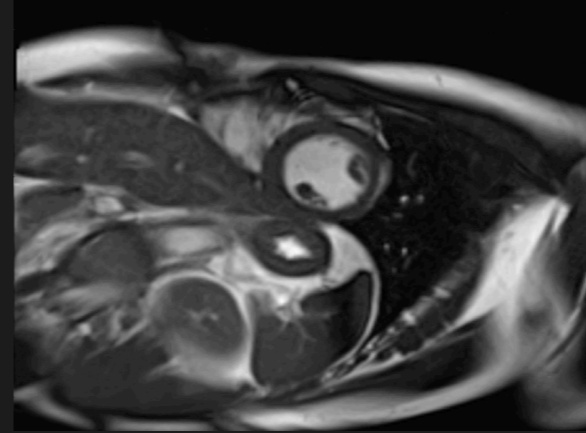
100 fps



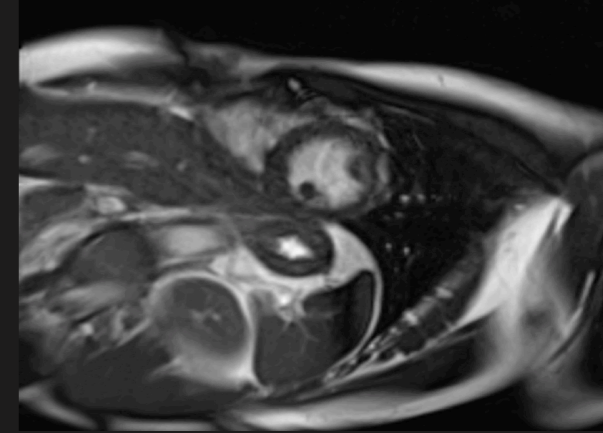
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10 fps

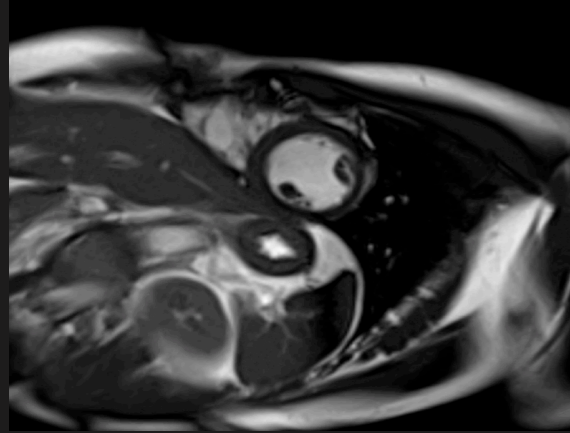


5 fps

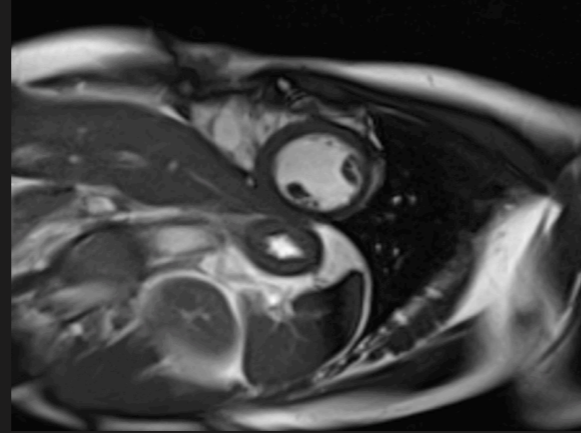


Temporal resolution

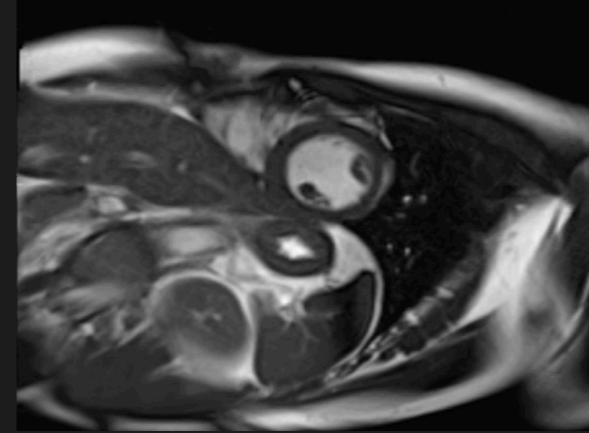
100 fps



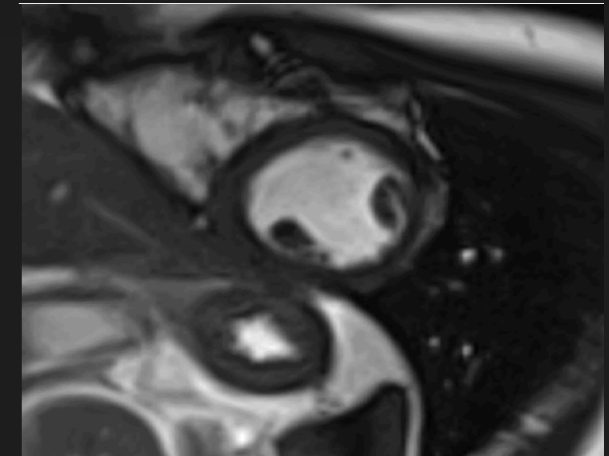
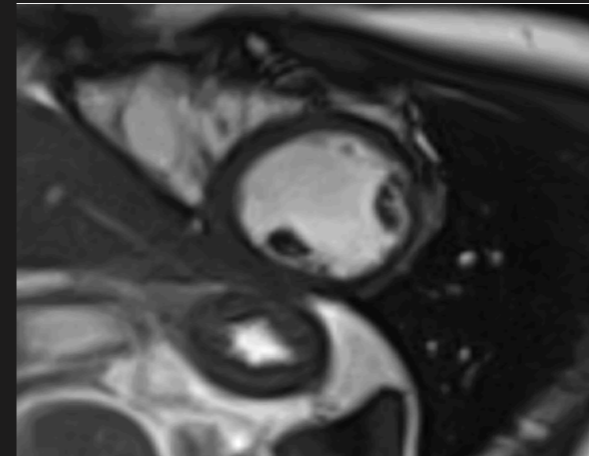
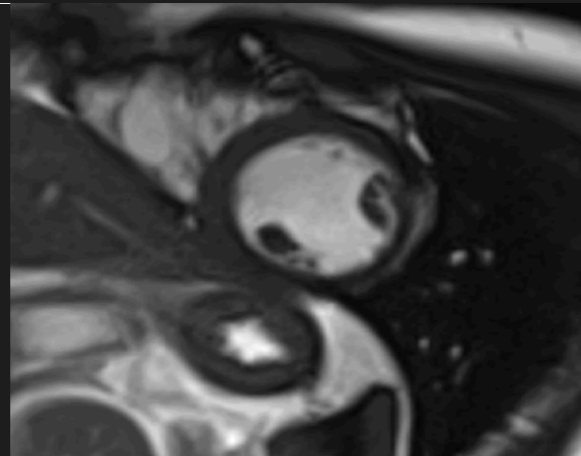
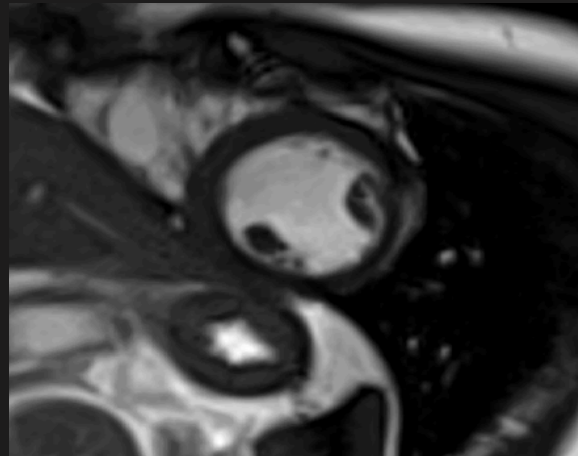
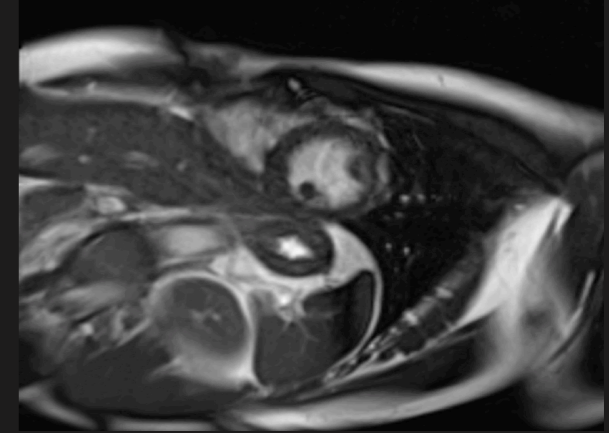
50 fps



10 fps

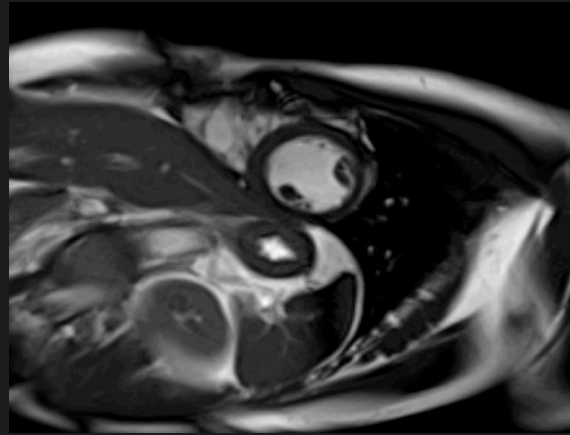


5 fps

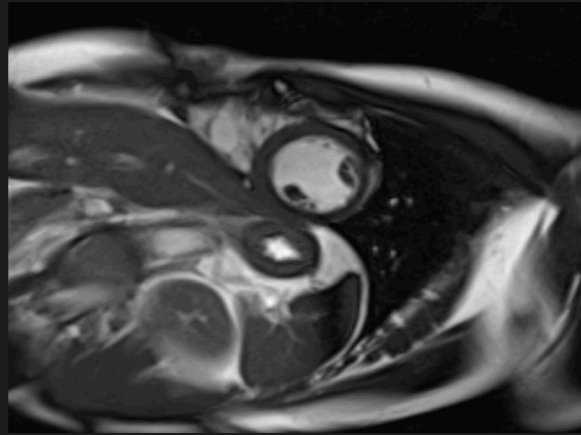


Temporal resolution

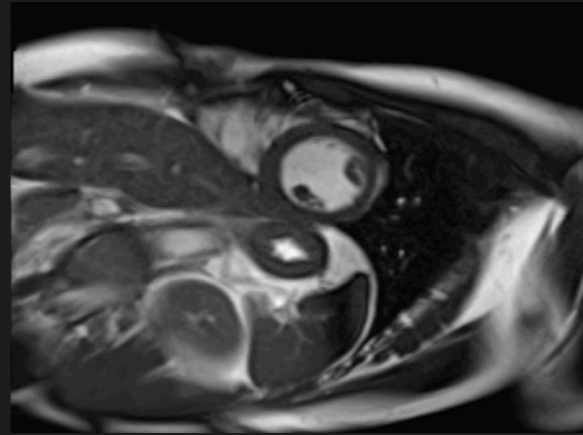
100 fps



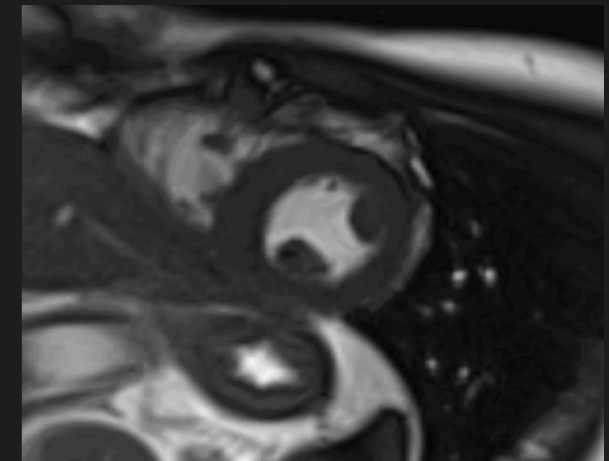
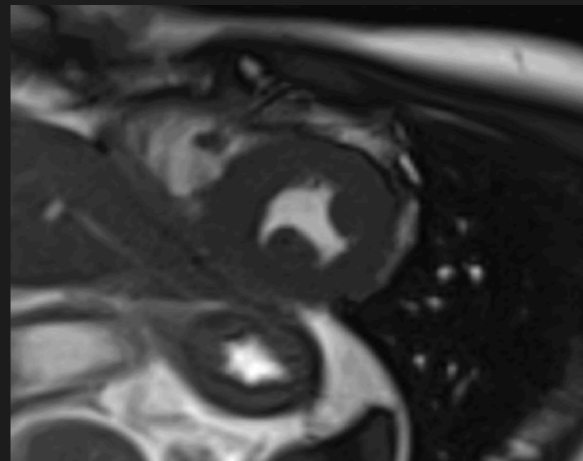
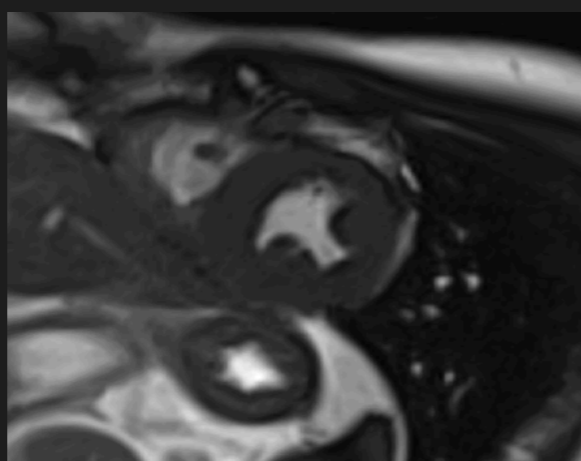
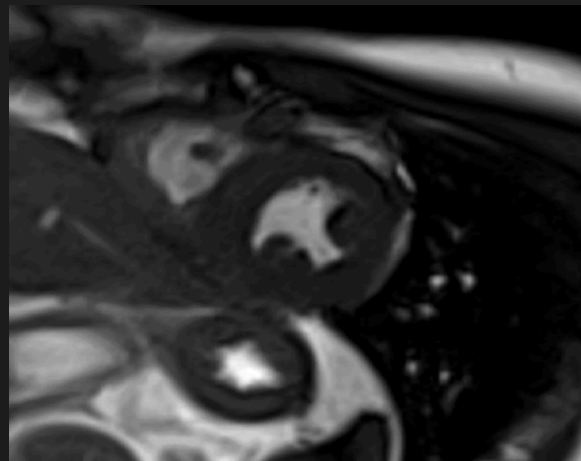
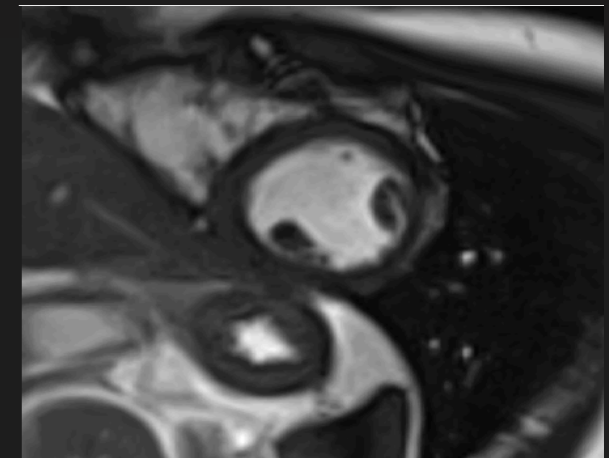
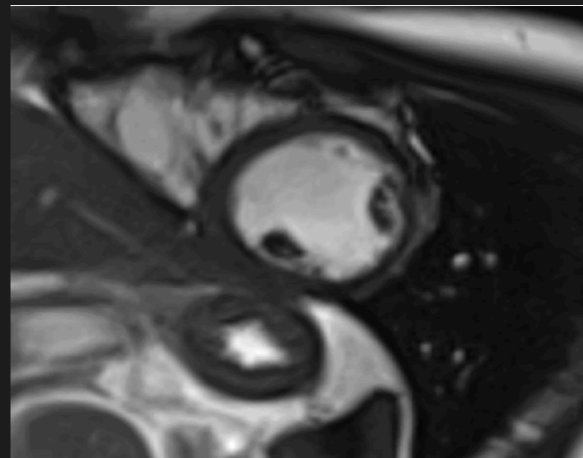
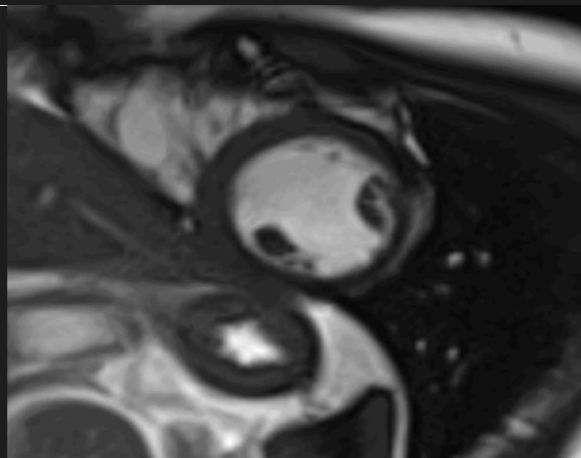
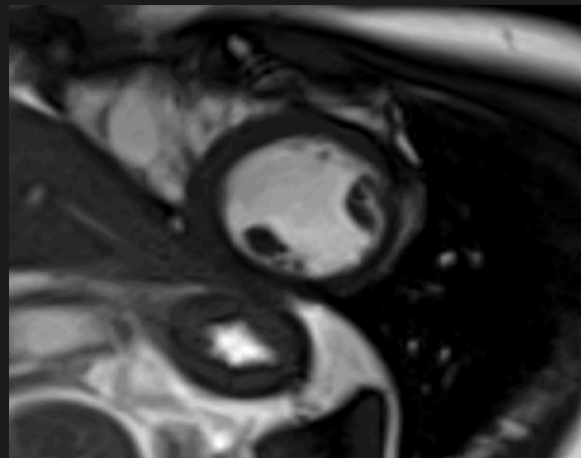
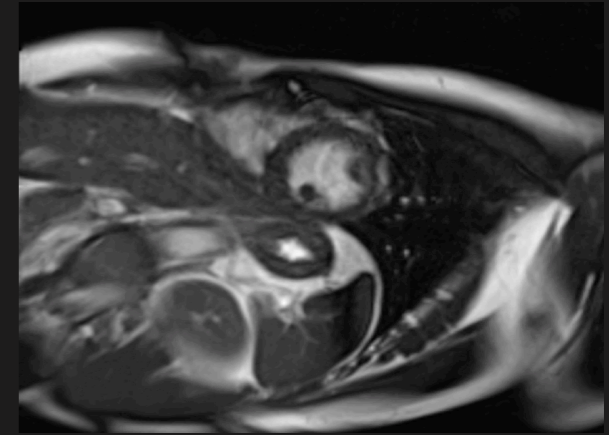
50 fps



10 fps

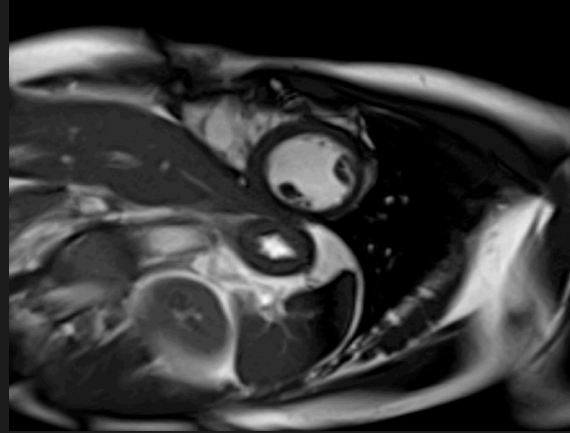


5 fps

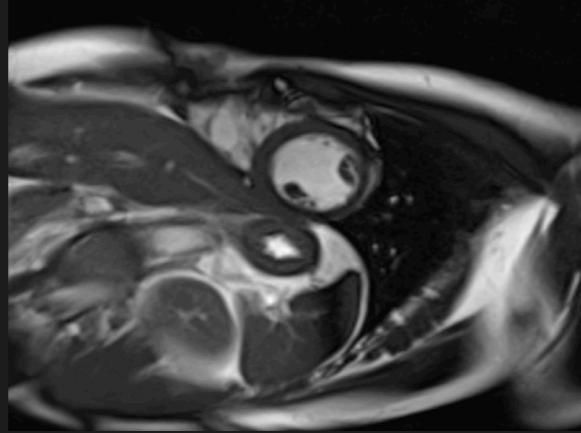


Temporal resolution

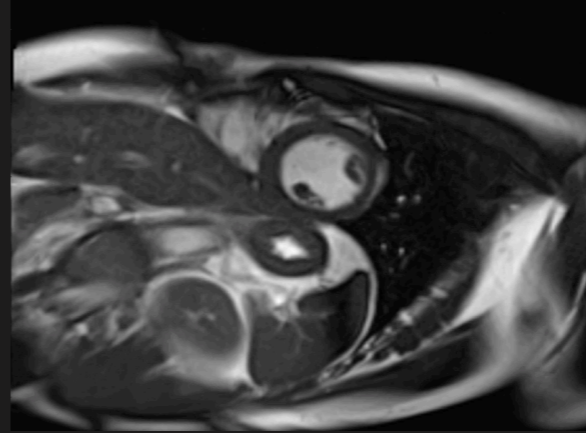
100 fps



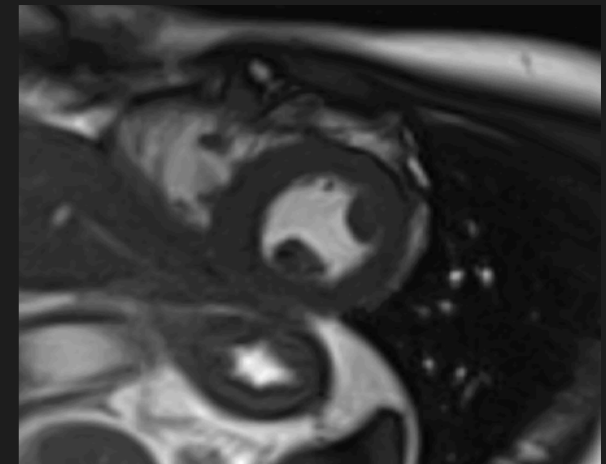
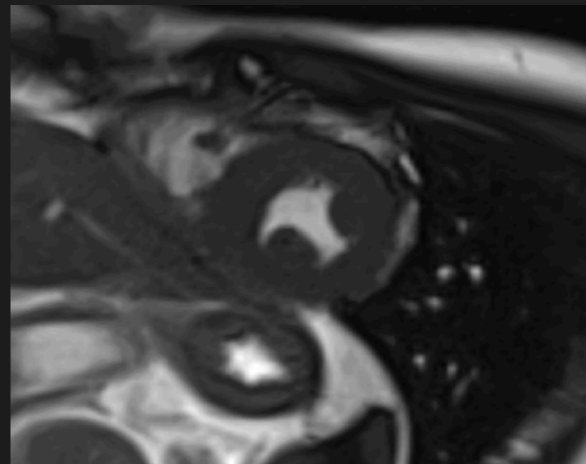
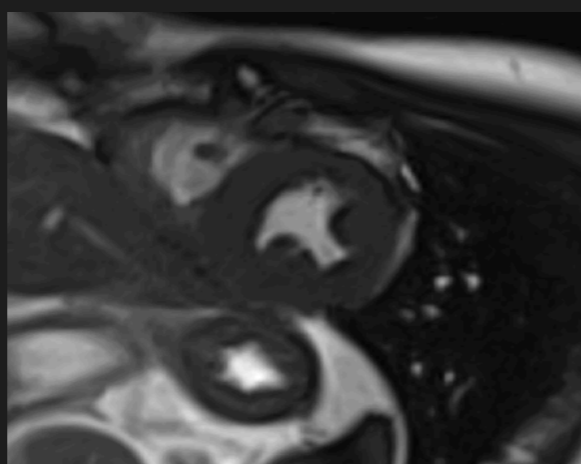
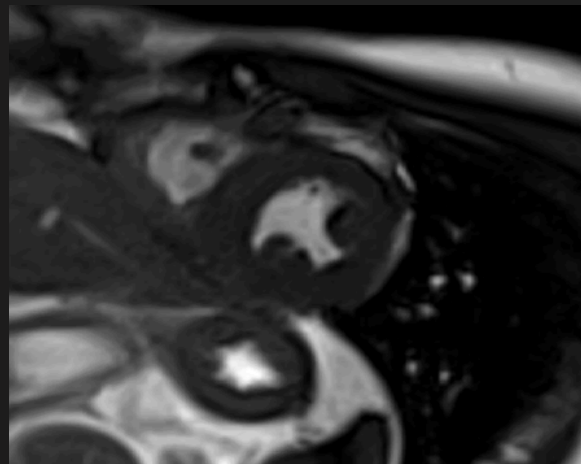
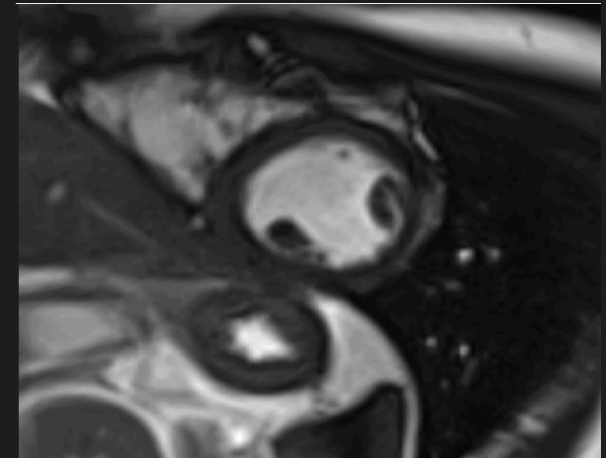
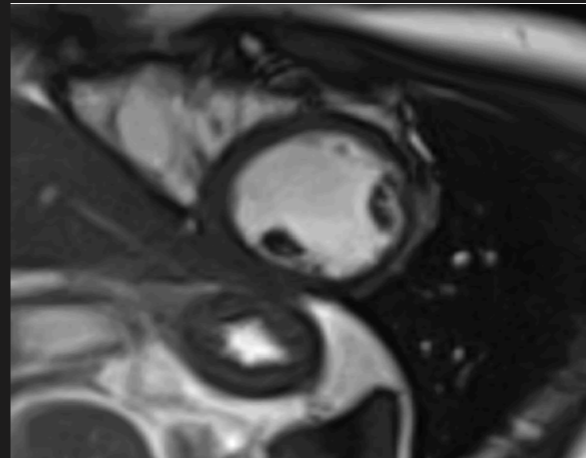
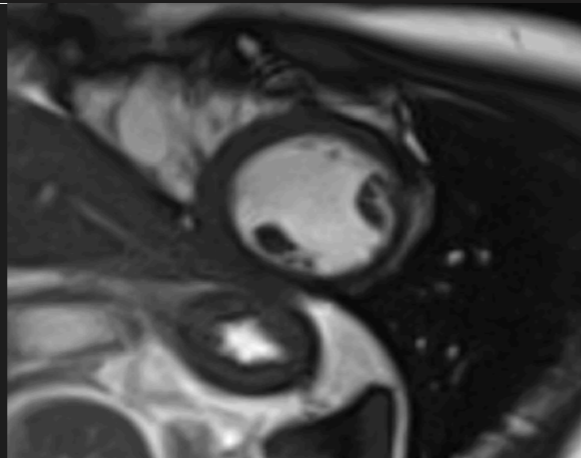
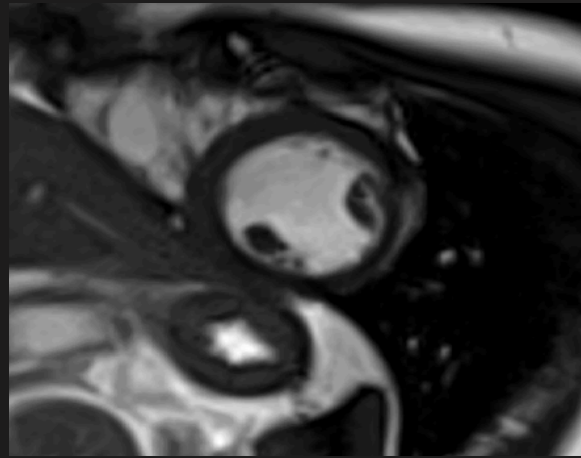
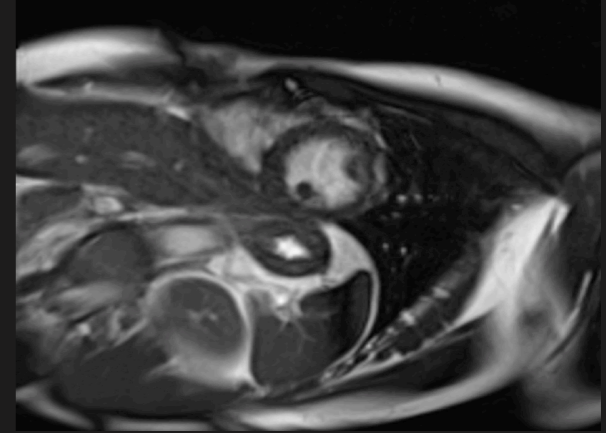
50 fps



10 fps



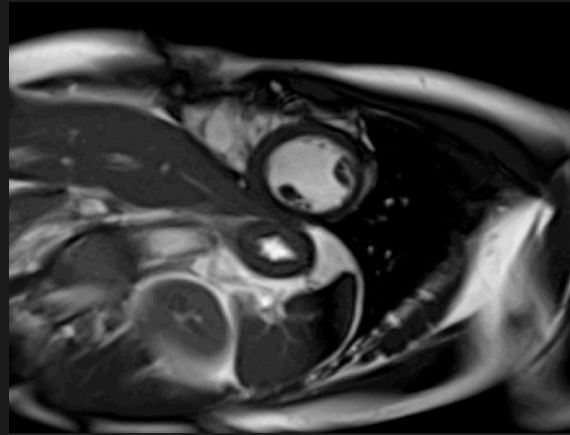
5 fps



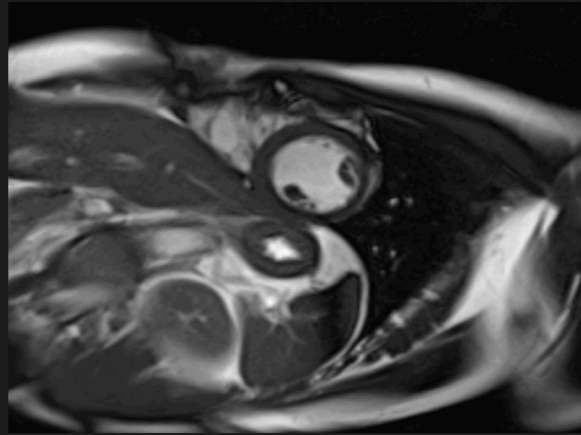
Overestimate ESV

Temporal resolution

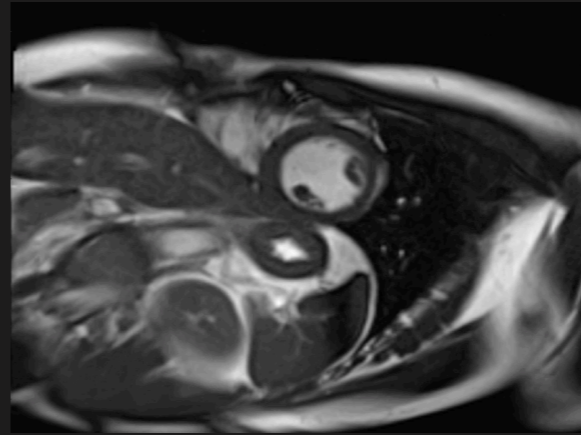
100 fps



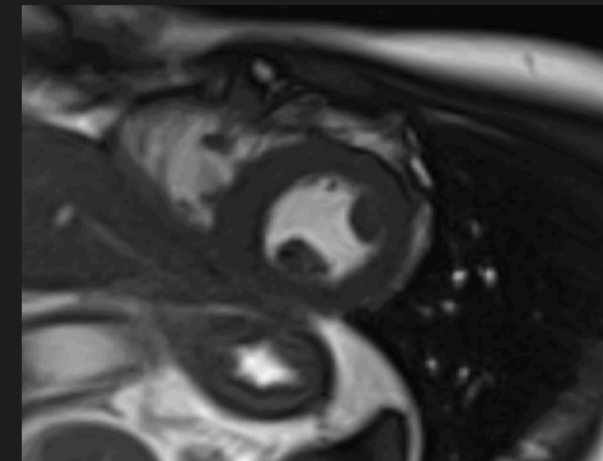
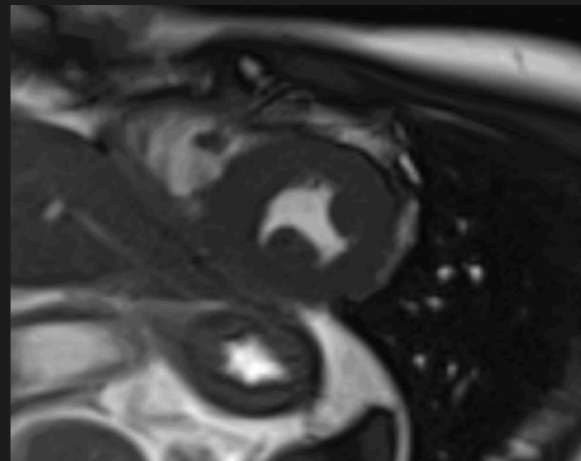
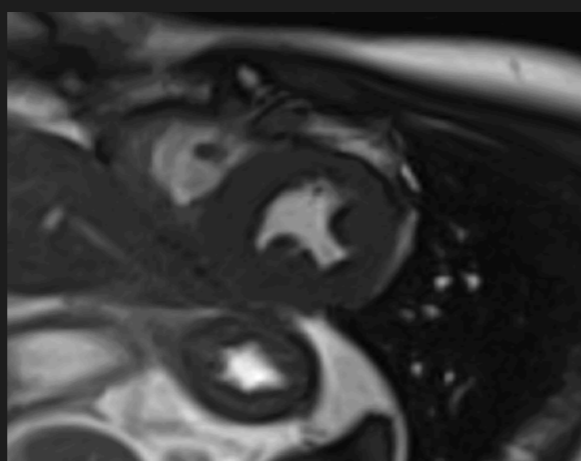
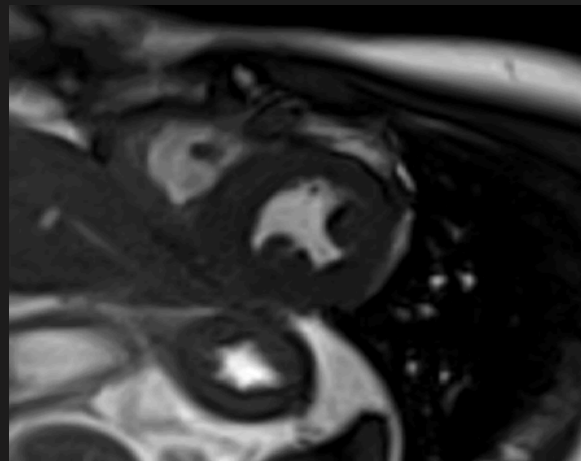
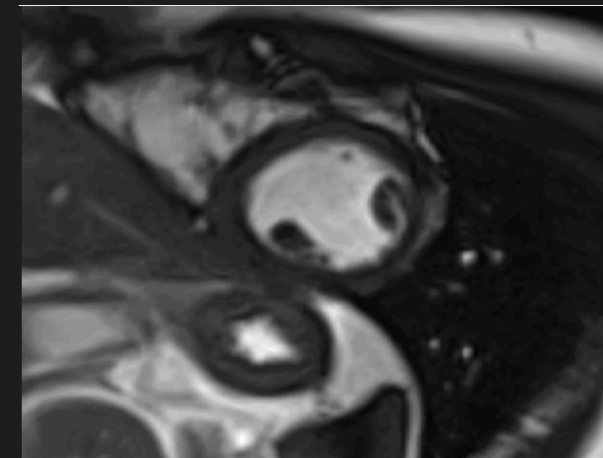
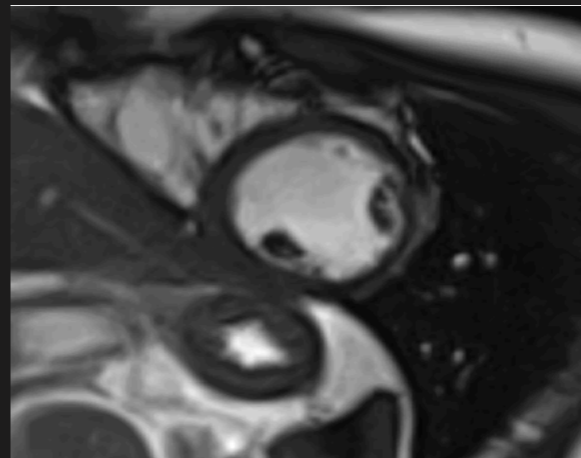
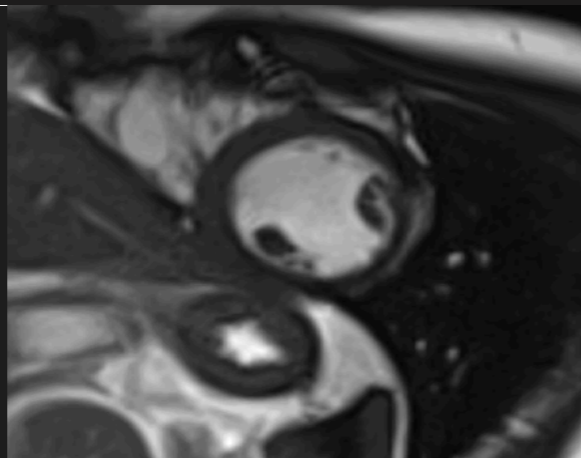
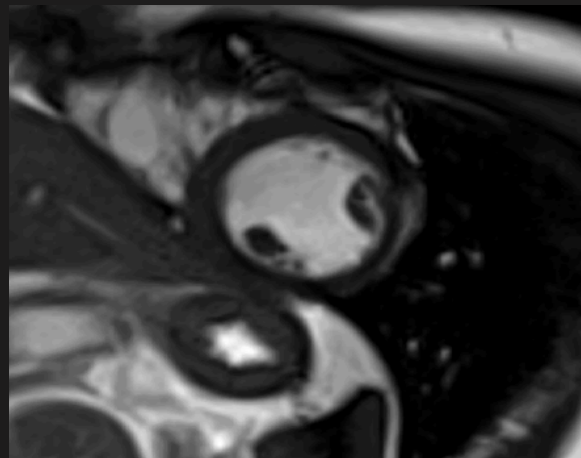
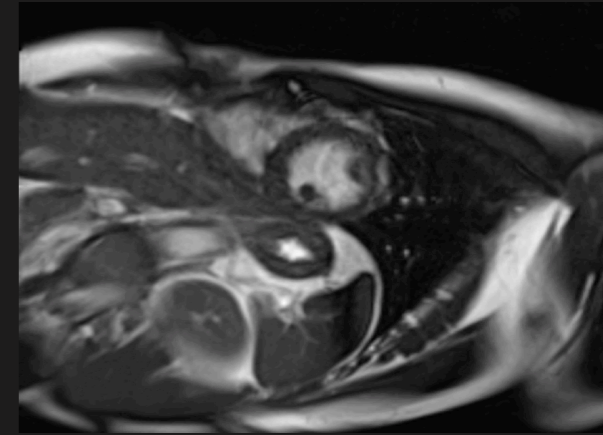
50 fps



10 fps



5 fps

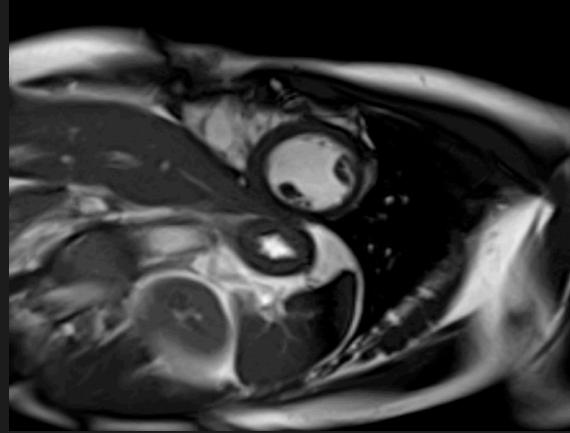


Overestimate ESV

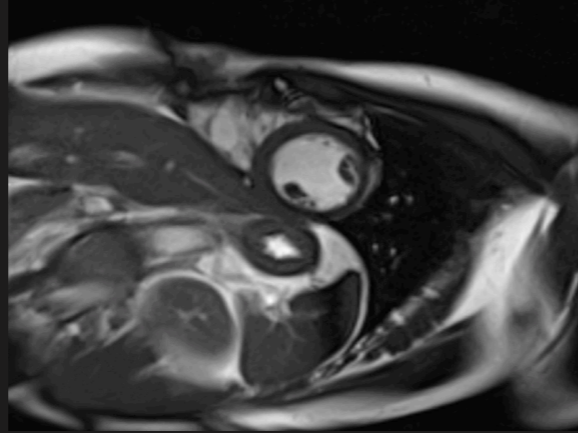
Underestimate EF

Temporal resolution

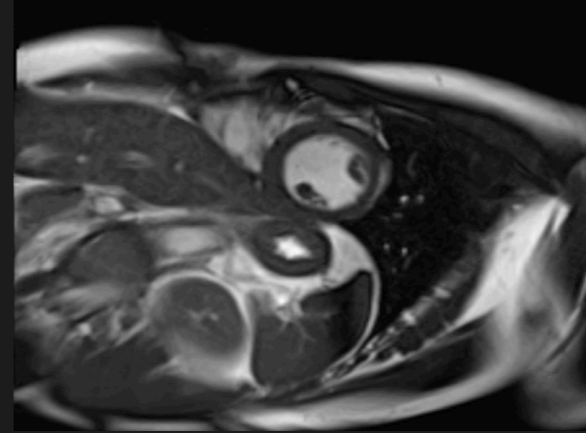
100 fps



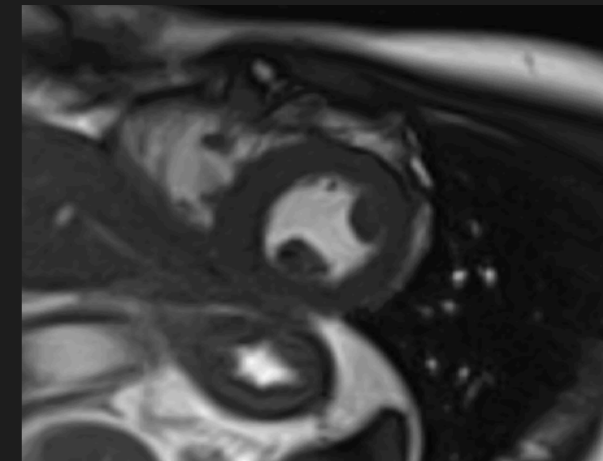
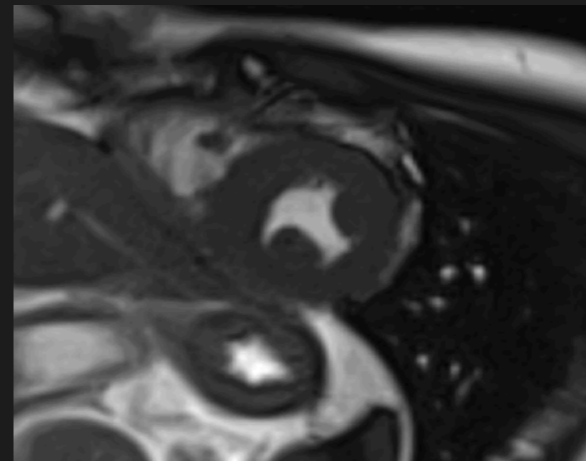
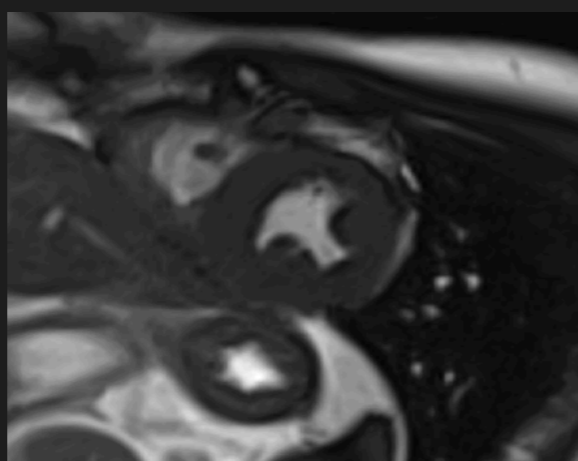
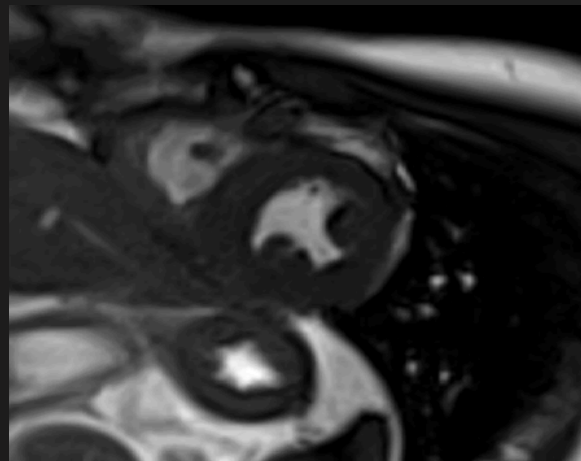
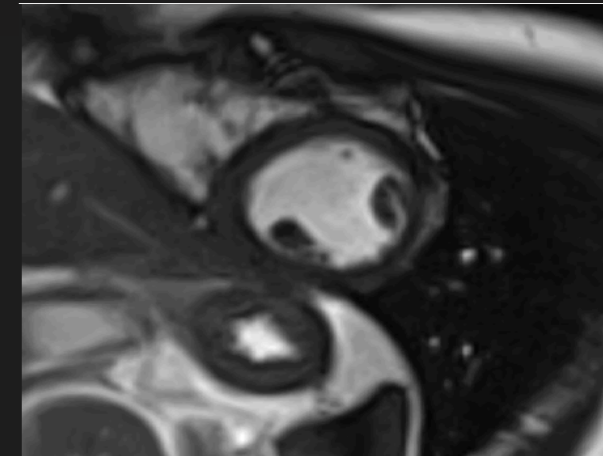
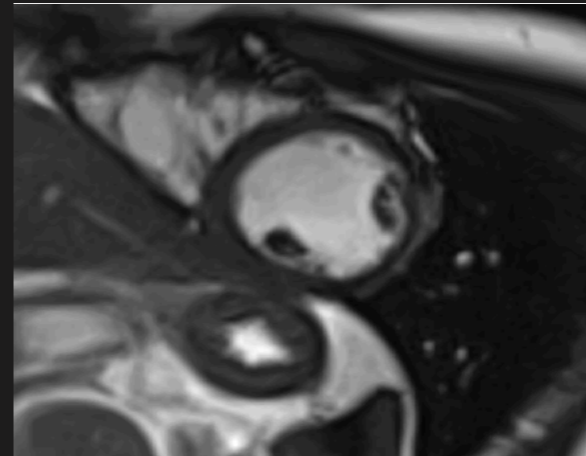
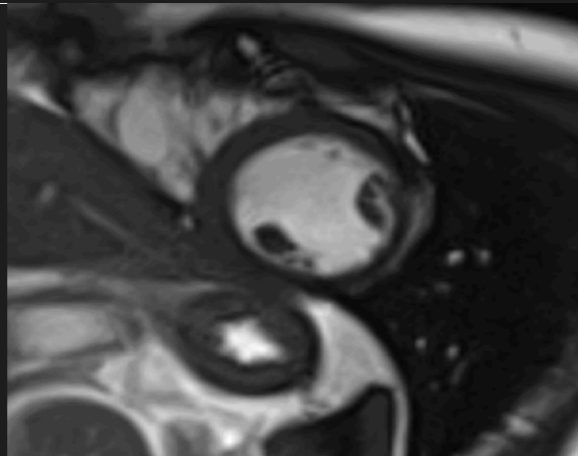
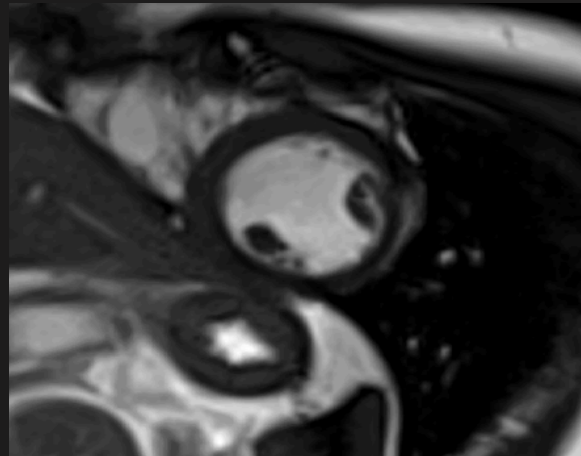
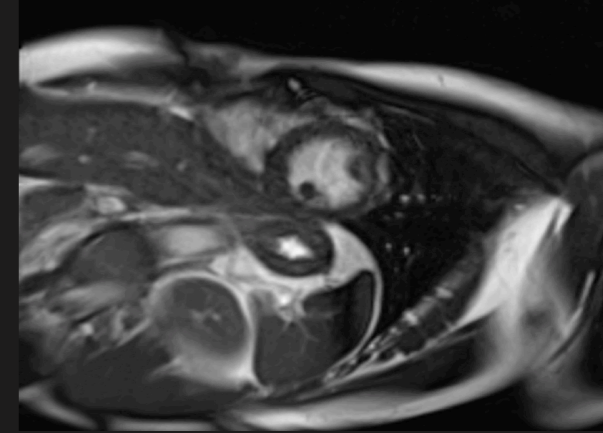
50 fps



10 fps



5 fps



Overestimate ESV

Underestimate EF

20-30 true phases





TR = 3ms



TR = 3ms

NoPE = 200



TR = 3ms

NoPE = 200

LPS = 10



TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm



**Temporal
resolution**

TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm



Temporal
resolution

$TR * LPS$

$TR = 3ms$

$NoPE = 200$

$LPS = 10$

$HR = 75bpm$



Temporal
resolution

$TR * LPS$

30ms

TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm



Temporal
resolution

$TR * LPS$

30ms

No of segments/
beats

TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm



TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm

Temporal
resolution

TR * LPS

30ms

No of segments/
beats

NoPE/
LPS



TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm

Temporal
resolution

TR * LPS

30ms

No of segments/
beats

NoPE/
LPS

20 beats



TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm

Temporal
resolution

TR * LPS

30ms

No of segments/
beats

NoPE/
LPS

20 beats

Breath hold
time



TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm

Temporal
resolution

TR * LPS

30ms

No of segments/
beats

NoPE/
LPS

20 beats

Breath hold
time

Beats *
RR int



TR = 3ms

NoPE = 200

LPS = 10

HR = 75bpm

Temporal
resolution

TR * LPS

30ms

No of segments/
beats

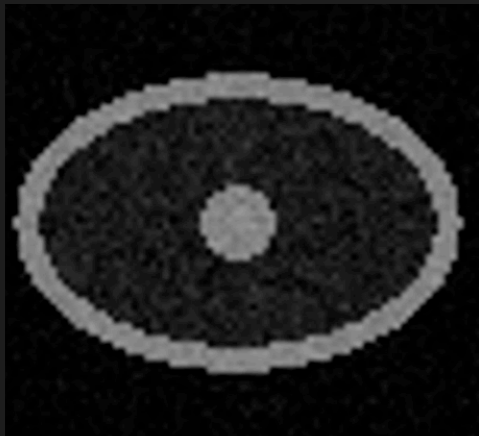
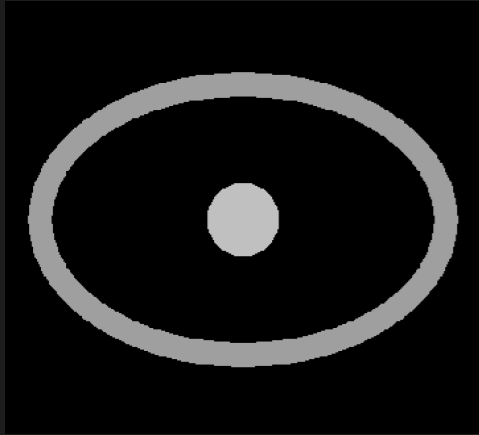
NoPE/
LPS

20 beats

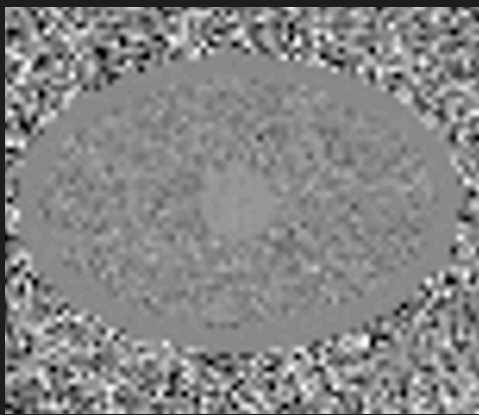
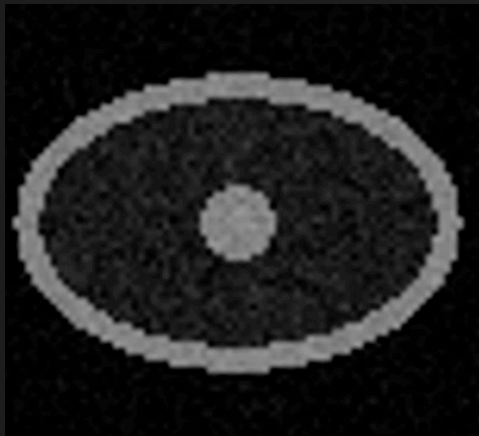
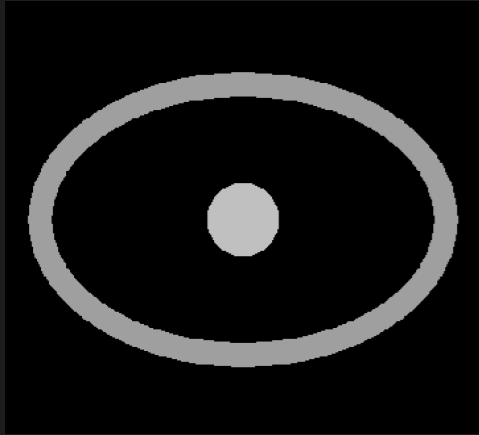
Breath hold
time

Beats *
RR int

16s

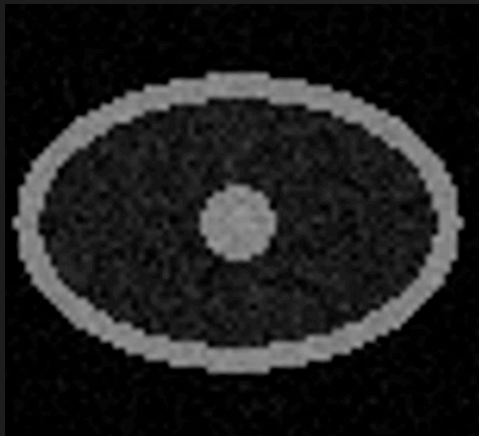
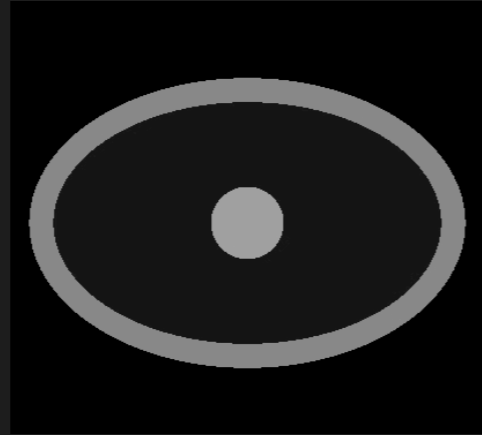
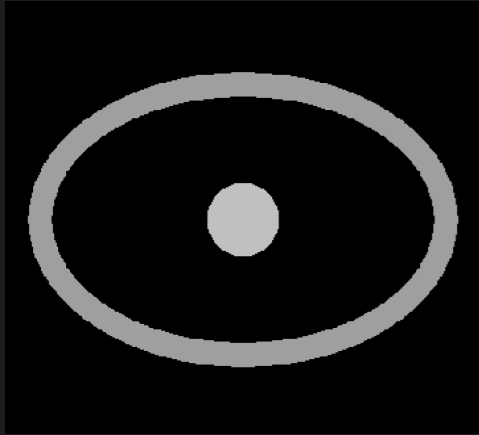


No artefact

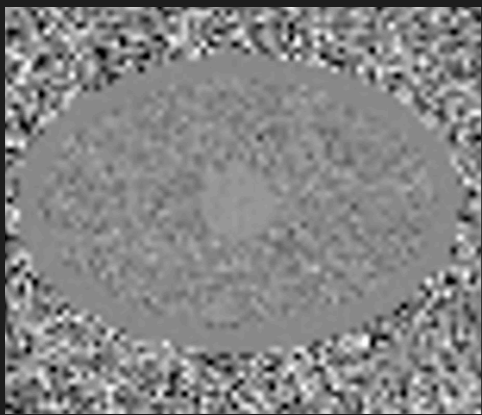
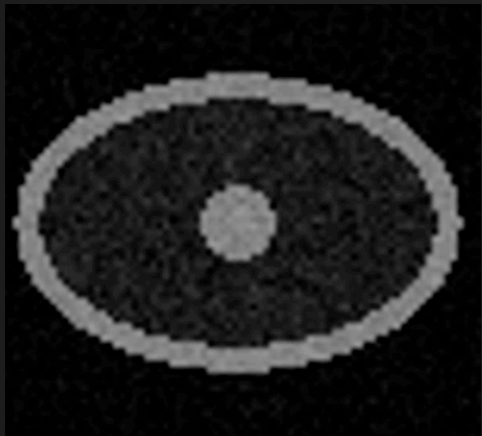
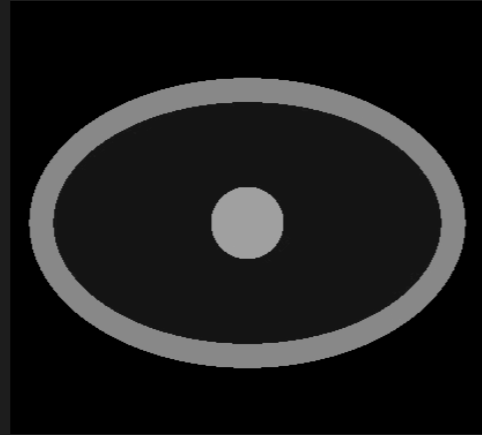
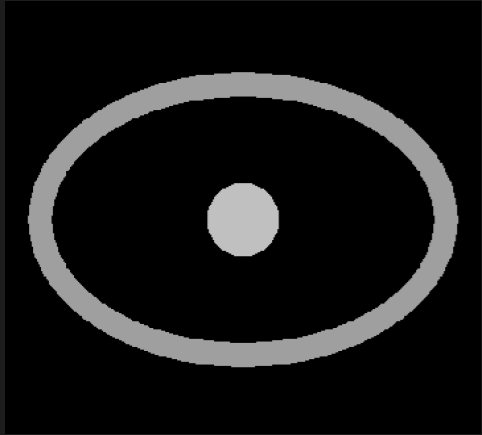


No artefact

Breathing

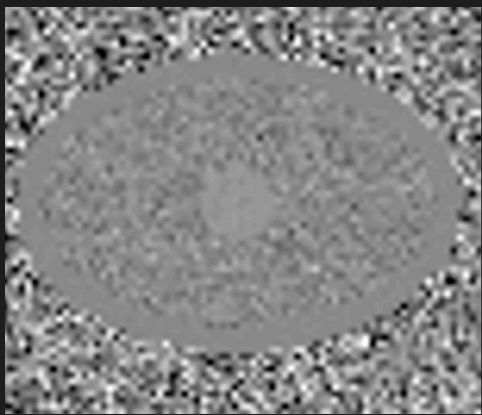
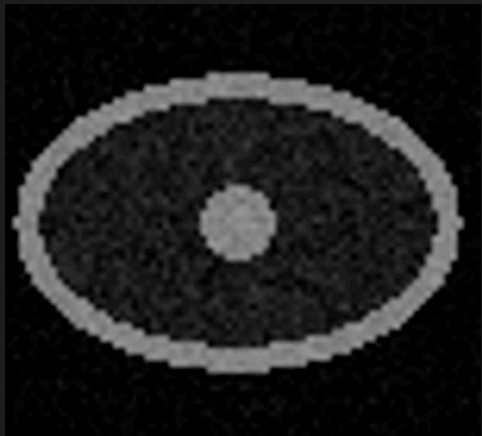
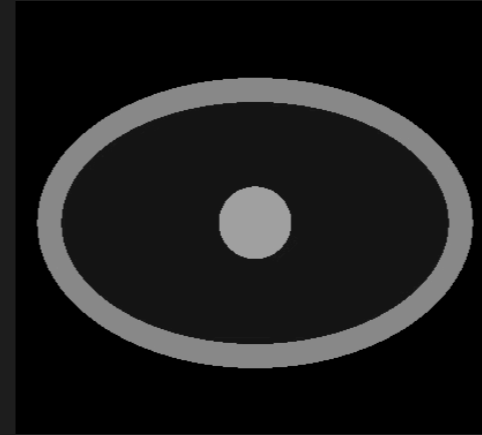
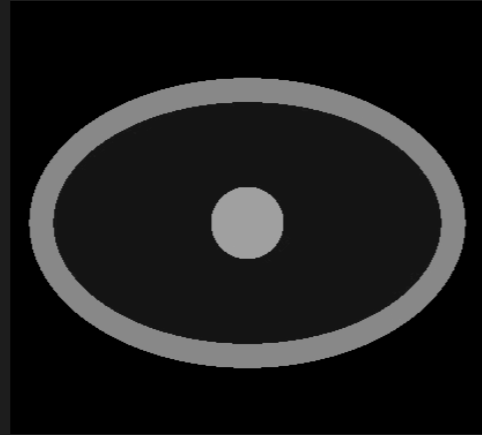
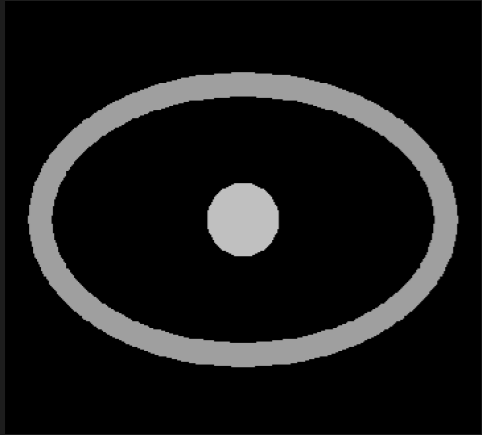


No artefact



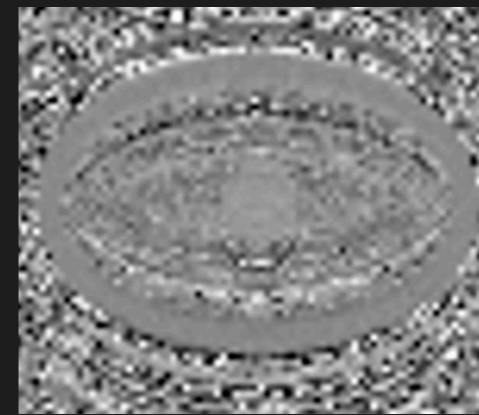
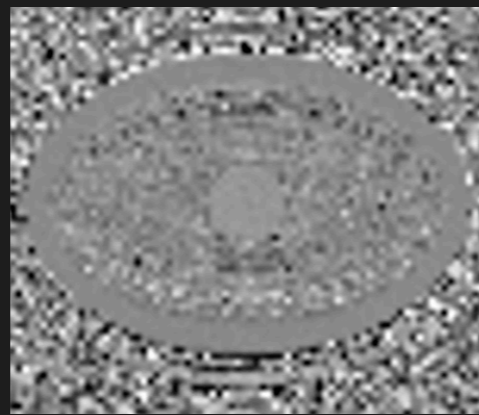
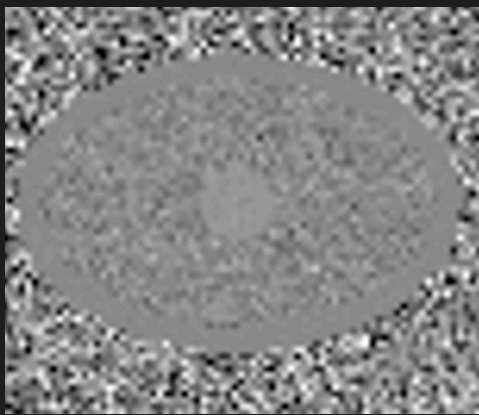
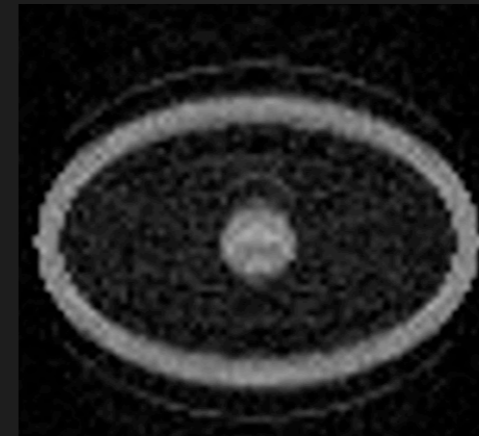
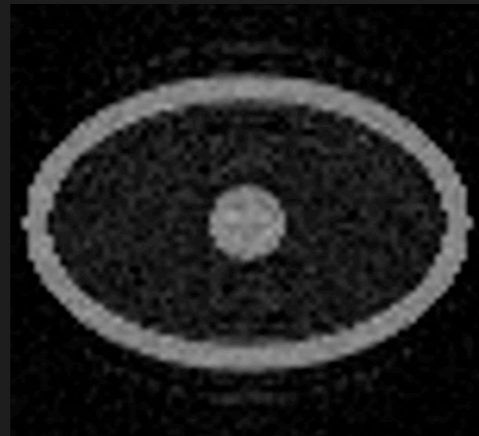
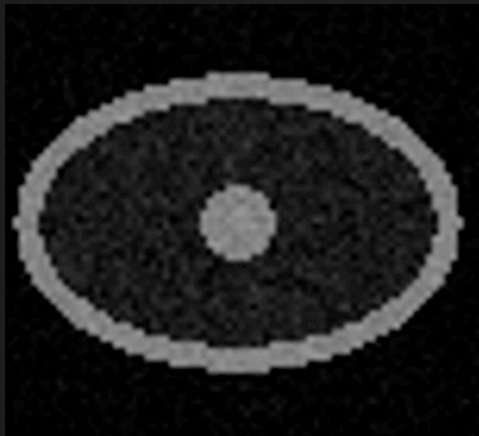
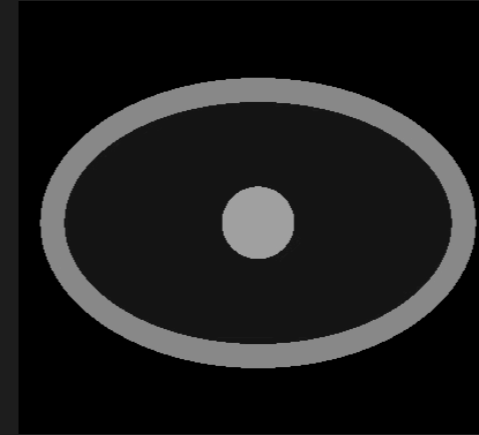
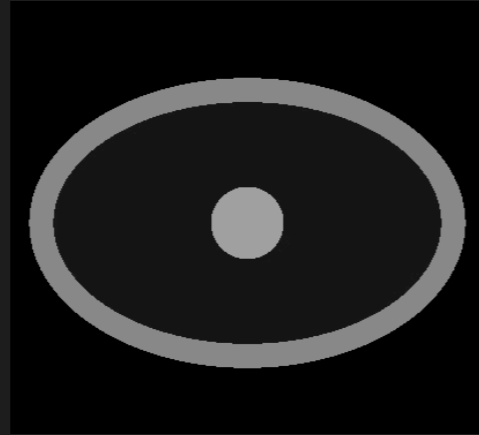
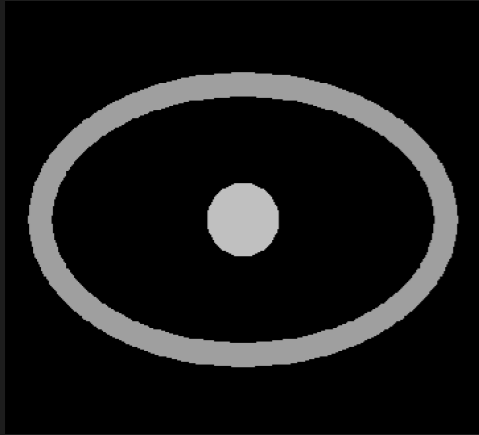
No artefact

Ghosting



No artefact

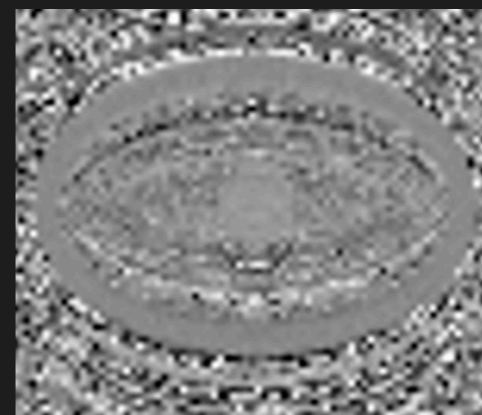
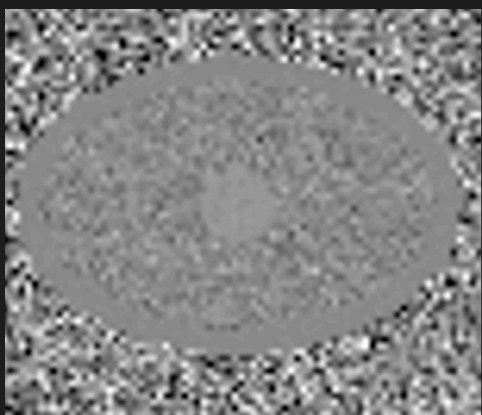
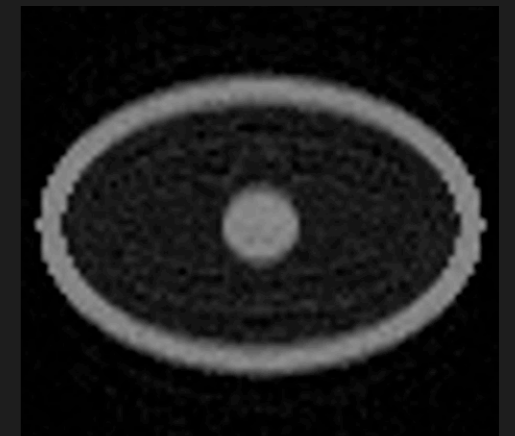
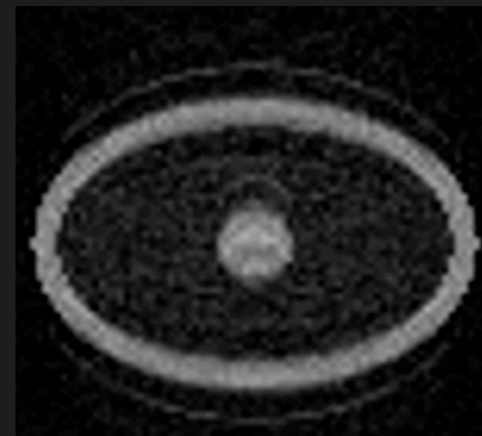
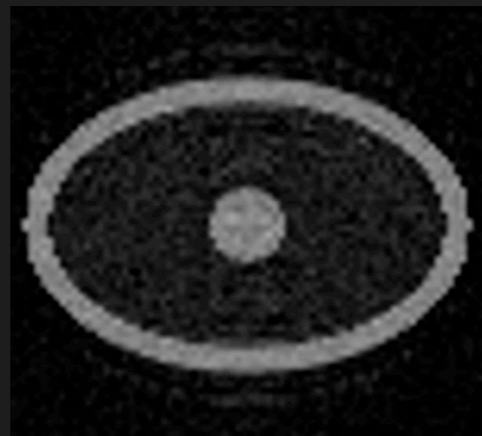
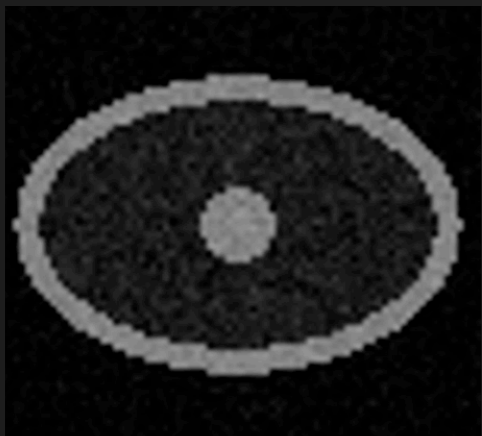
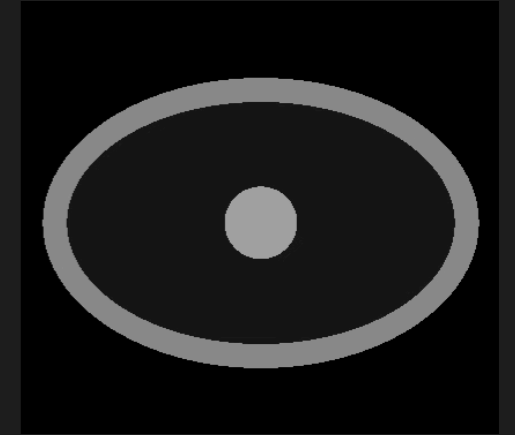
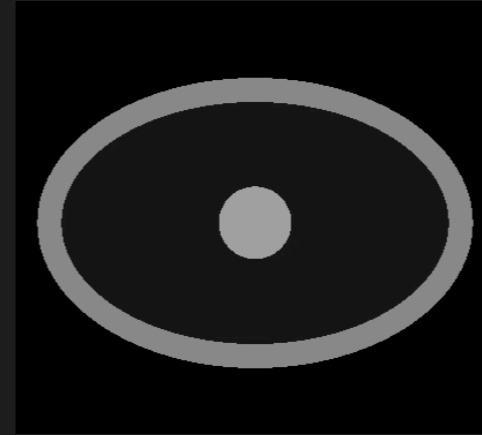
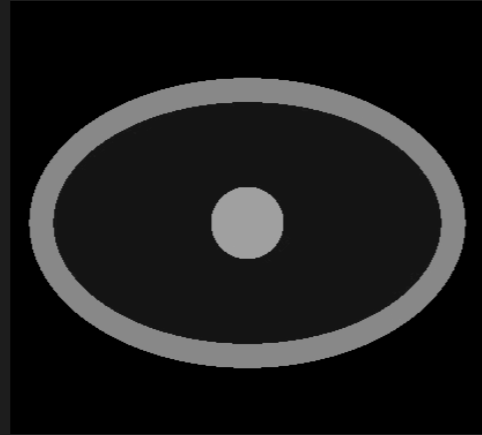
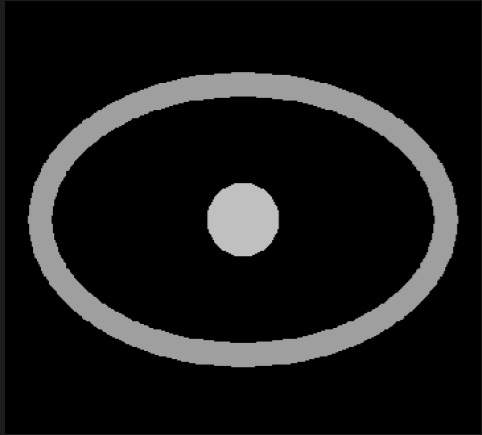
Ghosting



No artefact

Ghosting

Worse artefact



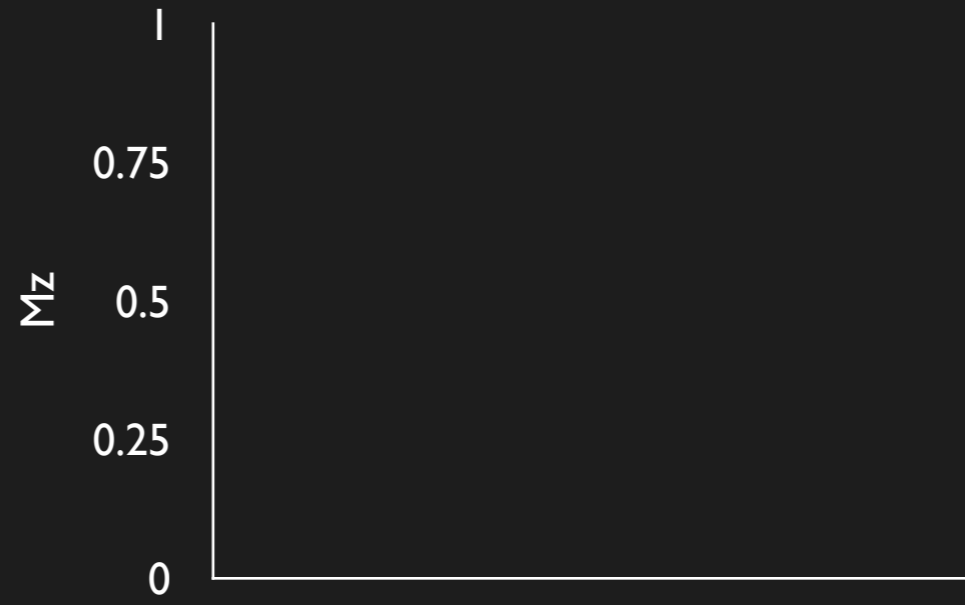
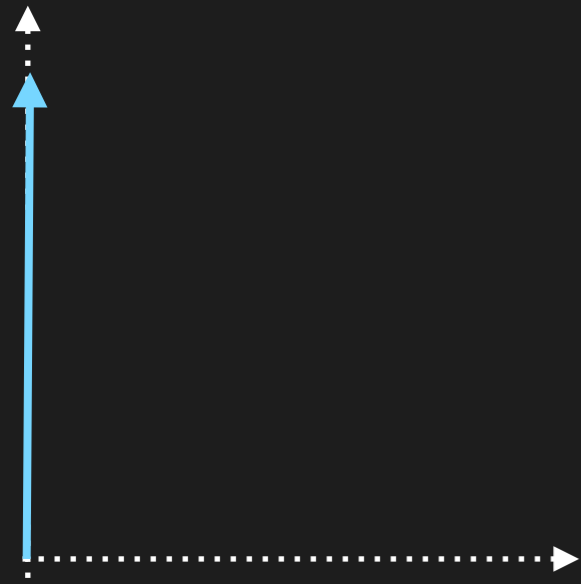
No artefact

Ghosting

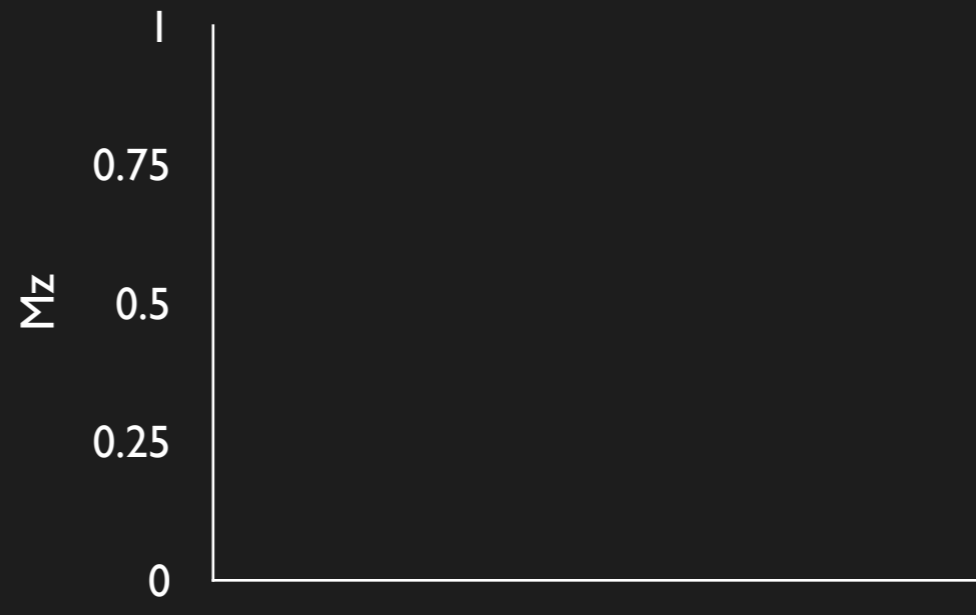
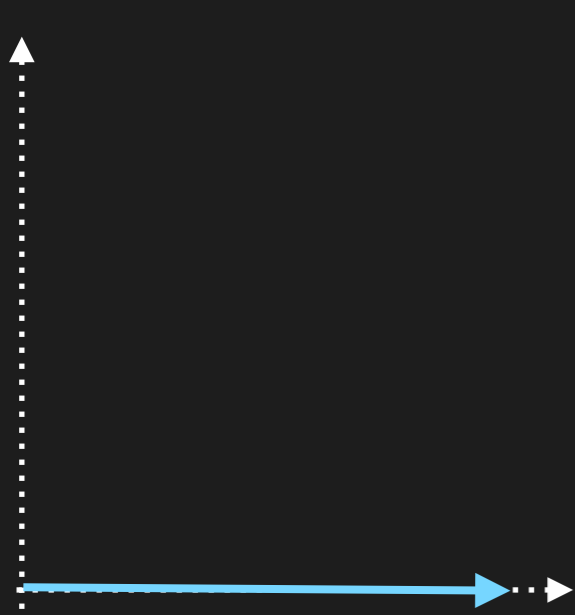
Worse artefact

Signal Average

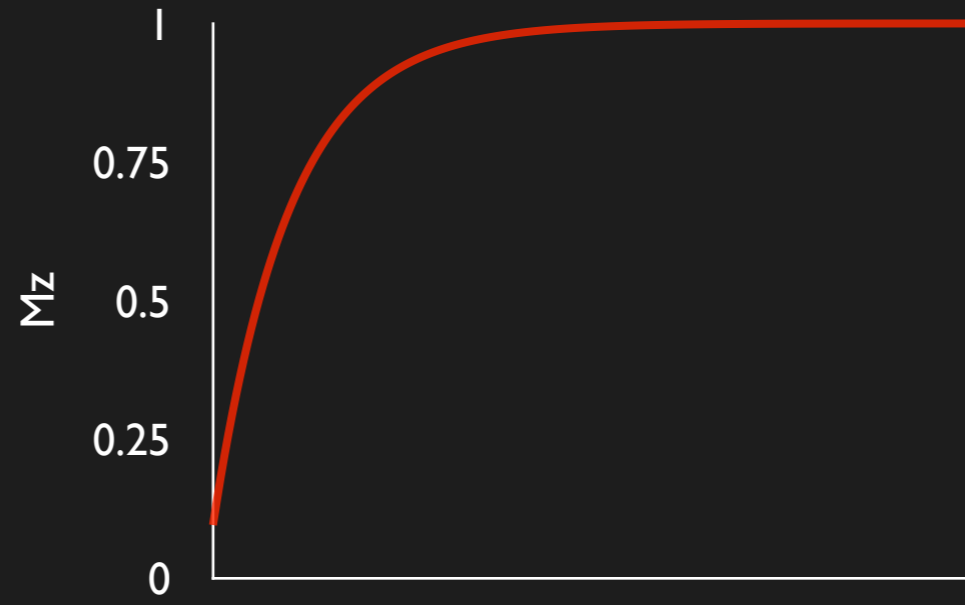
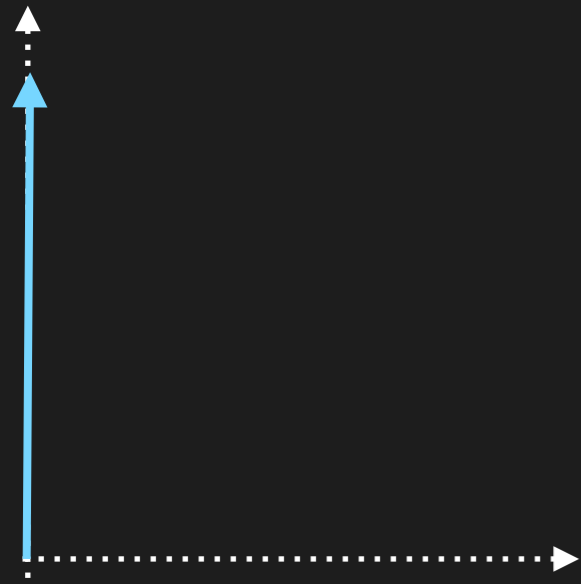
T1 preparation schemes



T1 preparation schemes

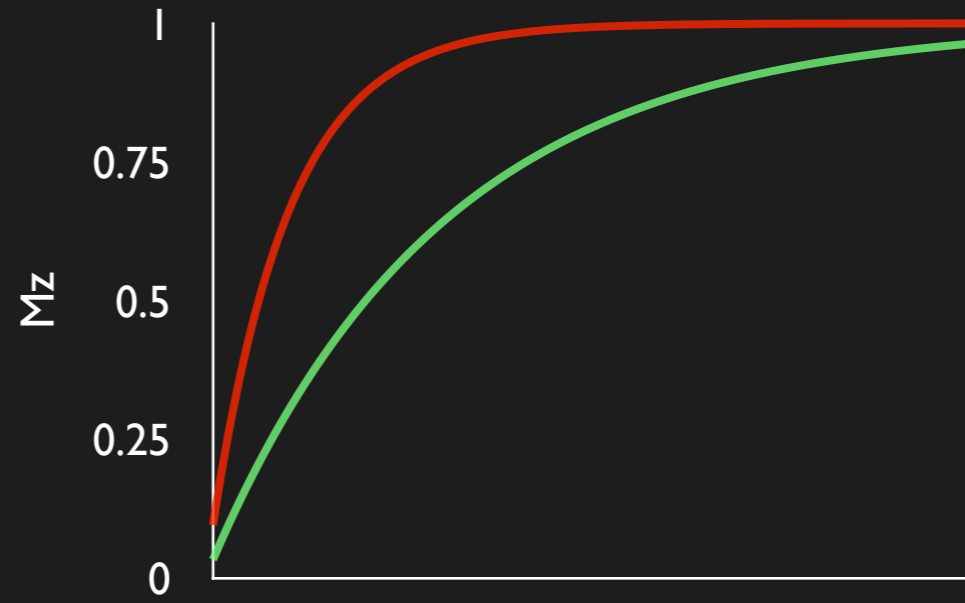
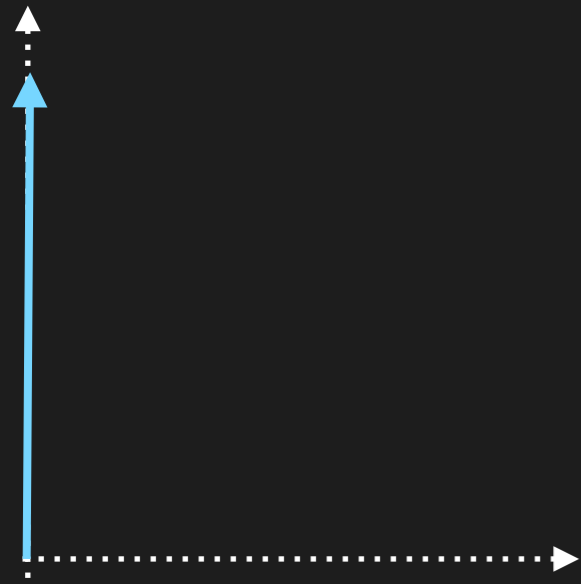


T1 preparation schemes



Short T1

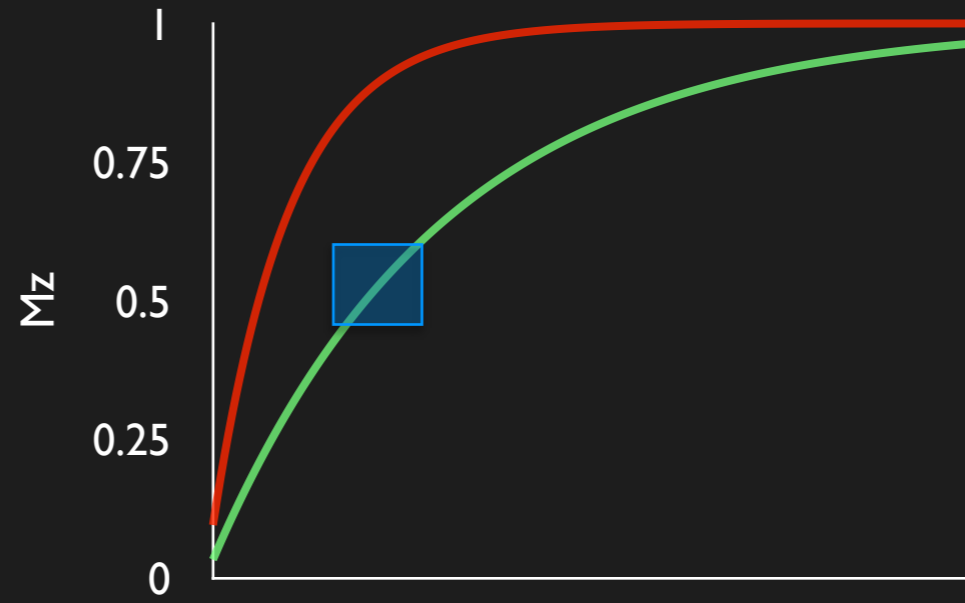
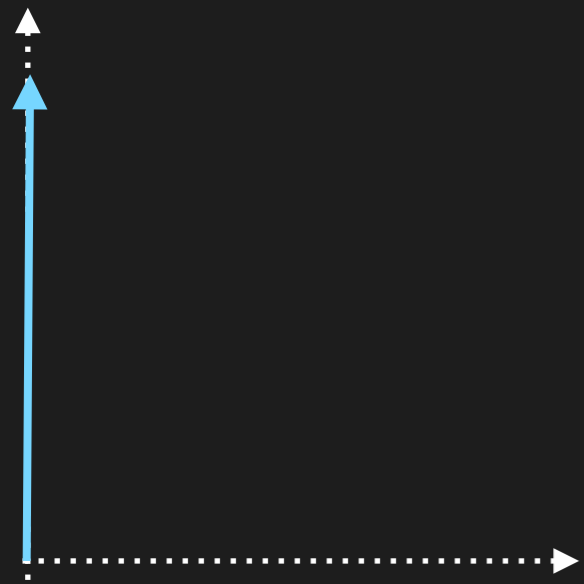
T1 preparation schemes



Short T1

Long T1

T1 preparation schemes

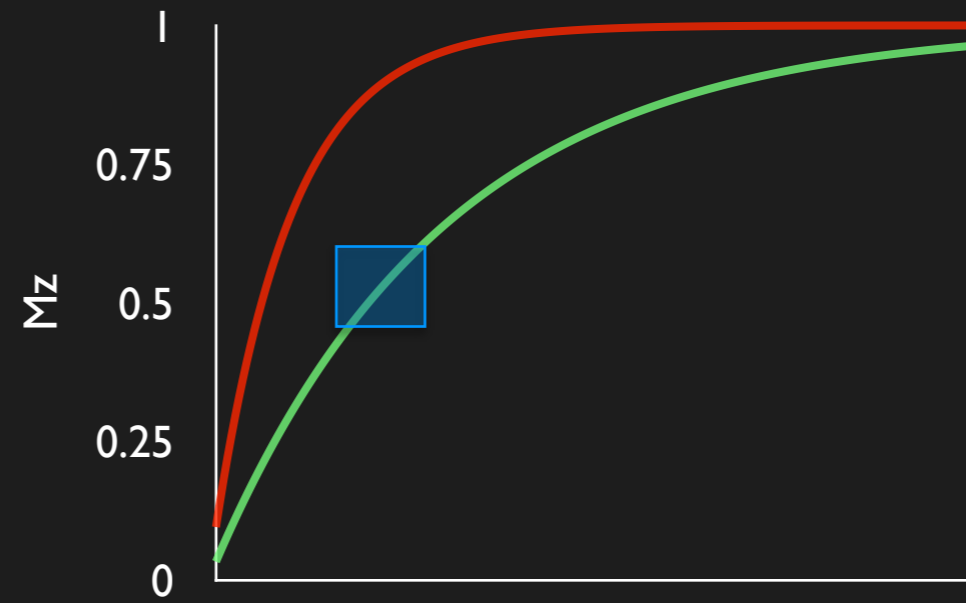
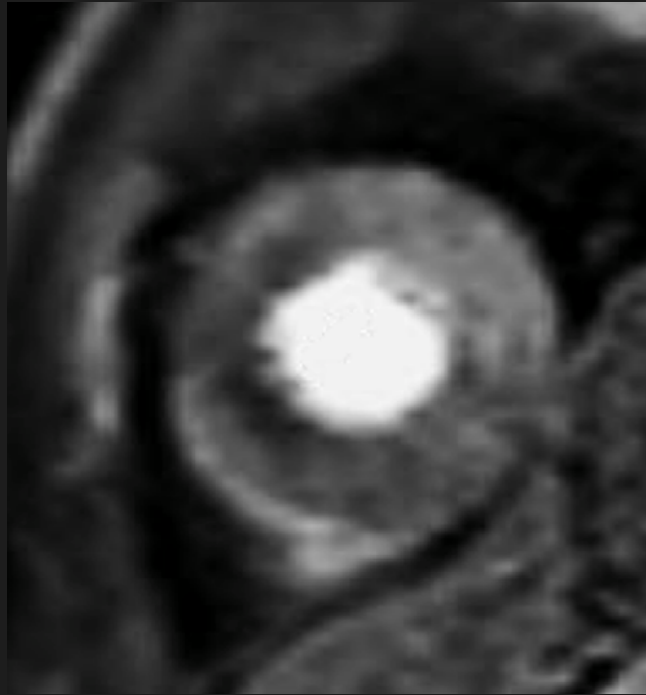


Short T1

Long T1

T1 dependant imaging

T1 preparation schemes

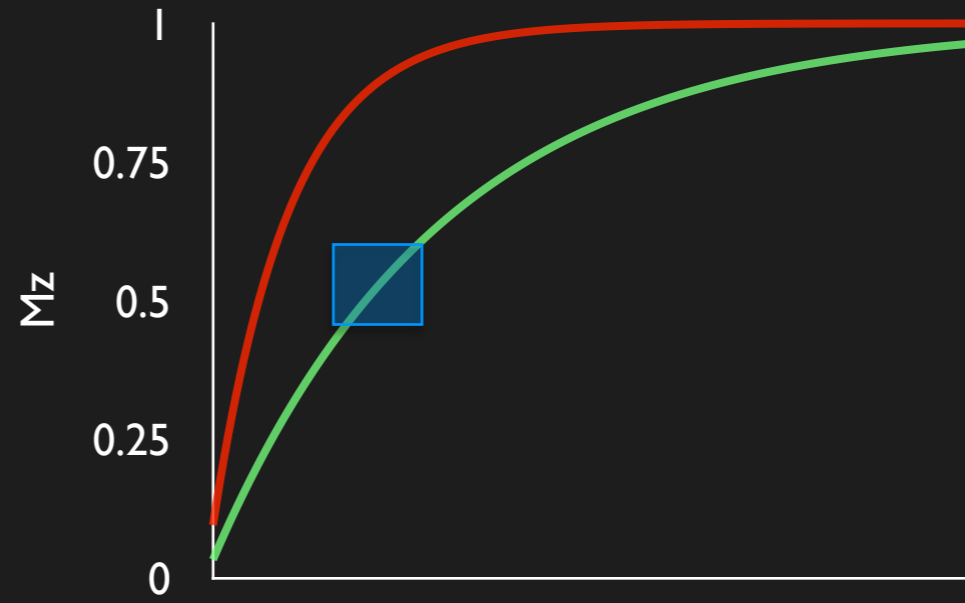
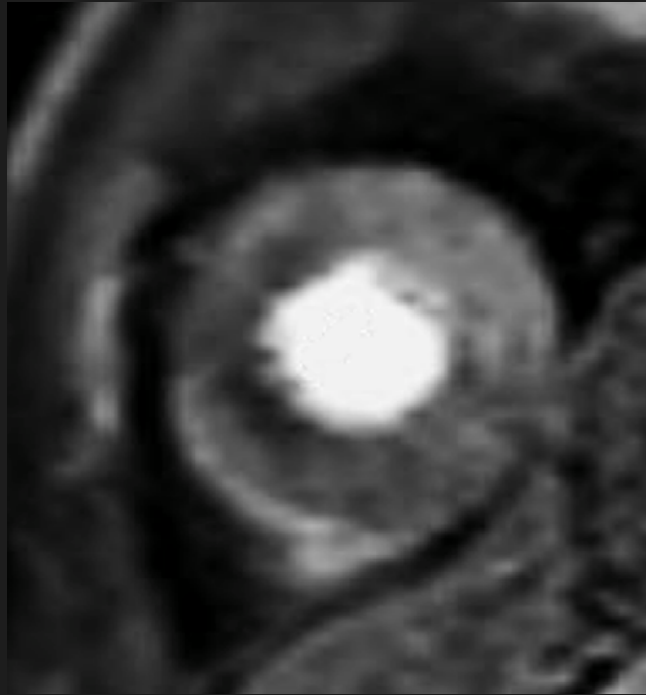


Short T1

Long T1

T1 dependant imaging

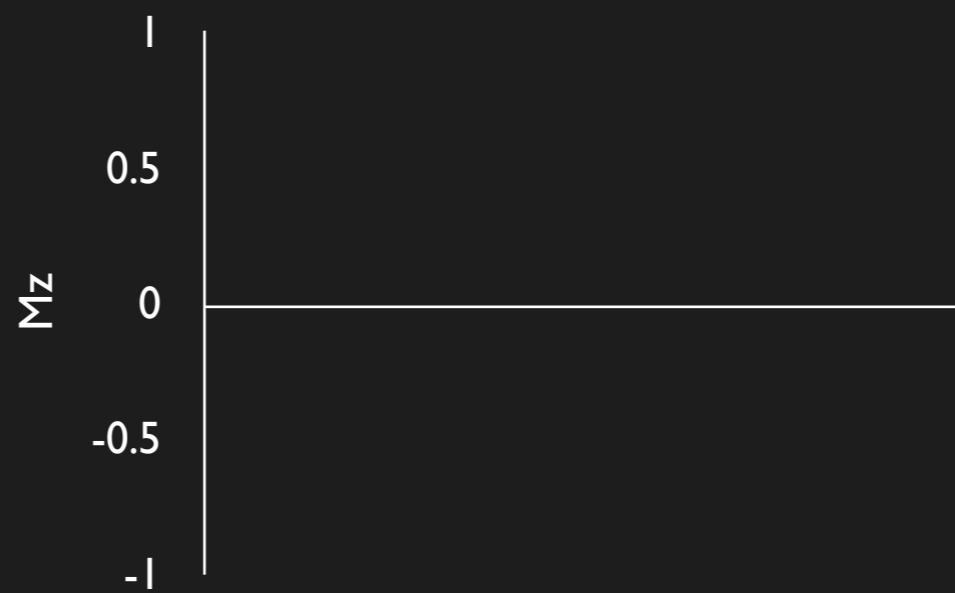
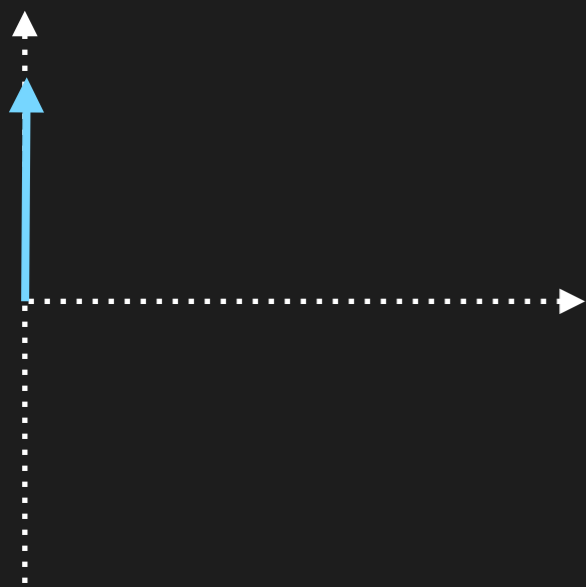
T1 preparation schemes



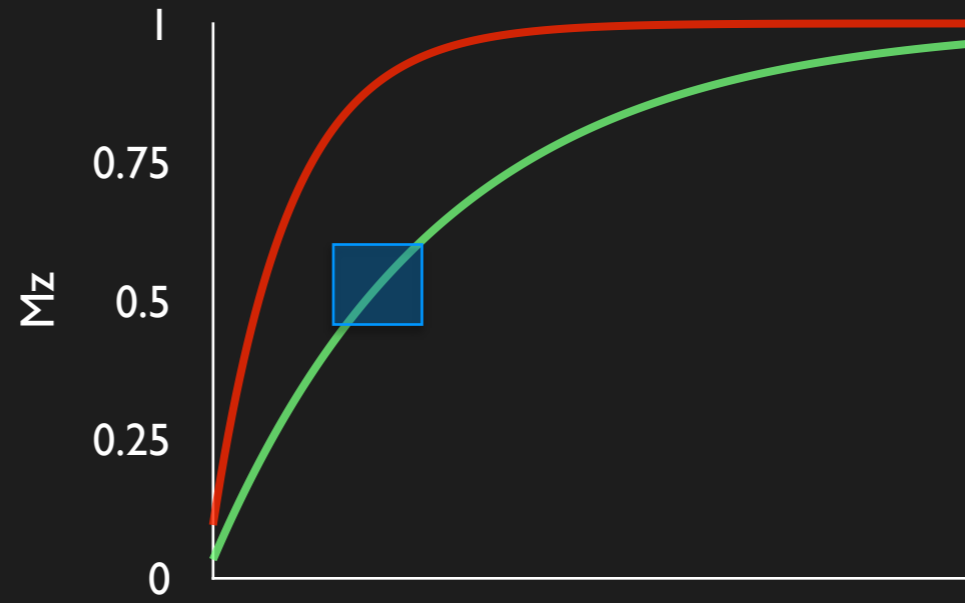
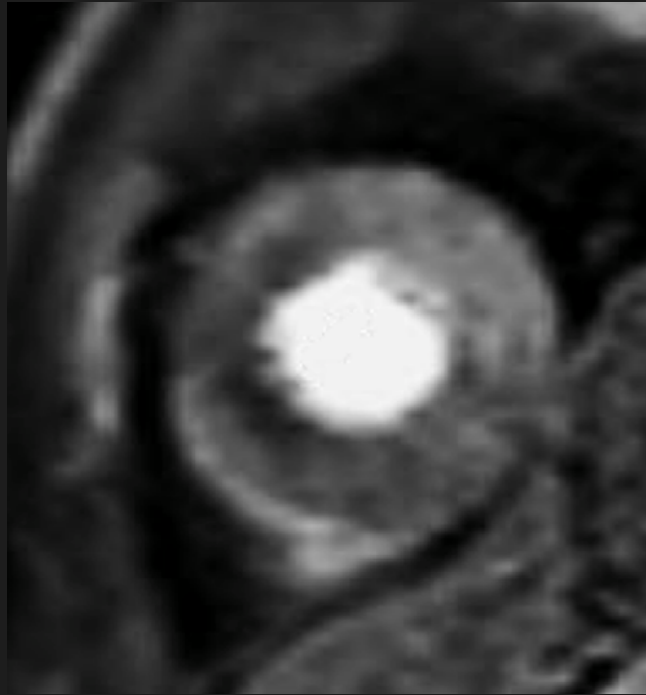
Short T1

Long T1

T1 dependant imaging



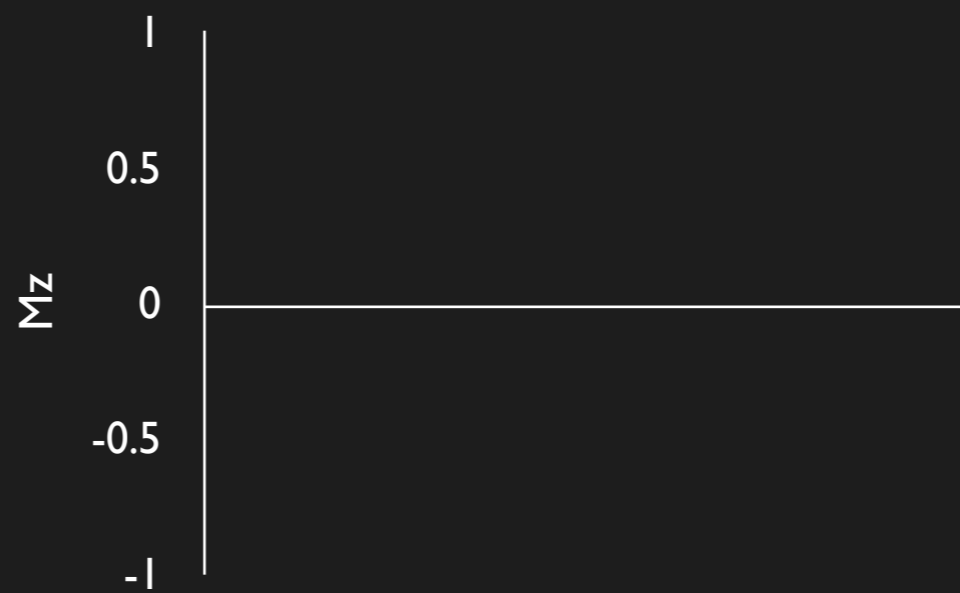
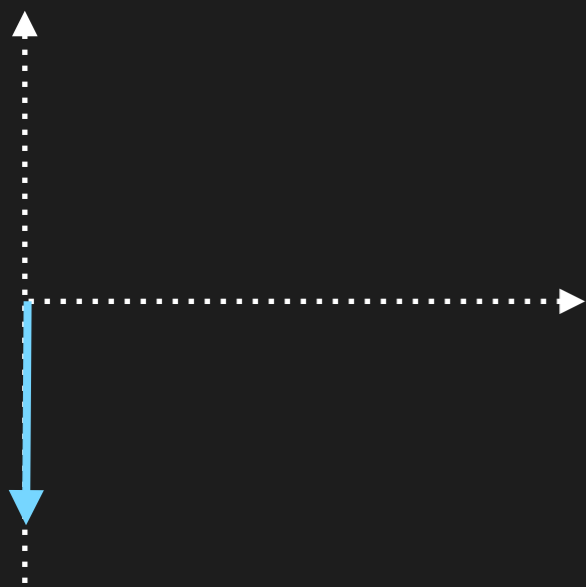
T1 preparation schemes



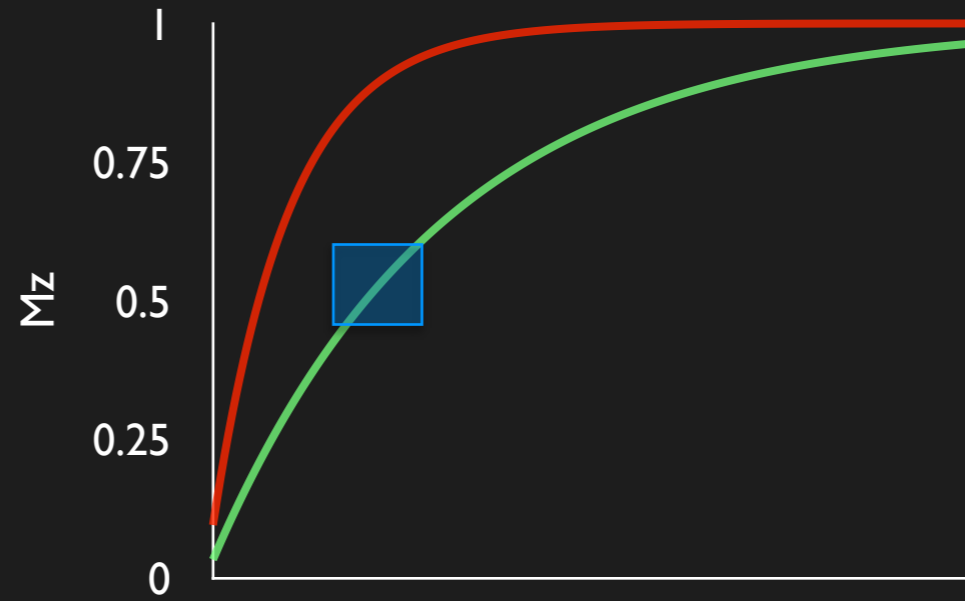
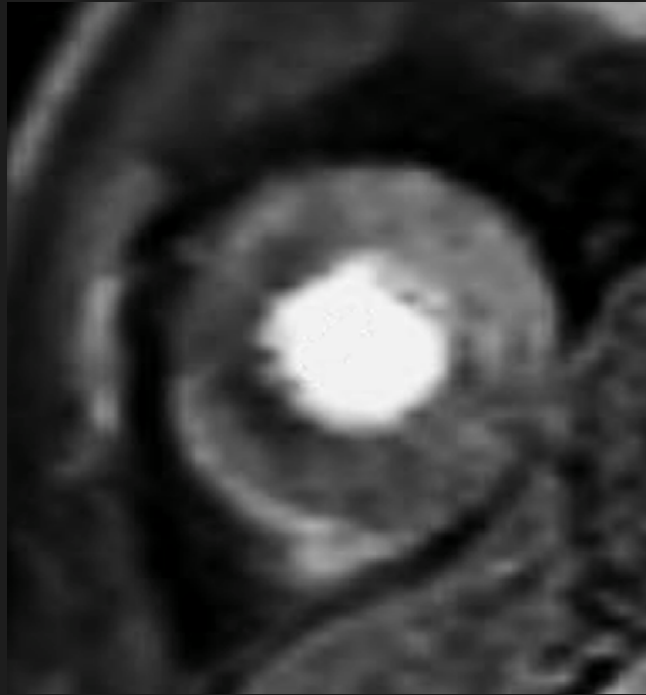
Short T1

Long T1

T1 dependant imaging



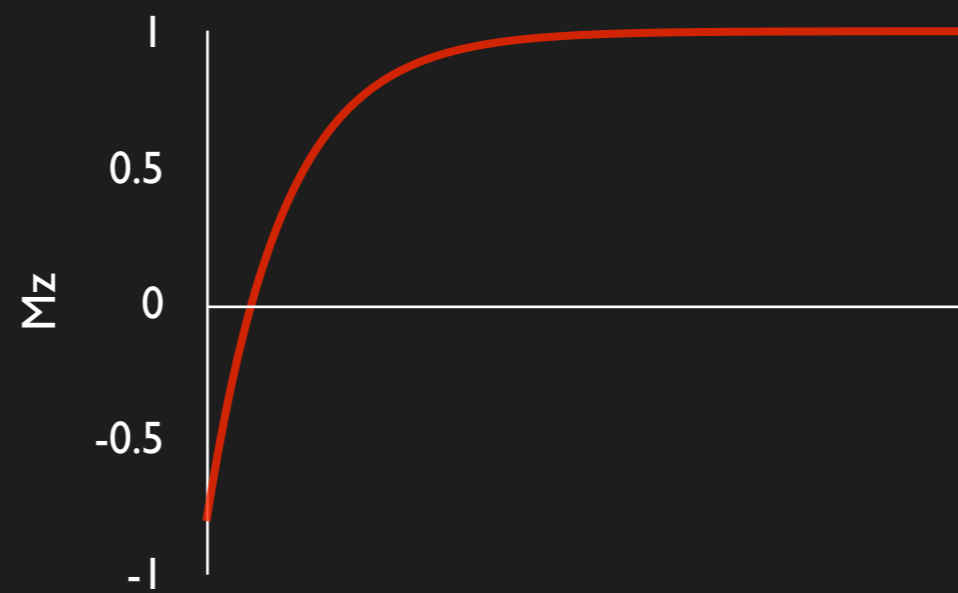
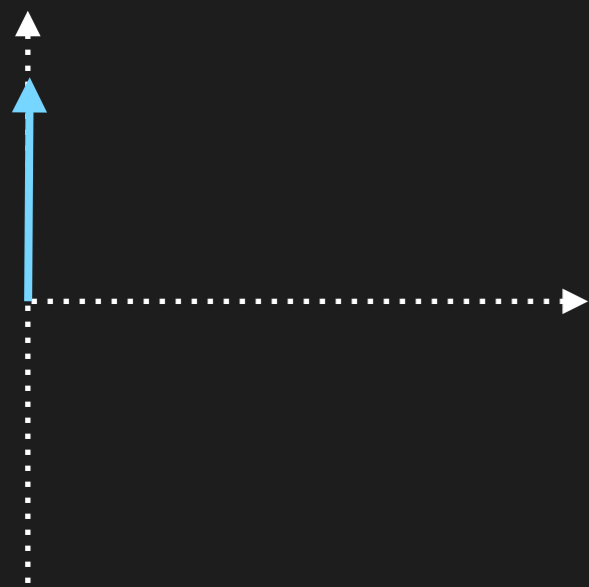
T1 preparation schemes



Short T1

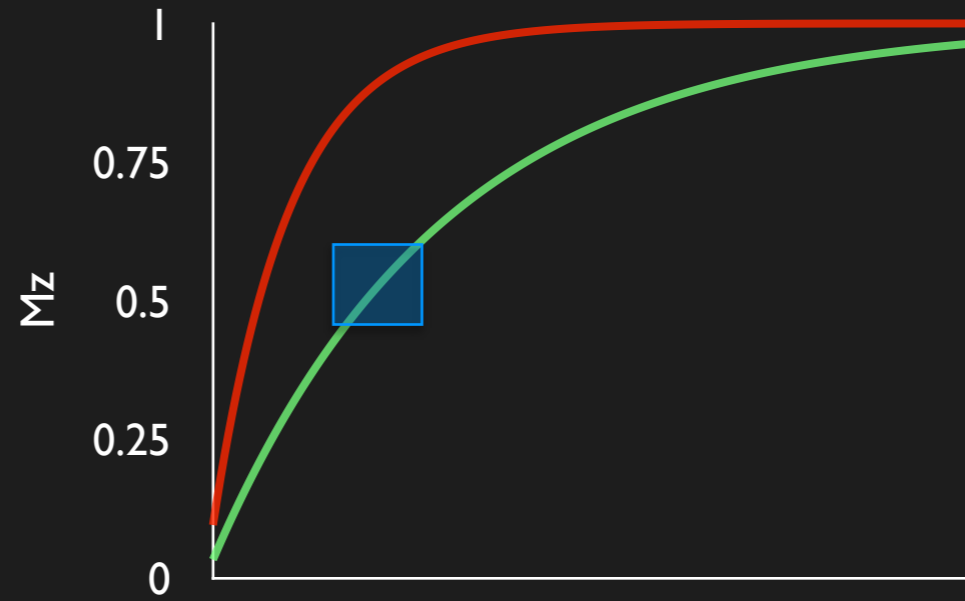
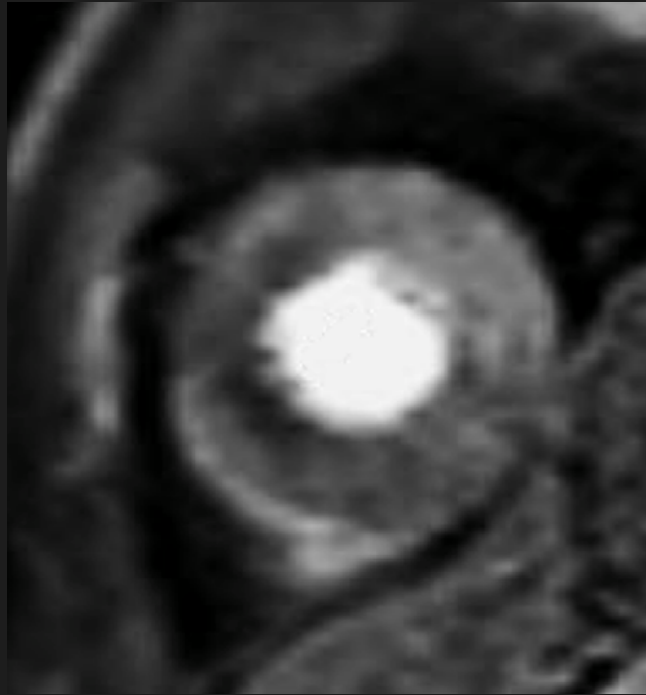
Long T1

T1 dependant imaging



Null point at $0.693 \cdot T1$

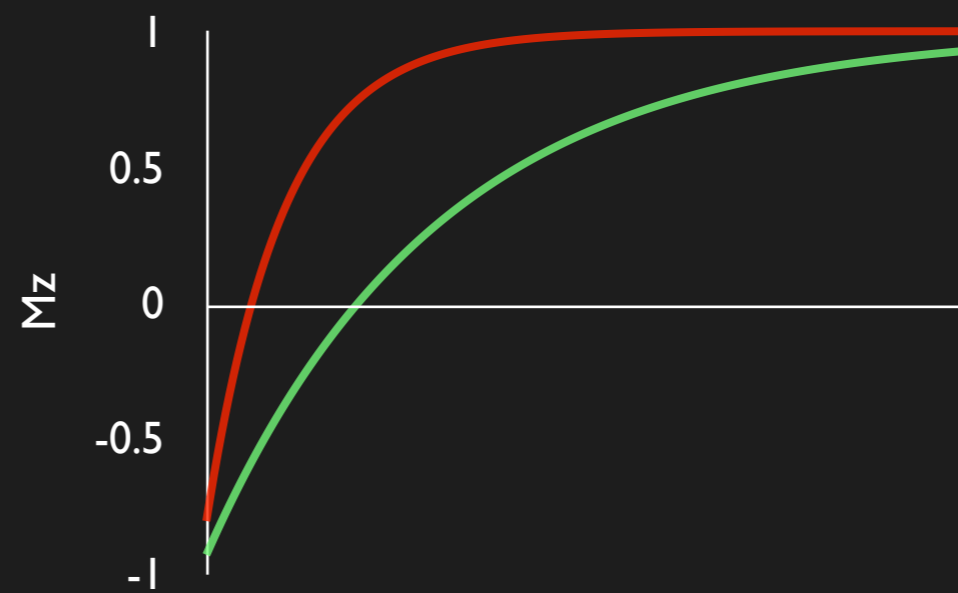
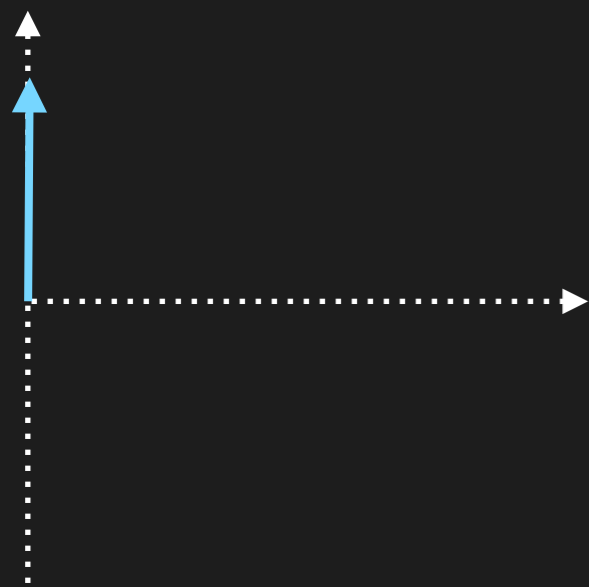
T1 preparation schemes



Short T1

Long T1

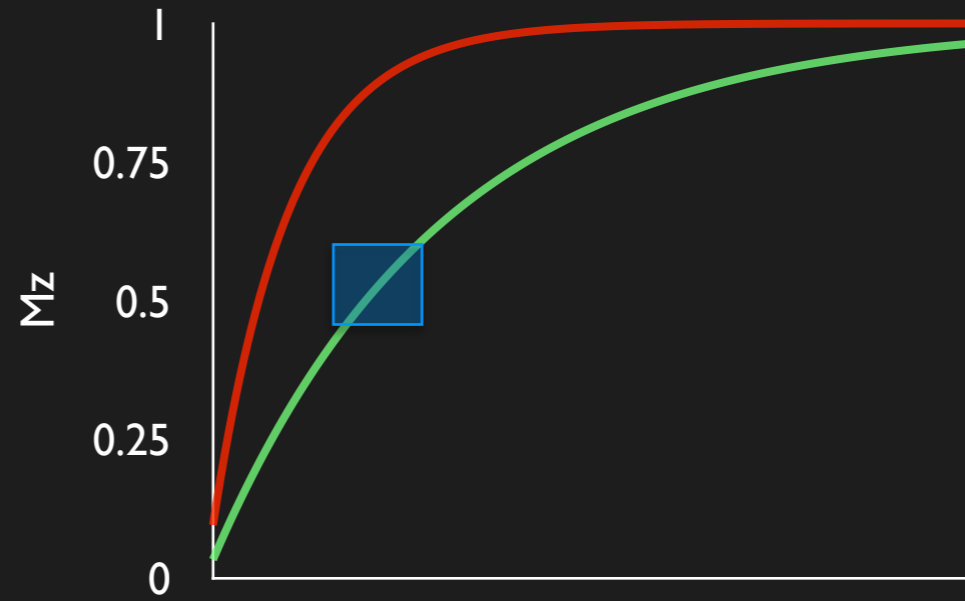
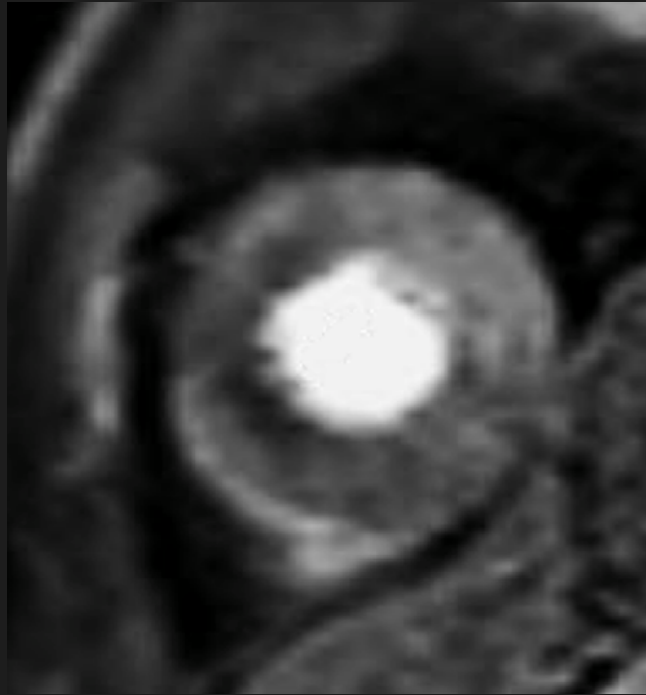
T1 dependant imaging



Null point at $0.693 \cdot T1$

Longer T1

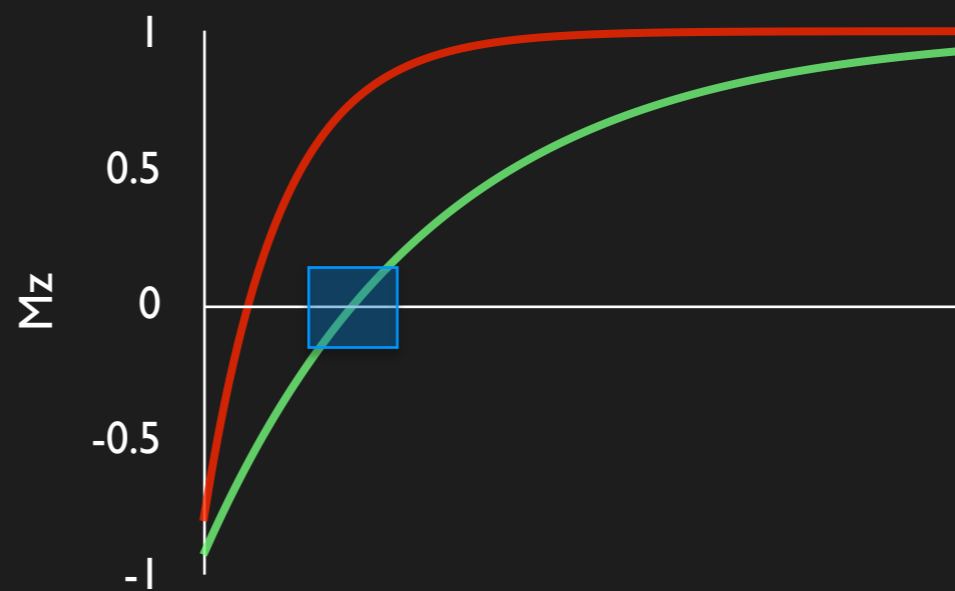
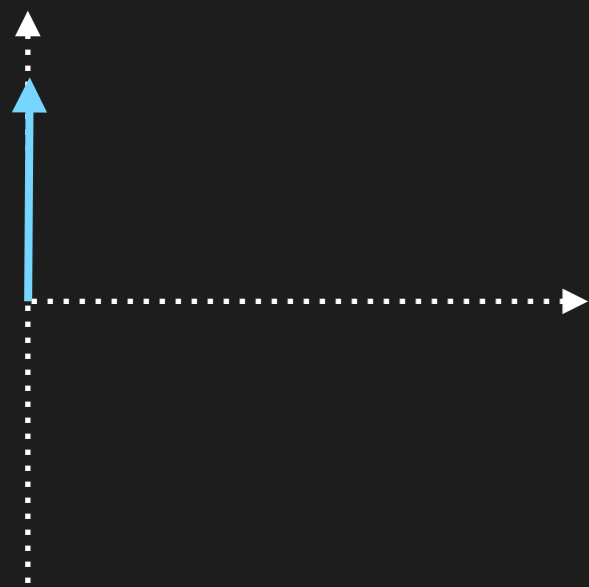
T1 preparation schemes



Short T1

Long T1

T1 dependant imaging

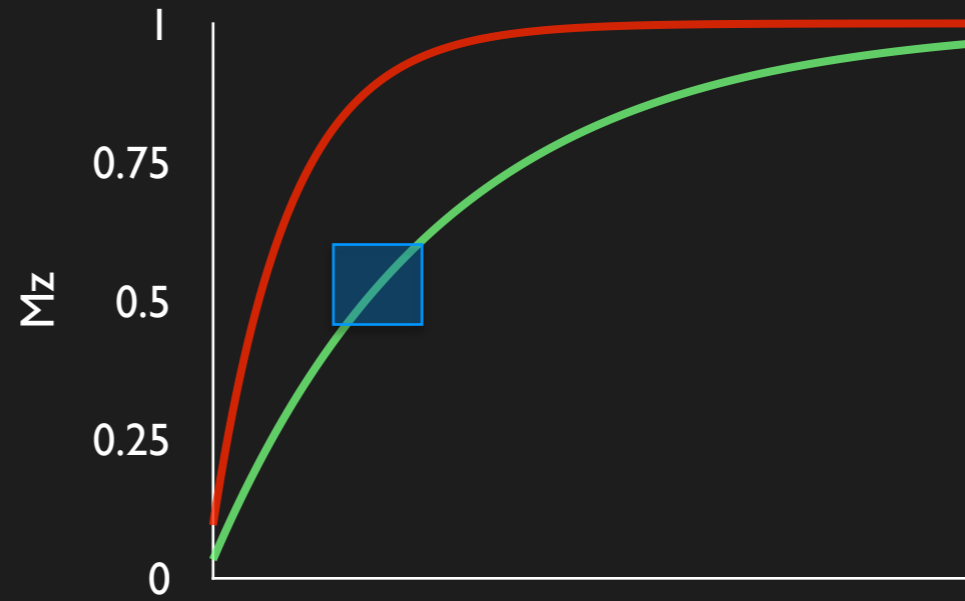
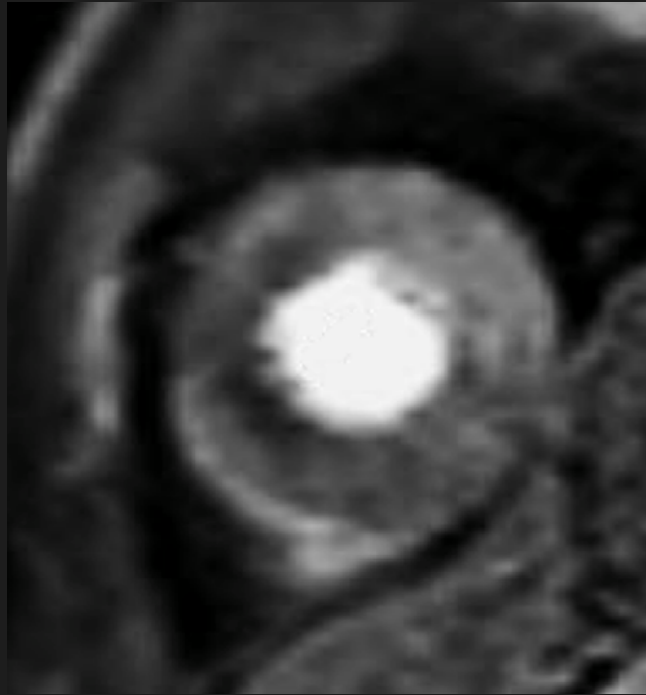


Null point at $0.693 \cdot T1$

Longer T1

High contrast

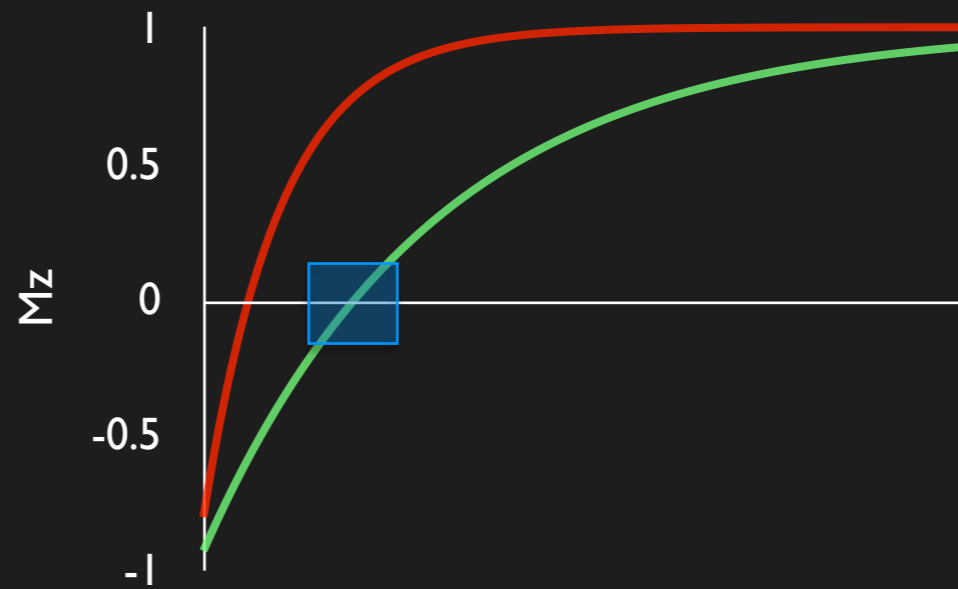
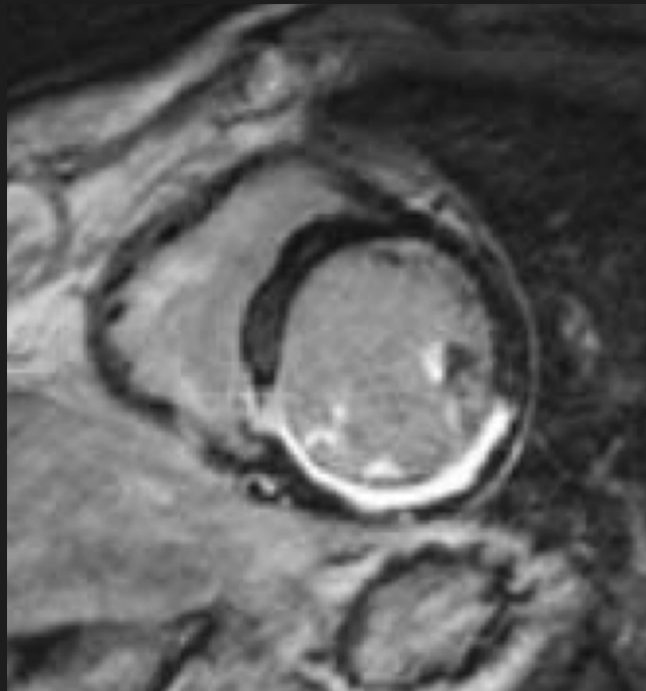
T1 preparation schemes



Short T1

Long T1

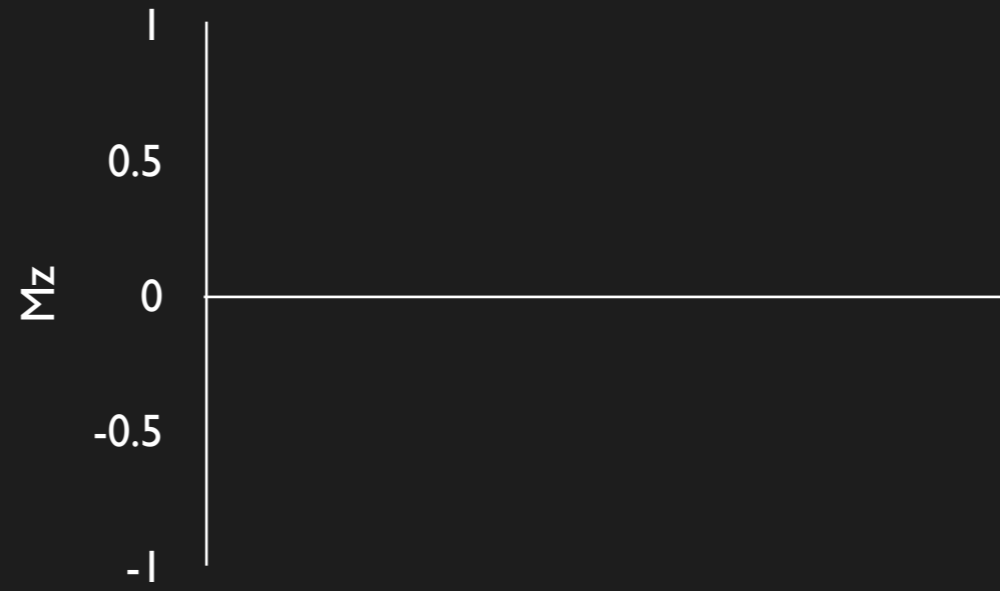
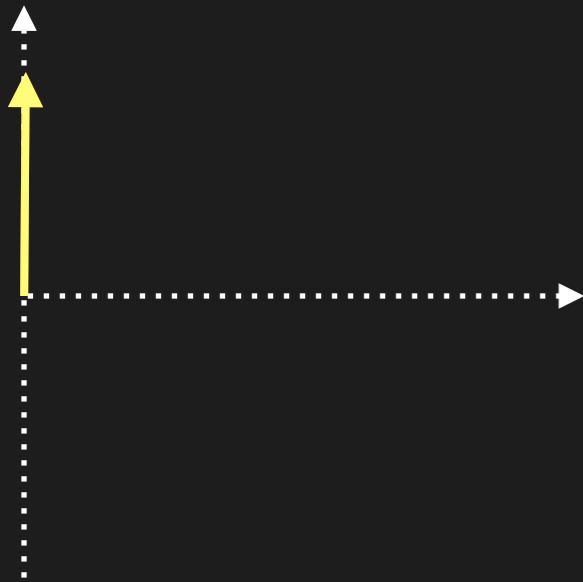
T1 dependant imaging

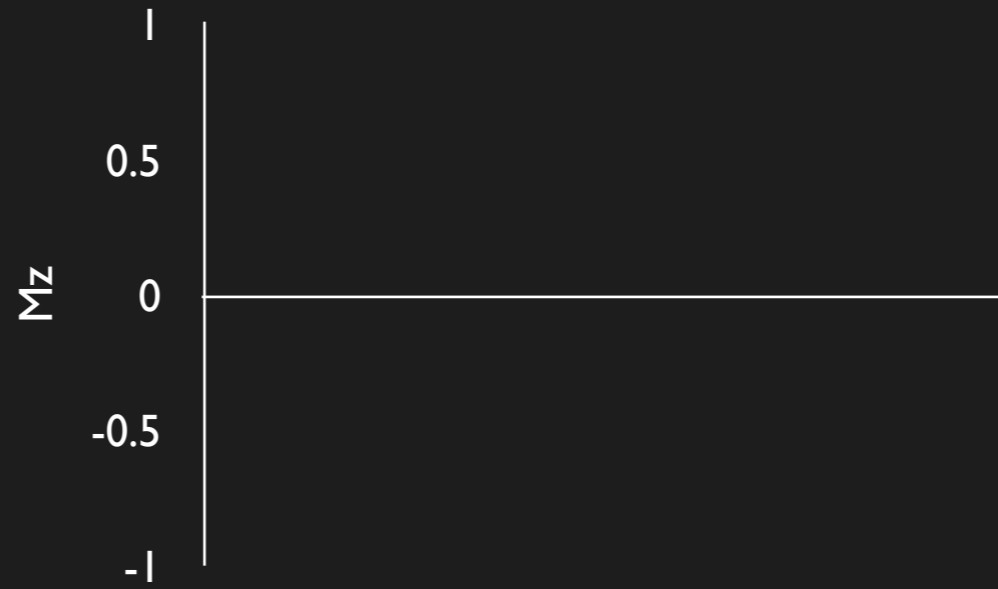
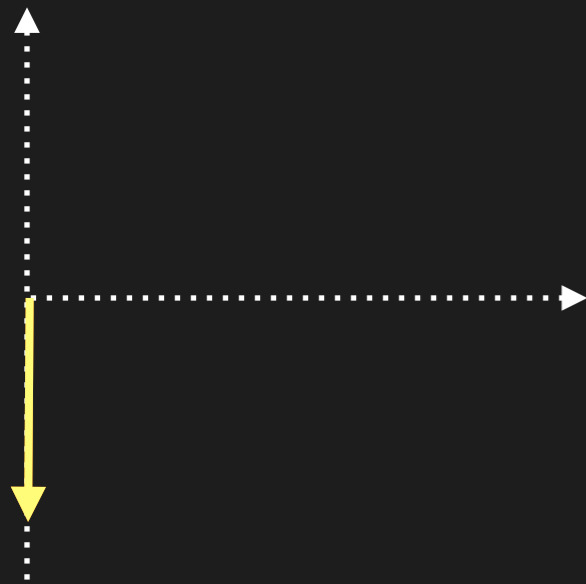


Null point at $0.693 \cdot T1$

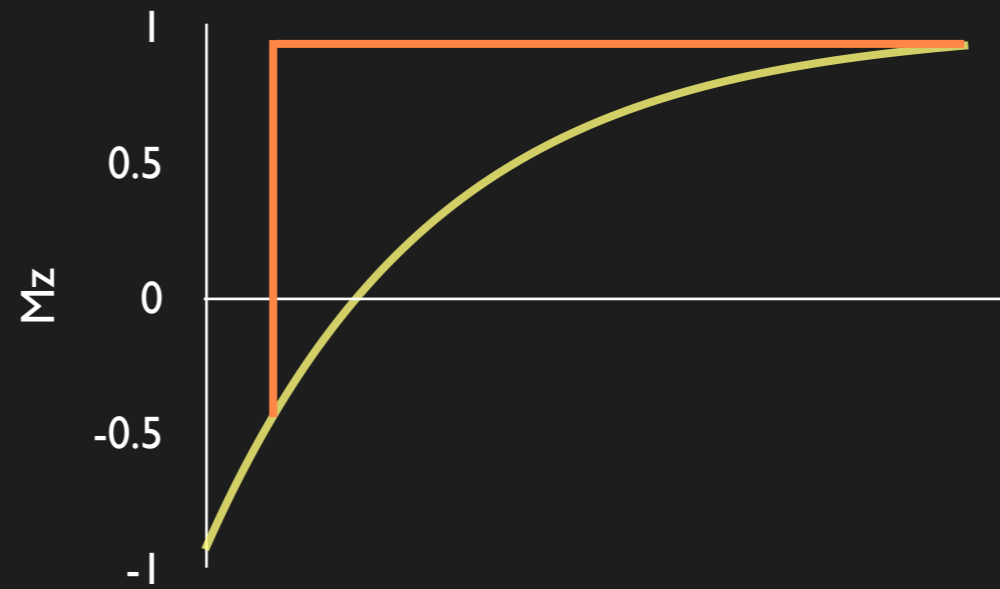
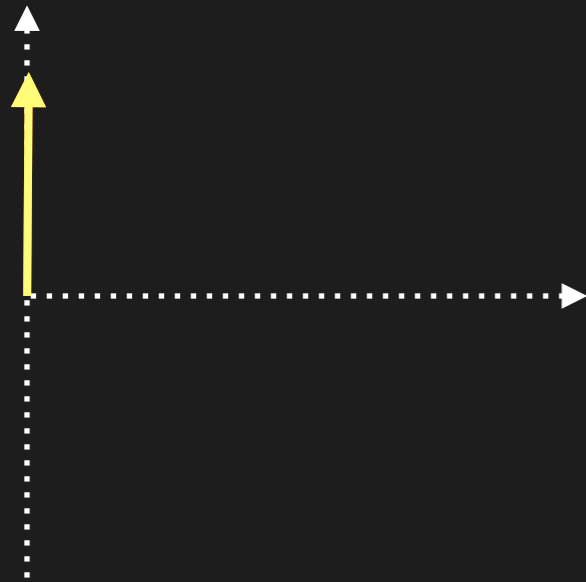
Longer T1

High contrast



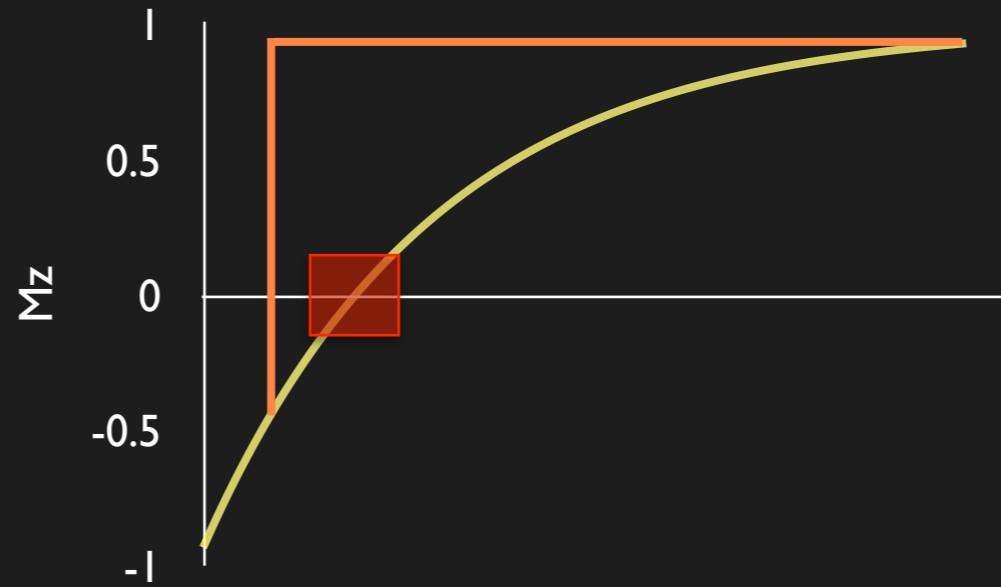
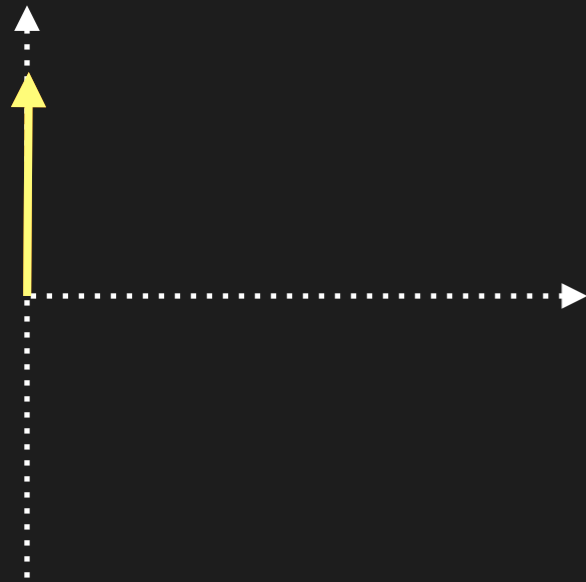


Non-selective inversion



Non-selective inversion

Slice re-inverted

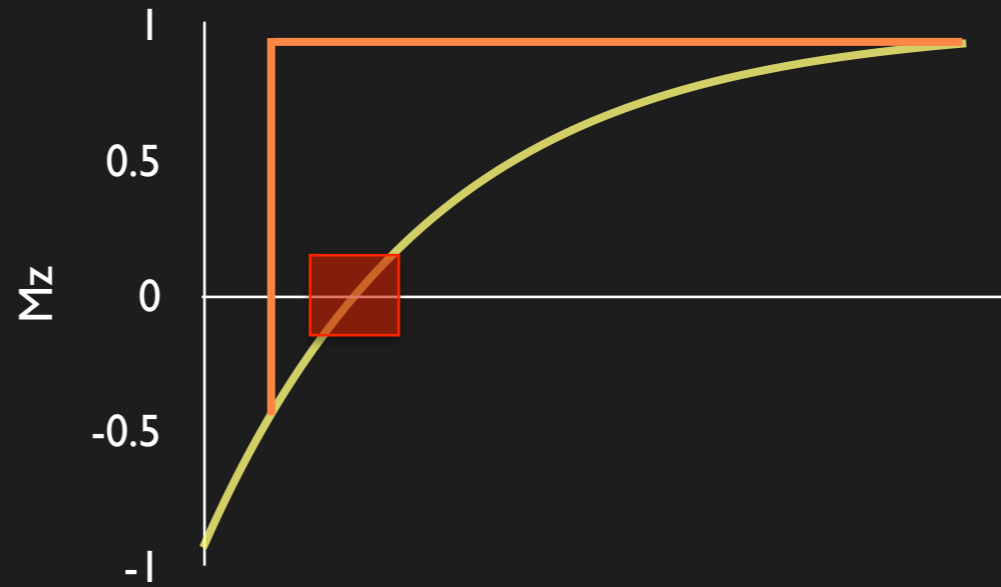
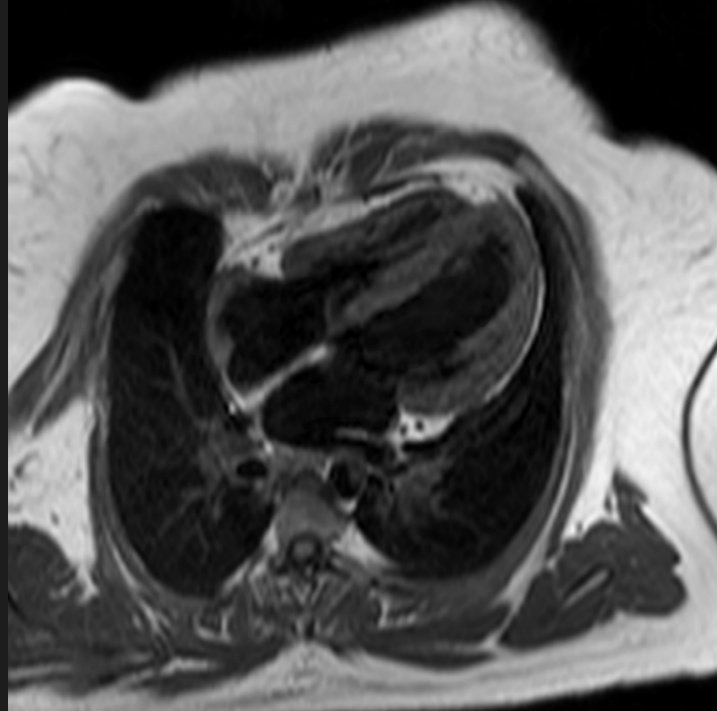


Non-selective inversion

Slice re-inverted

Blood nulled

More inversion recovery - DIR and TIR

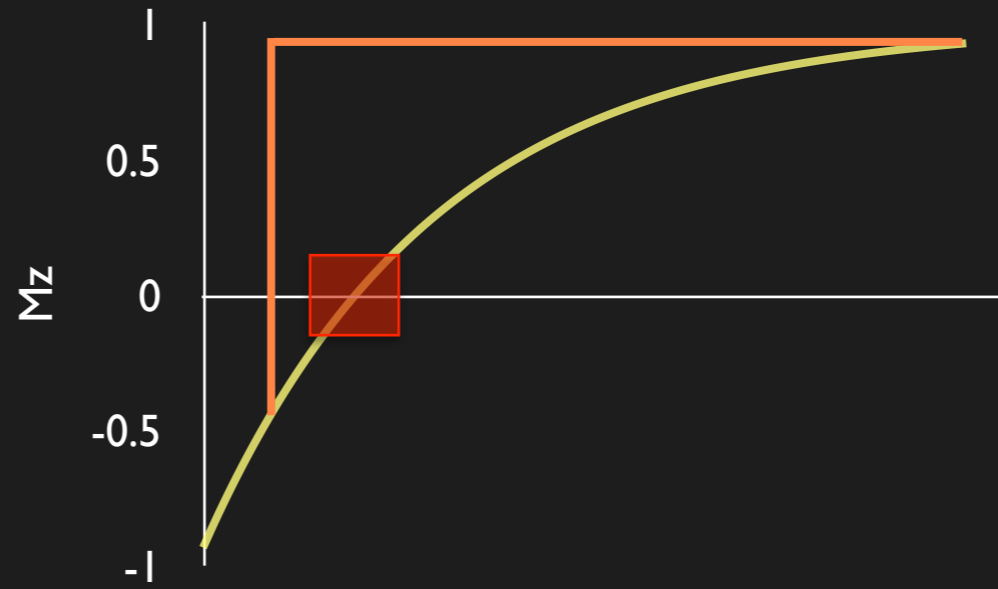
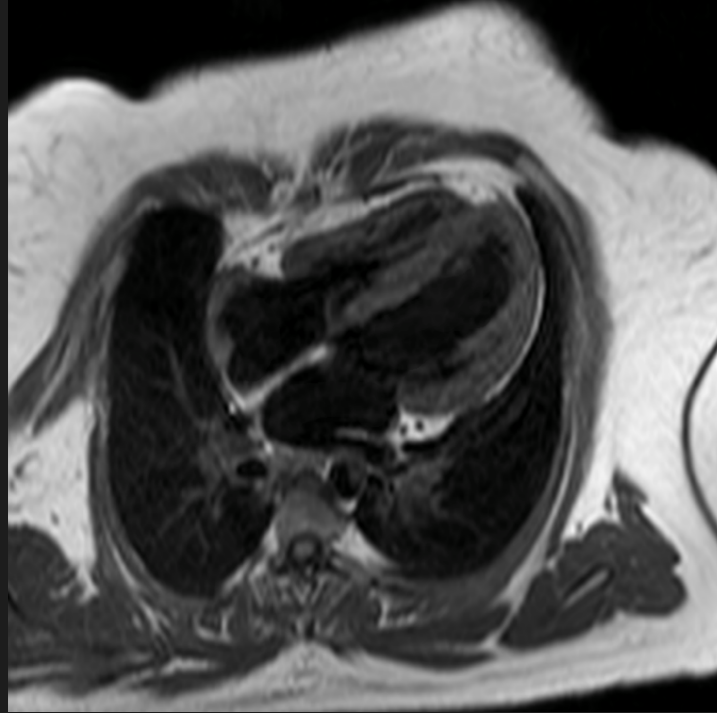


Non-selective inversion

Slice re-inverted

Blood nulled

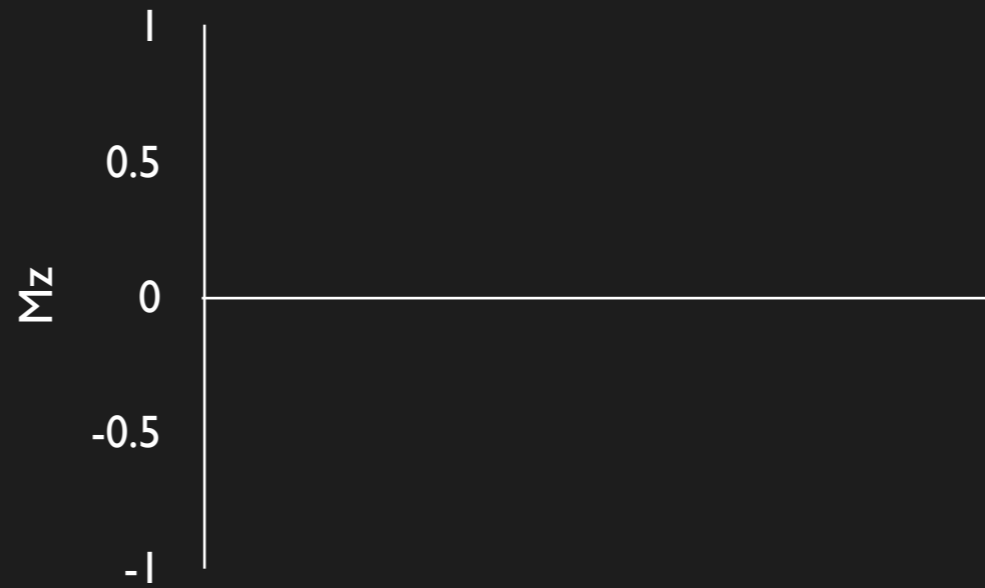
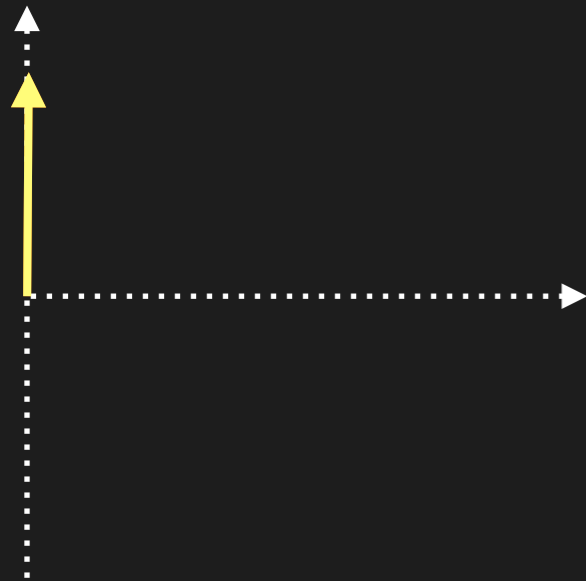
More inversion recovery - DIR and TIR



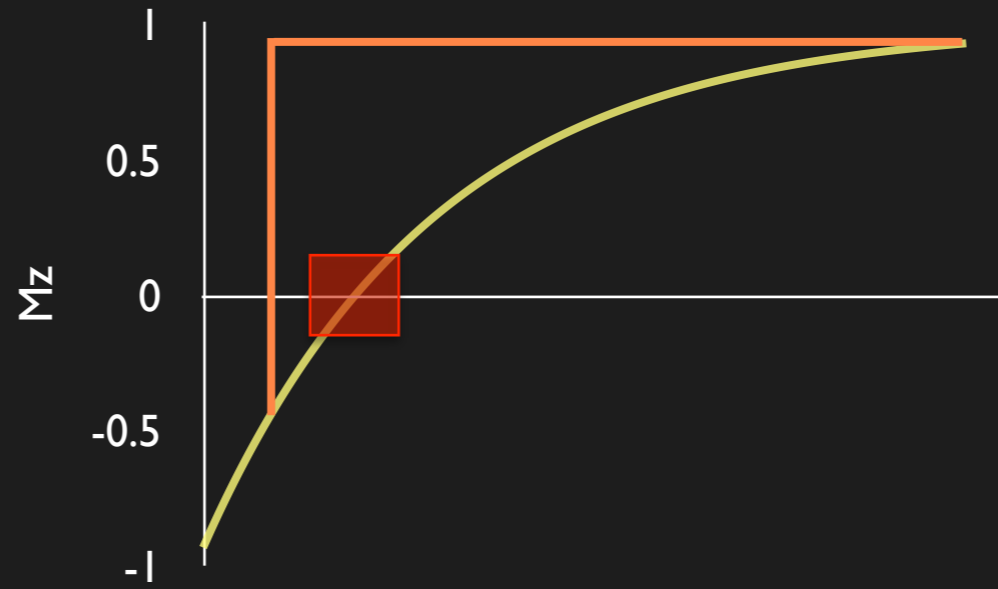
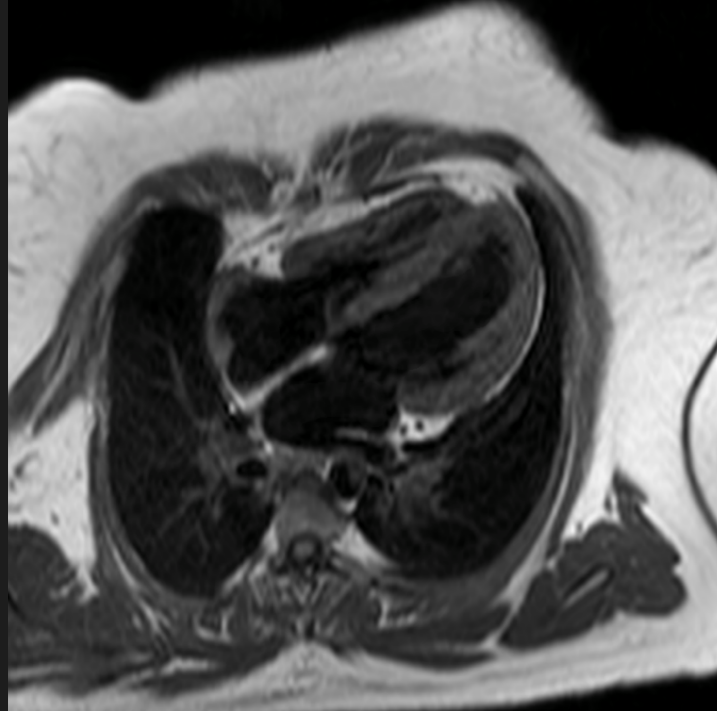
Non-selective inversion

Slice re-inverted

Blood nulled



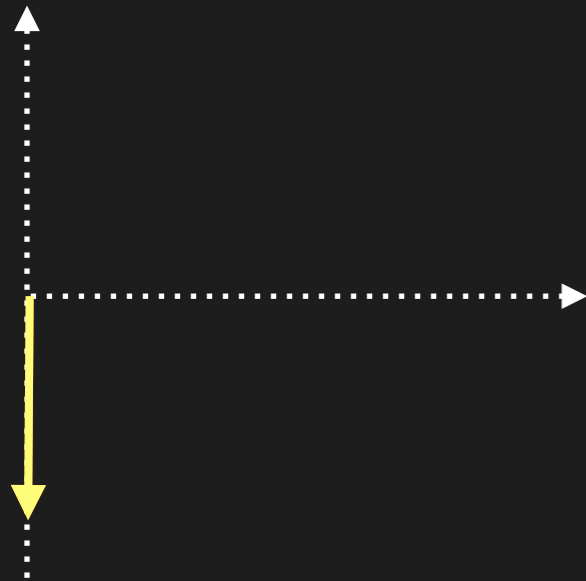
More inversion recovery - DIR and TIR



Non-selective inversion

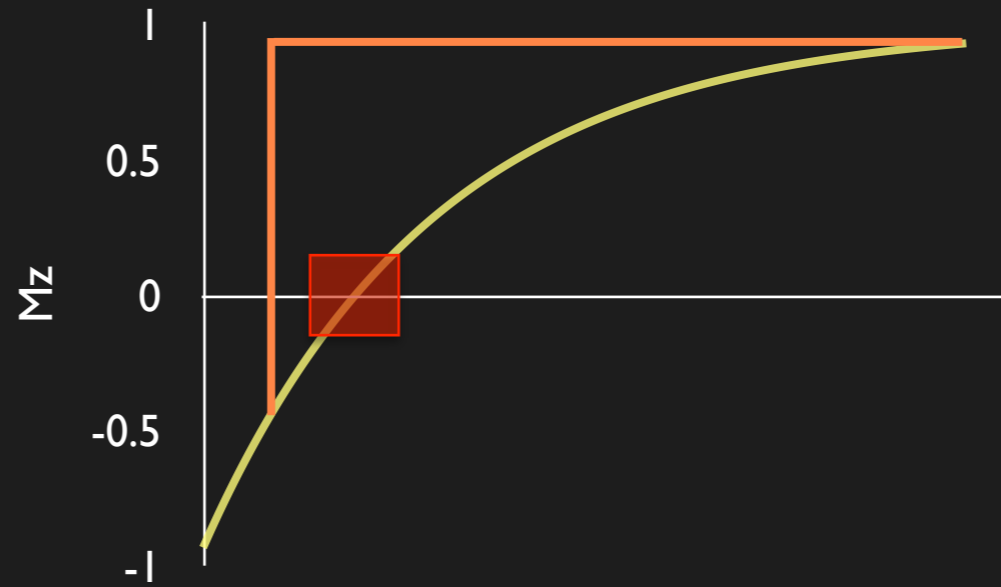
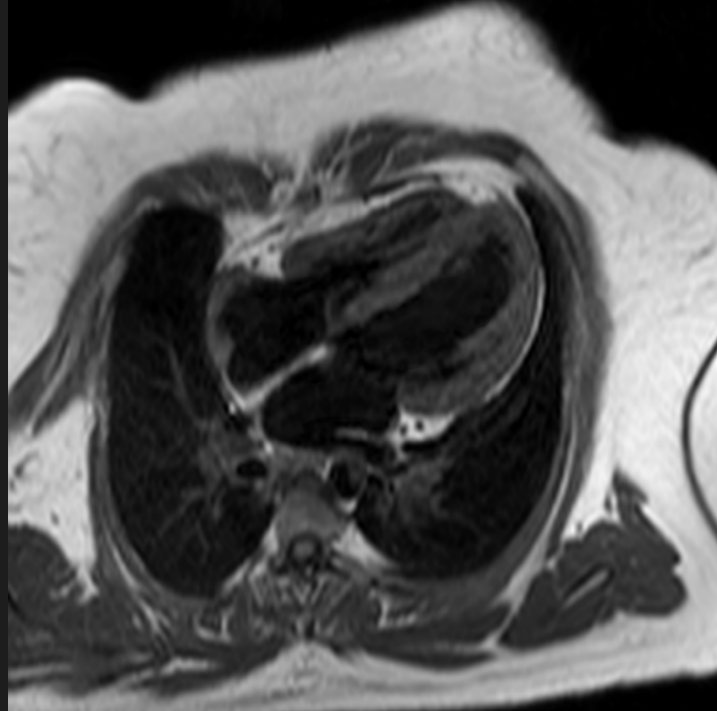
Slice re-inverted

Blood nulled



Non-selective inversion

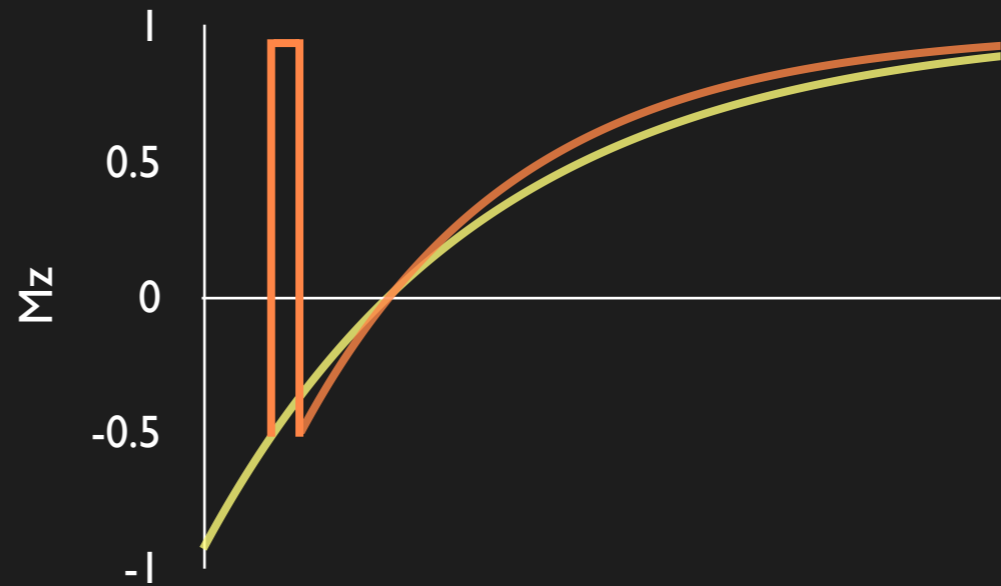
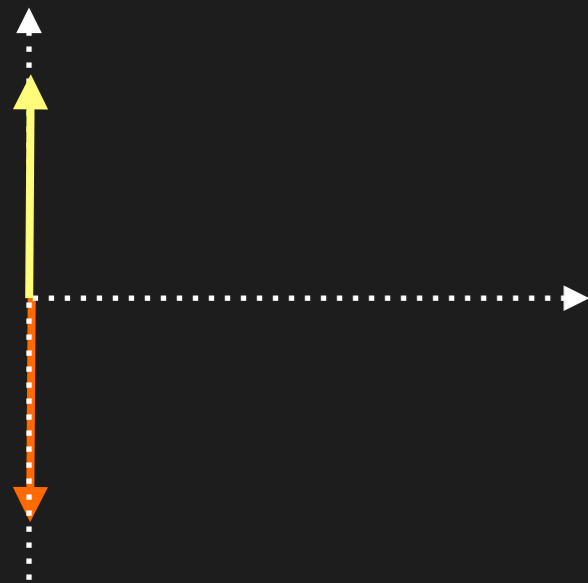
More inversion recovery - DIR and TIR



Non-selective inversion

Slice re-inverted

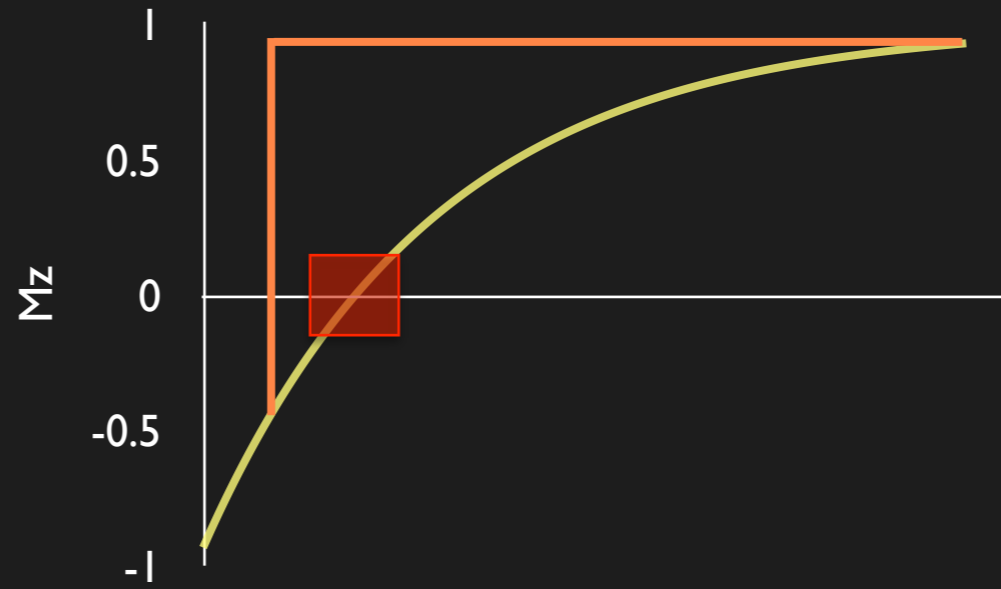
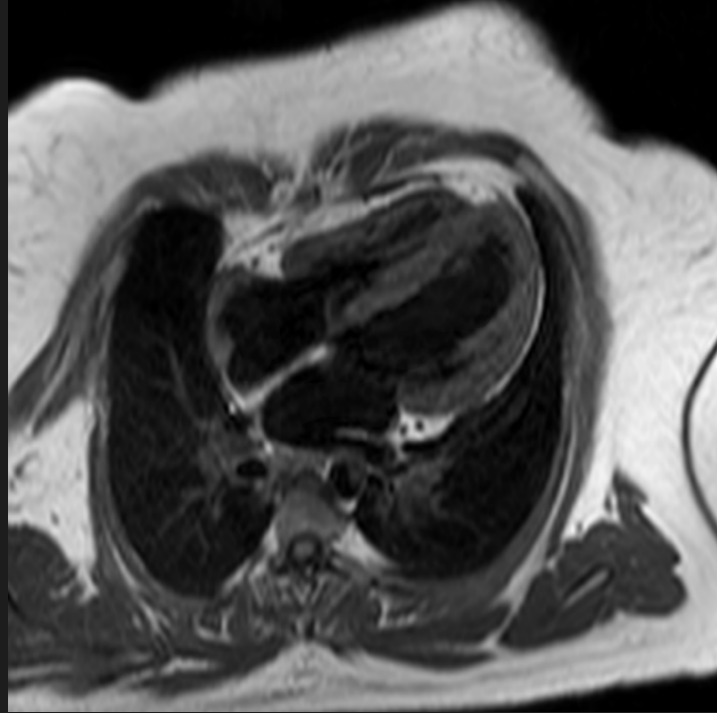
Blood nulled



Non-selective inversion

Slice re-inverted x 2

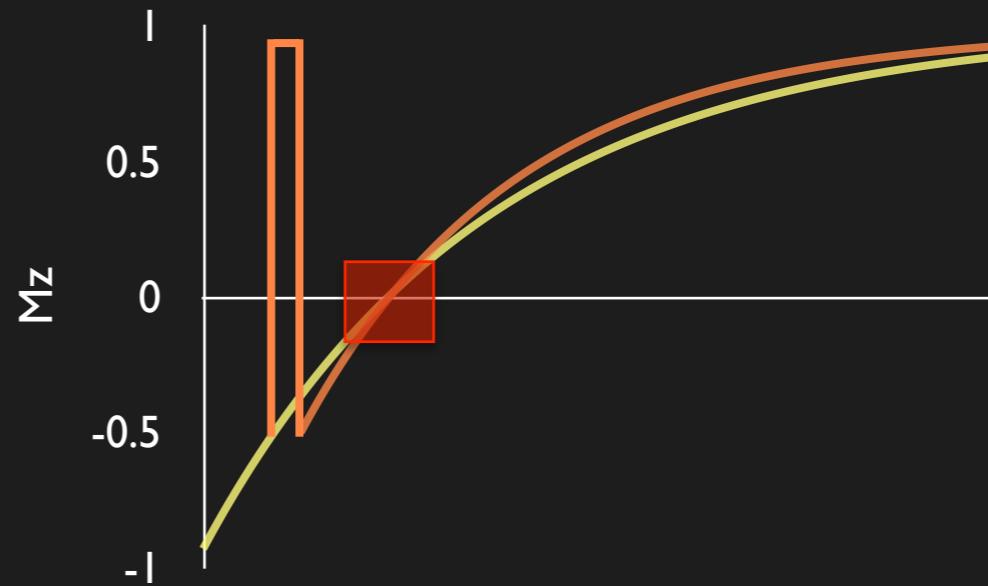
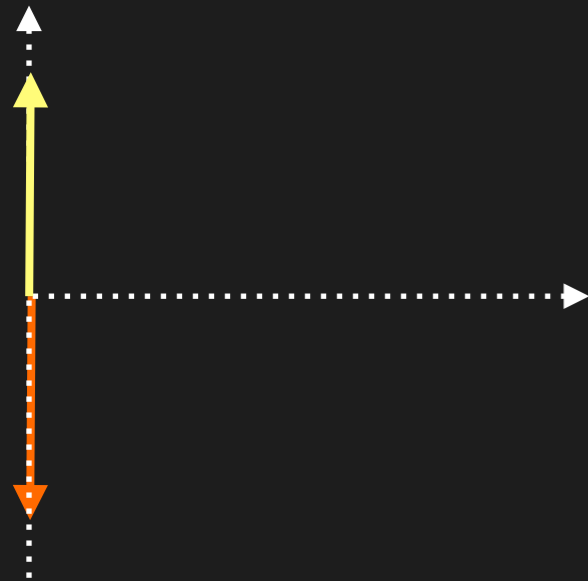
More inversion recovery - DIR and TIR



Non-selective inversion

Slice re-inverted

Blood nulled

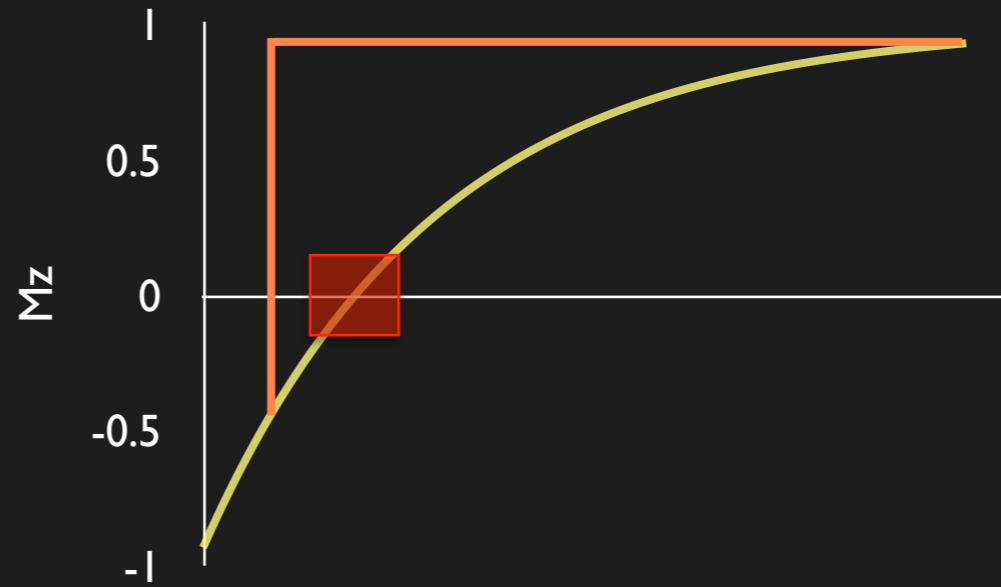
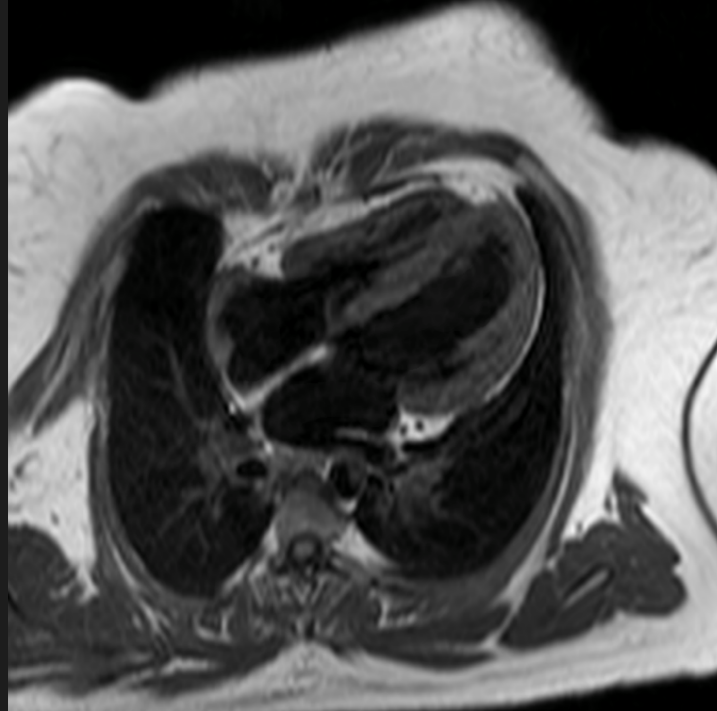


Non-selective inversion

Slice re-inverted x 2

Blood and fat inverted

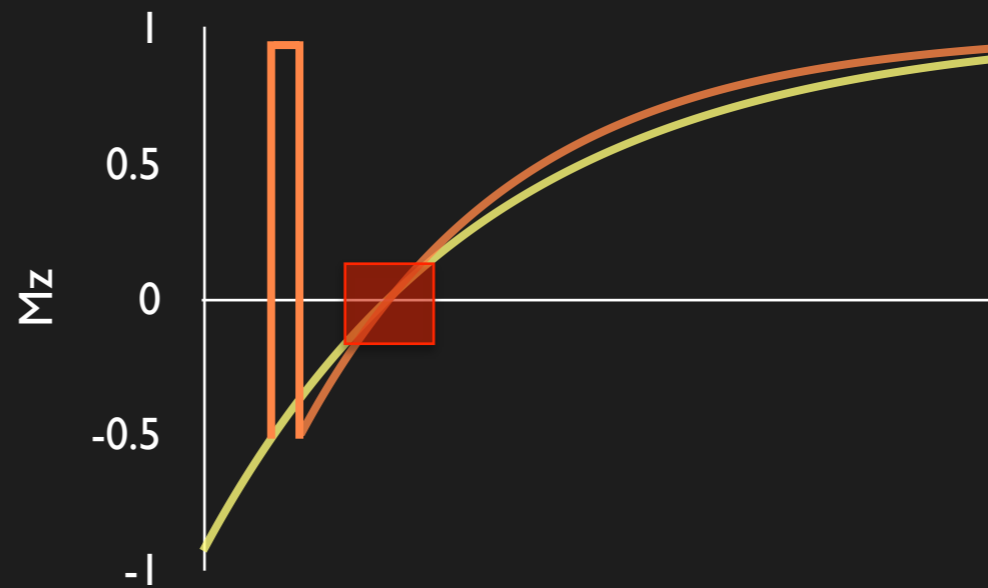
More inversion recovery - DIR and TIR



Non-selective inversion

Slice re-inverted

Blood nulled



Non-selective inversion

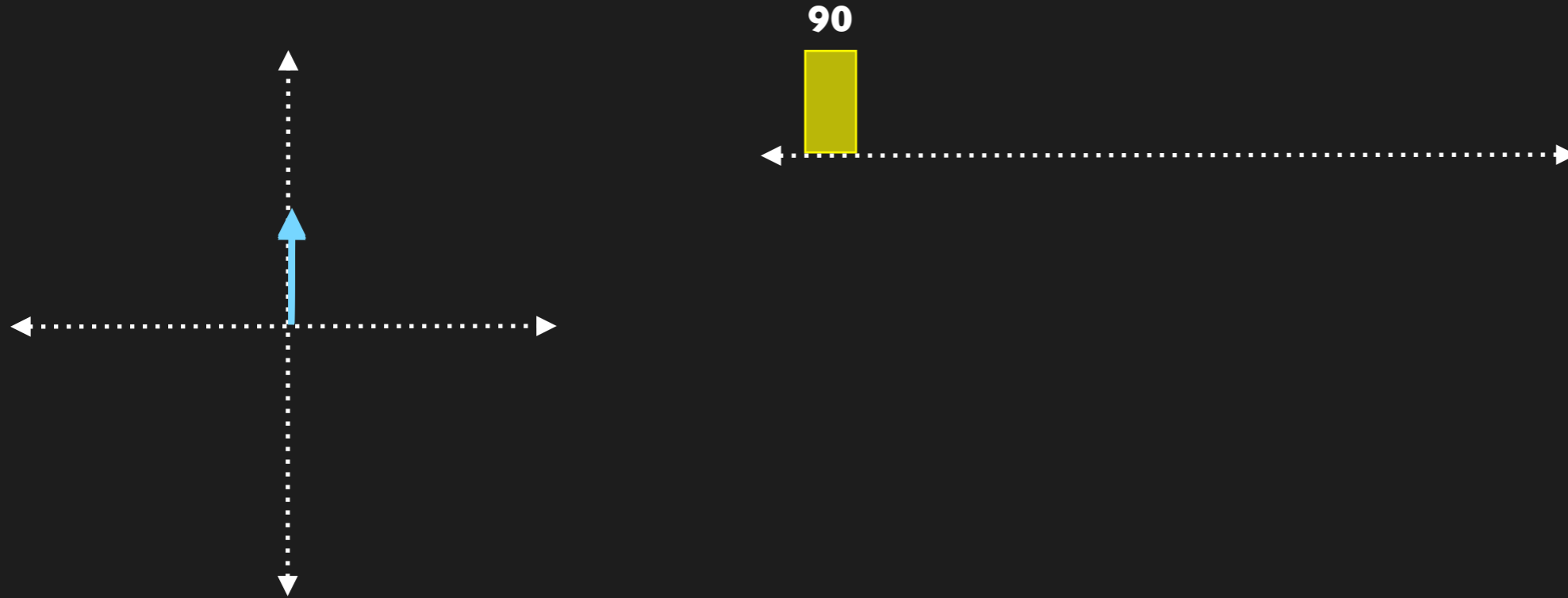
Slice re-inverted x 2

Blood and fat inverted

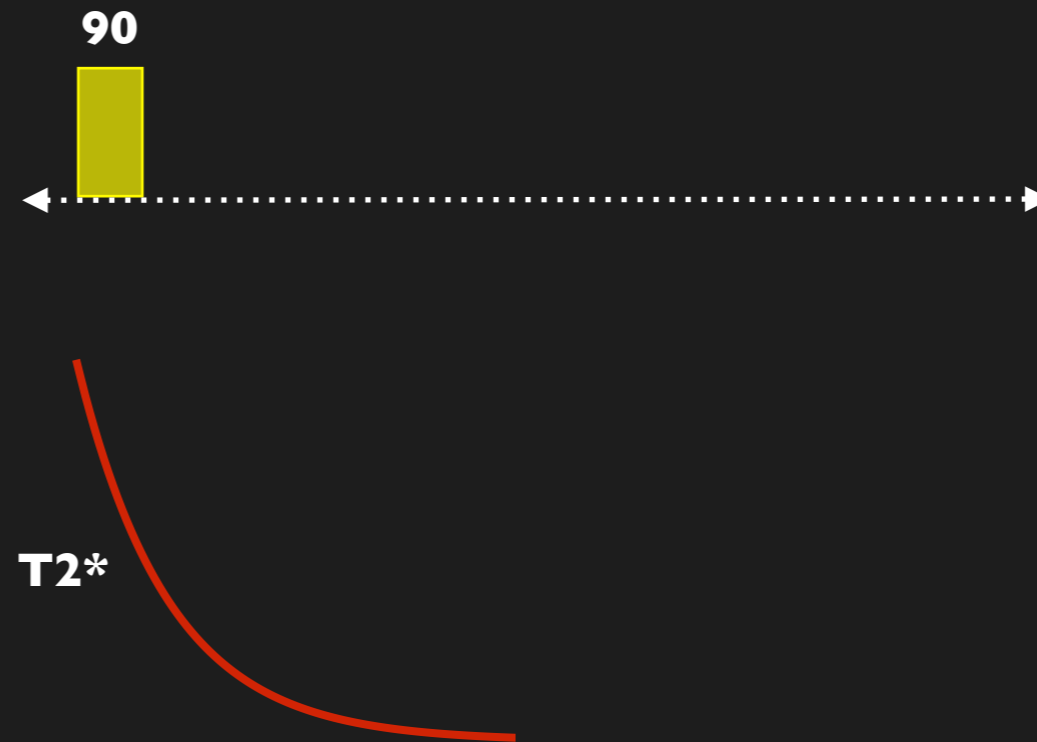
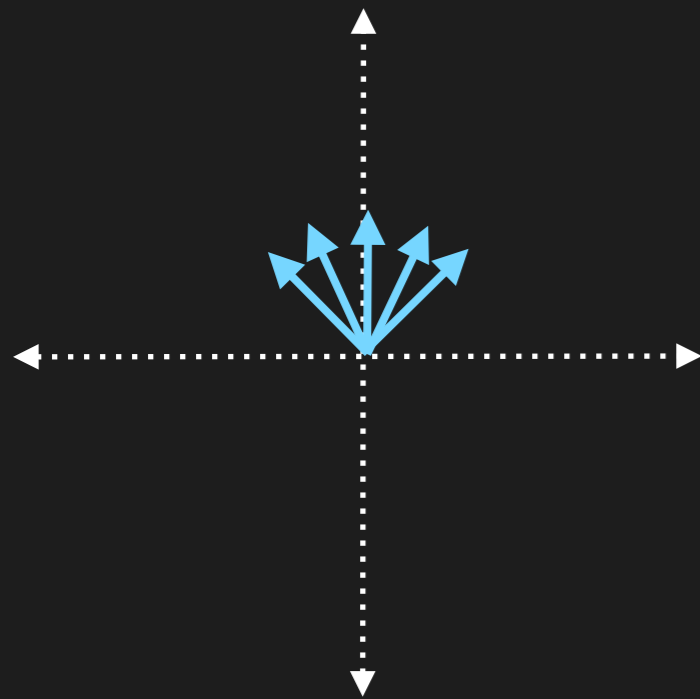
Spin Echo



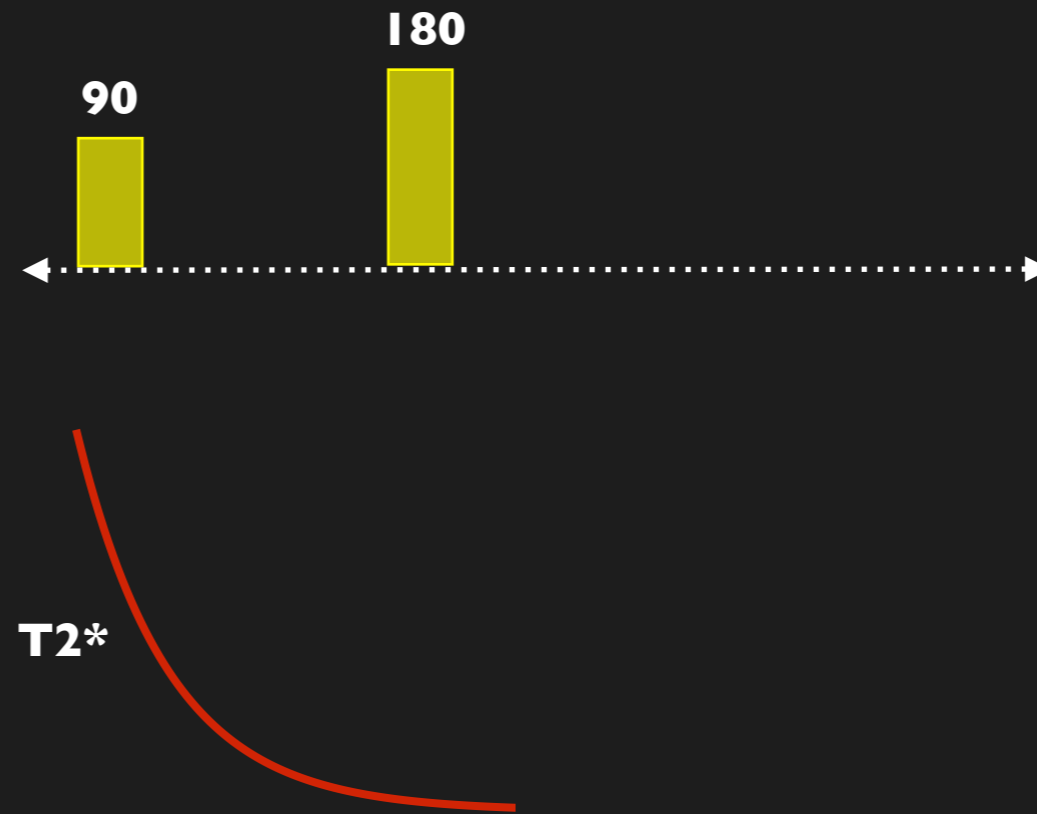
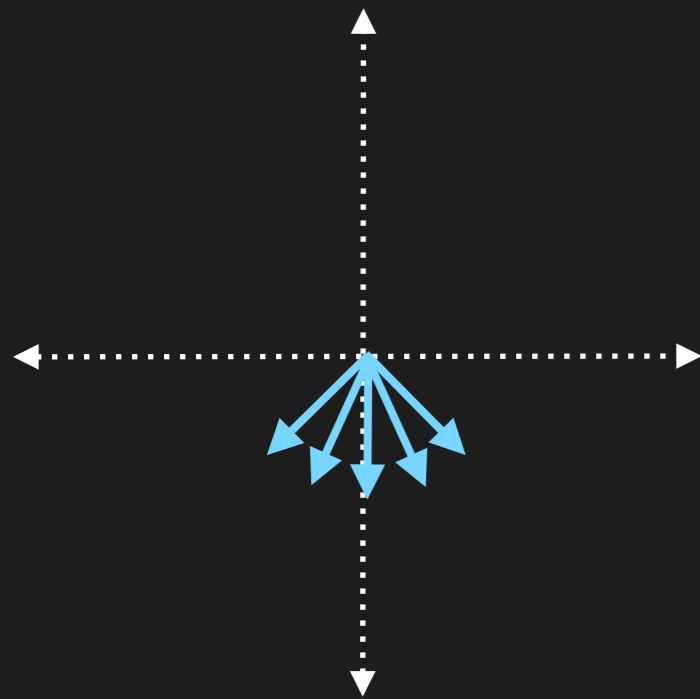
Spin Echo



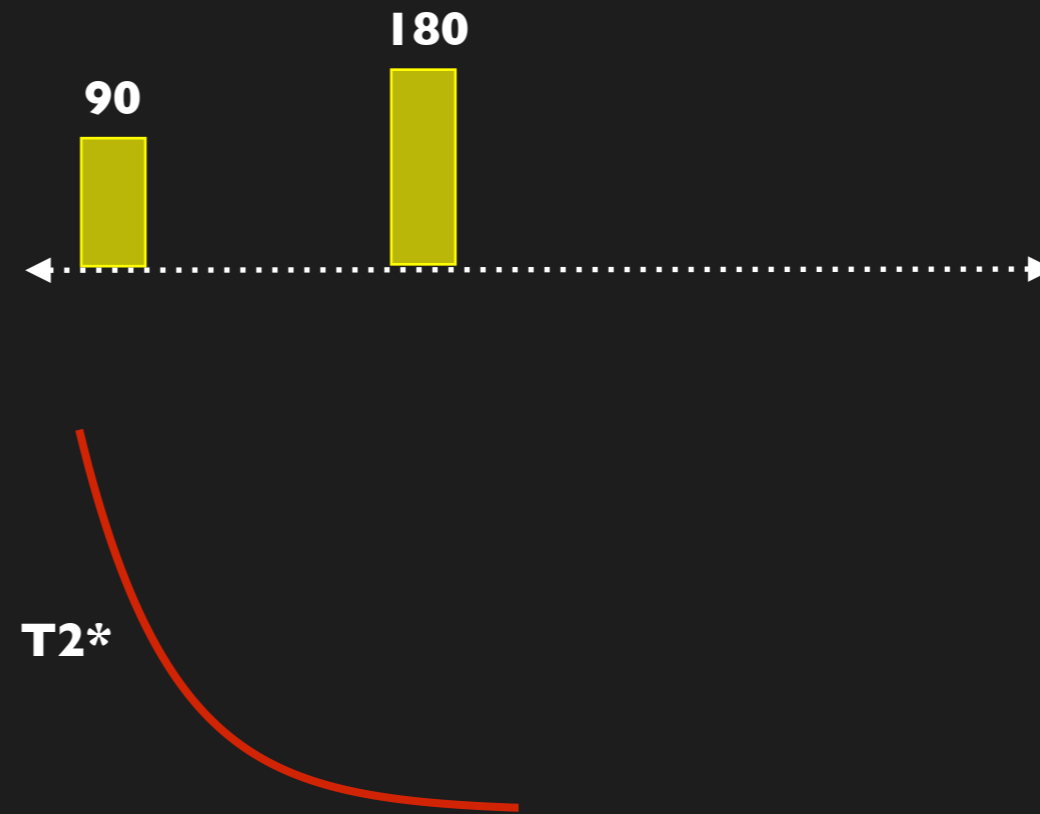
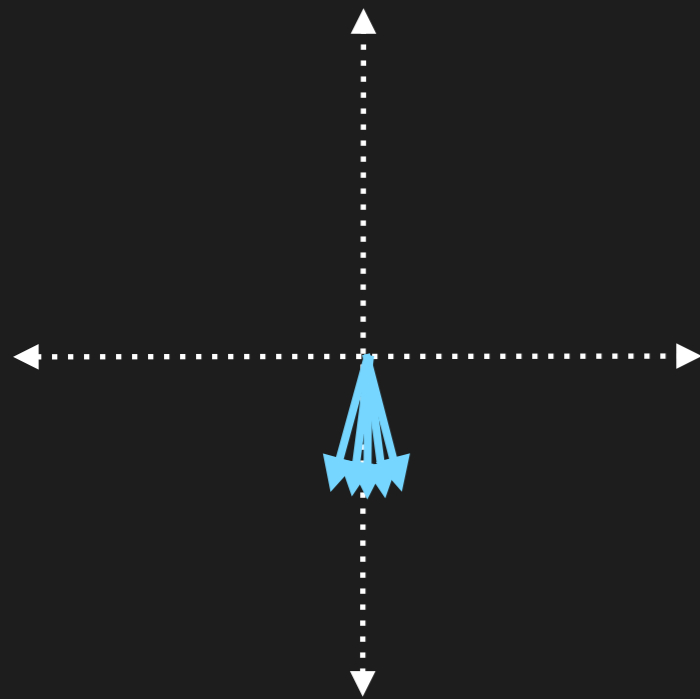
Spin Echo



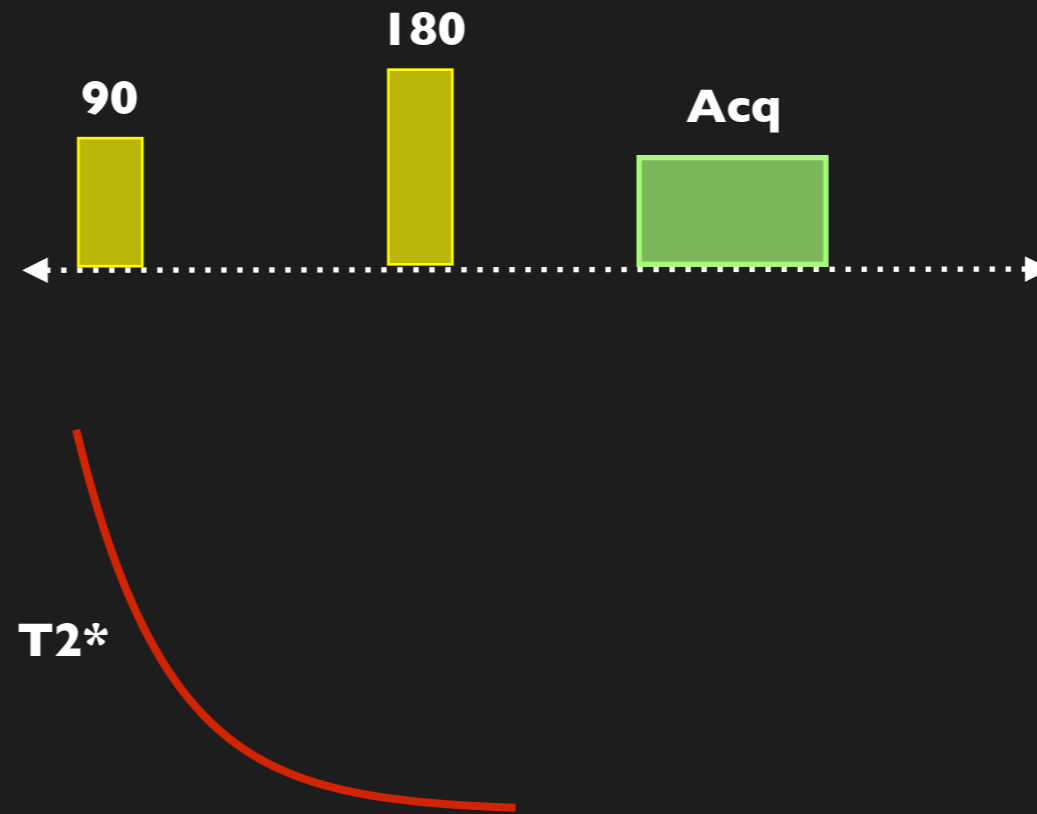
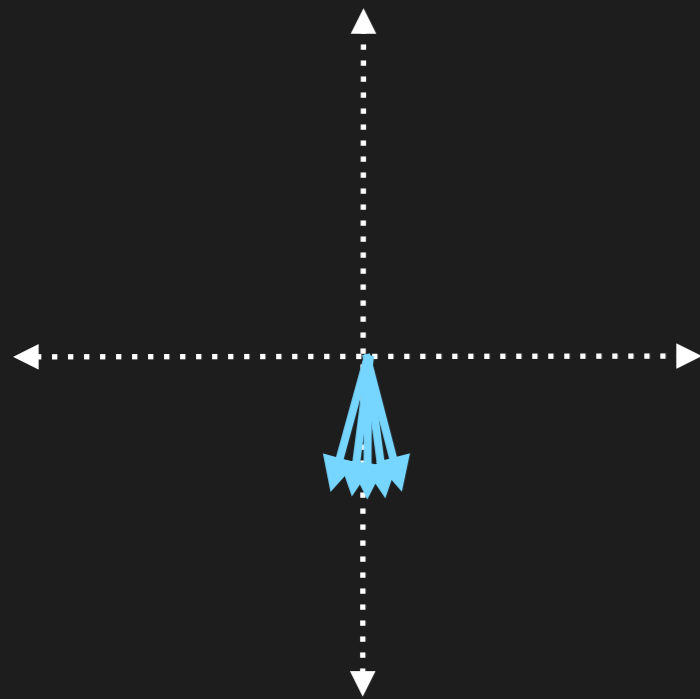
Spin Echo



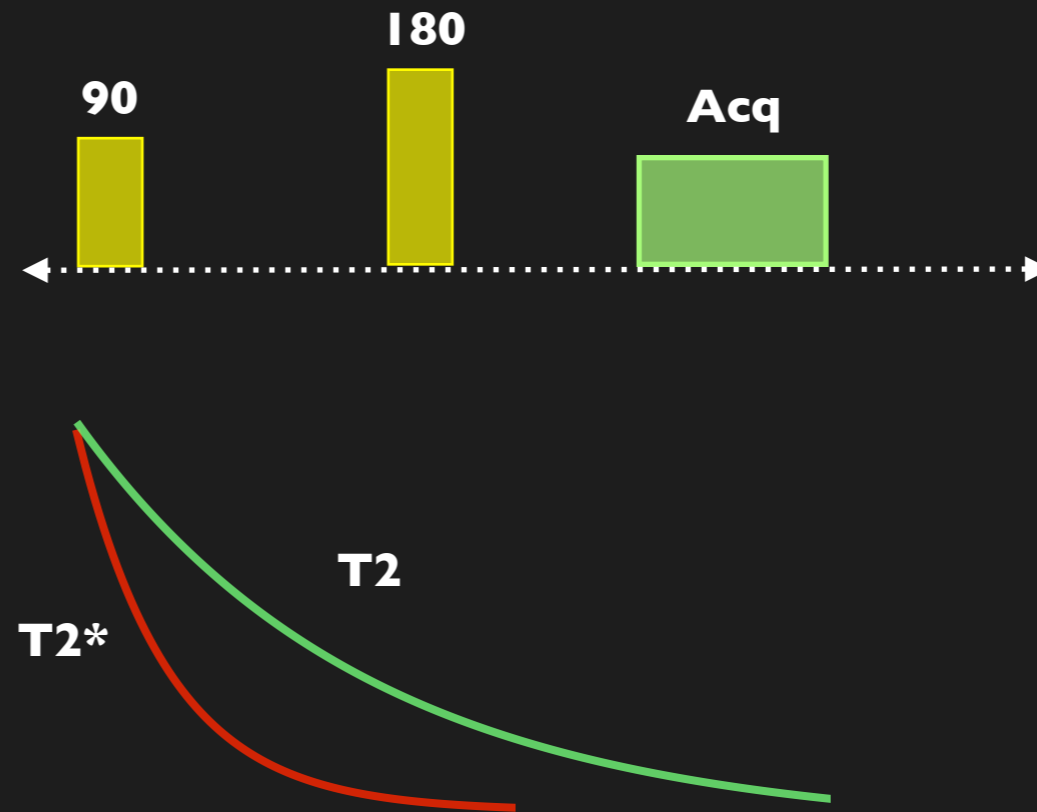
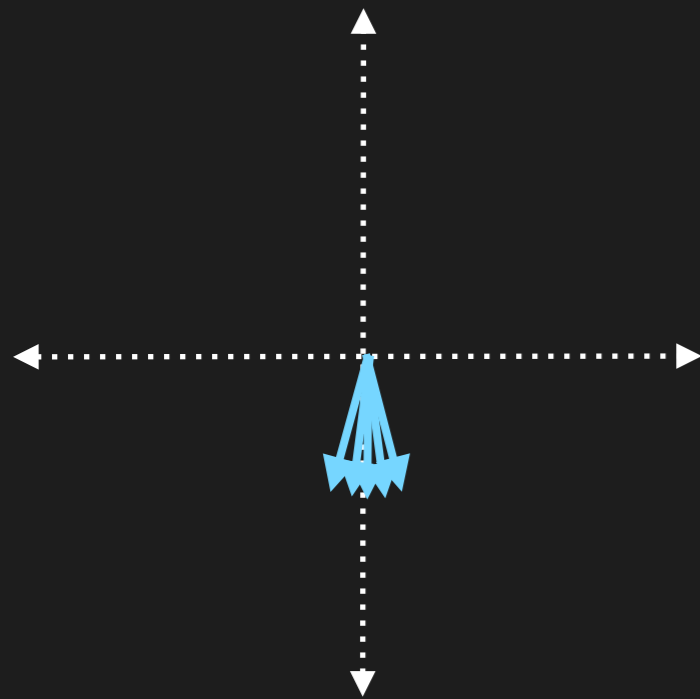
Spin Echo



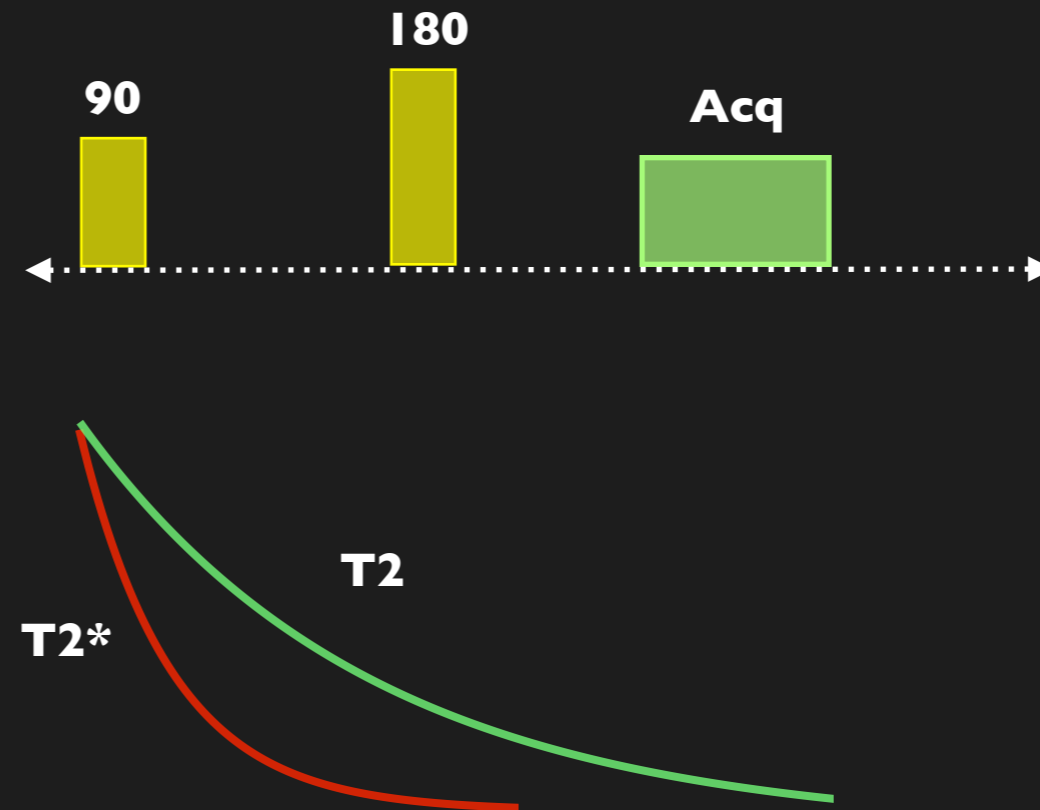
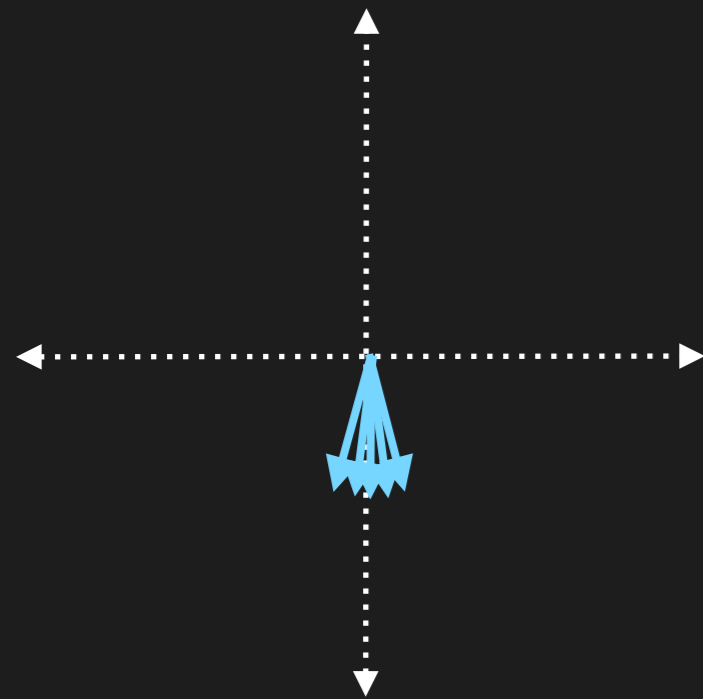
Spin Echo



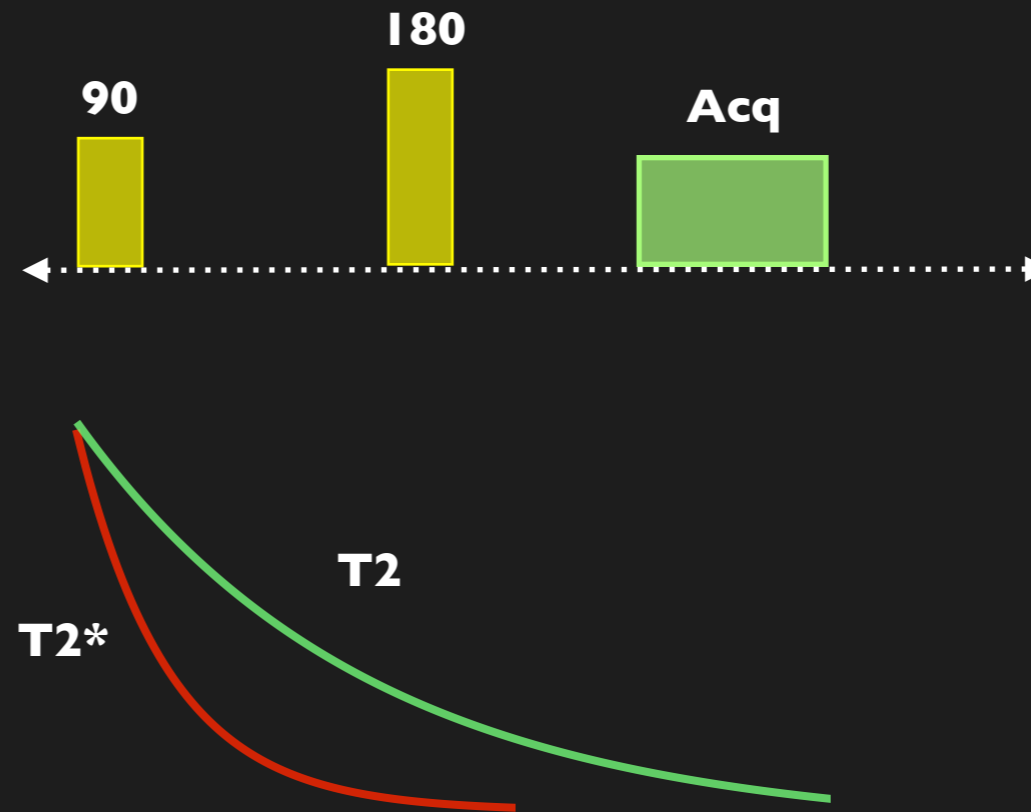
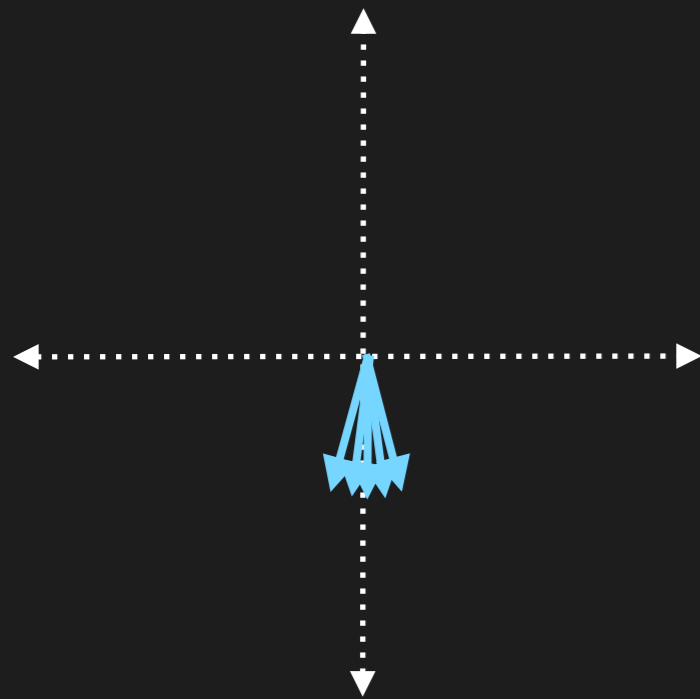
Spin Echo



Spin Echo



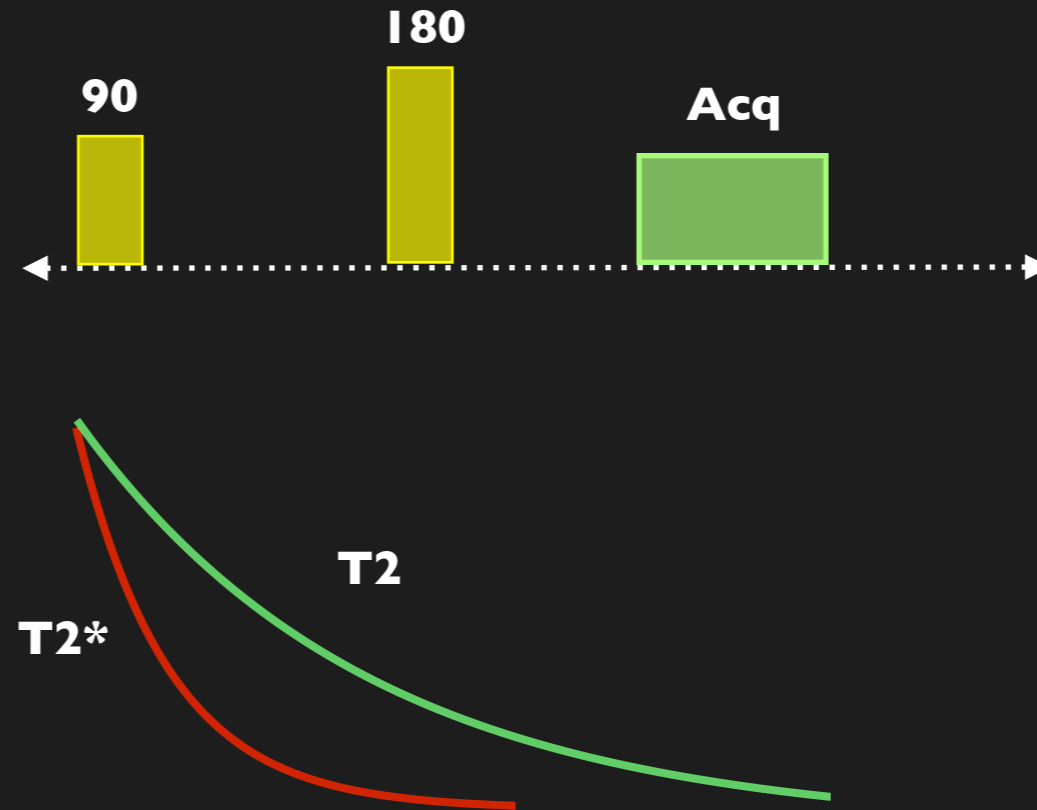
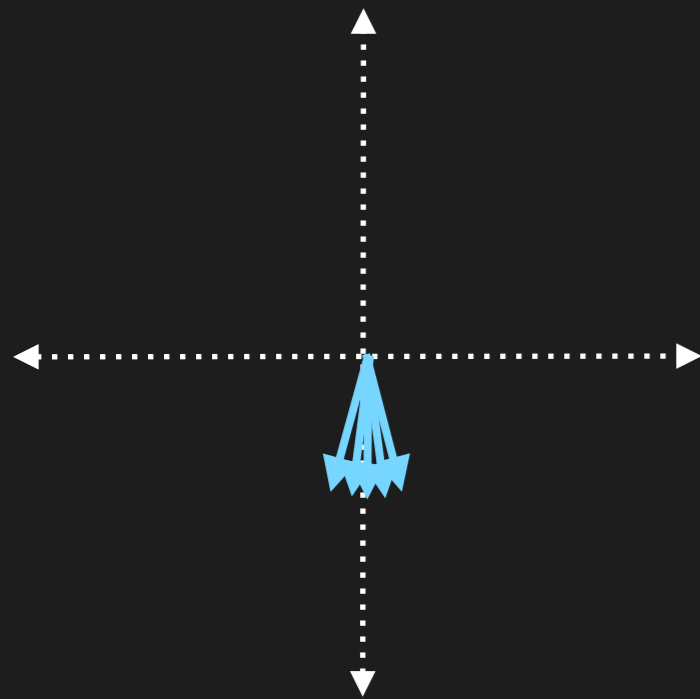
Spin Echo



High Signal

Slow

Spin Echo

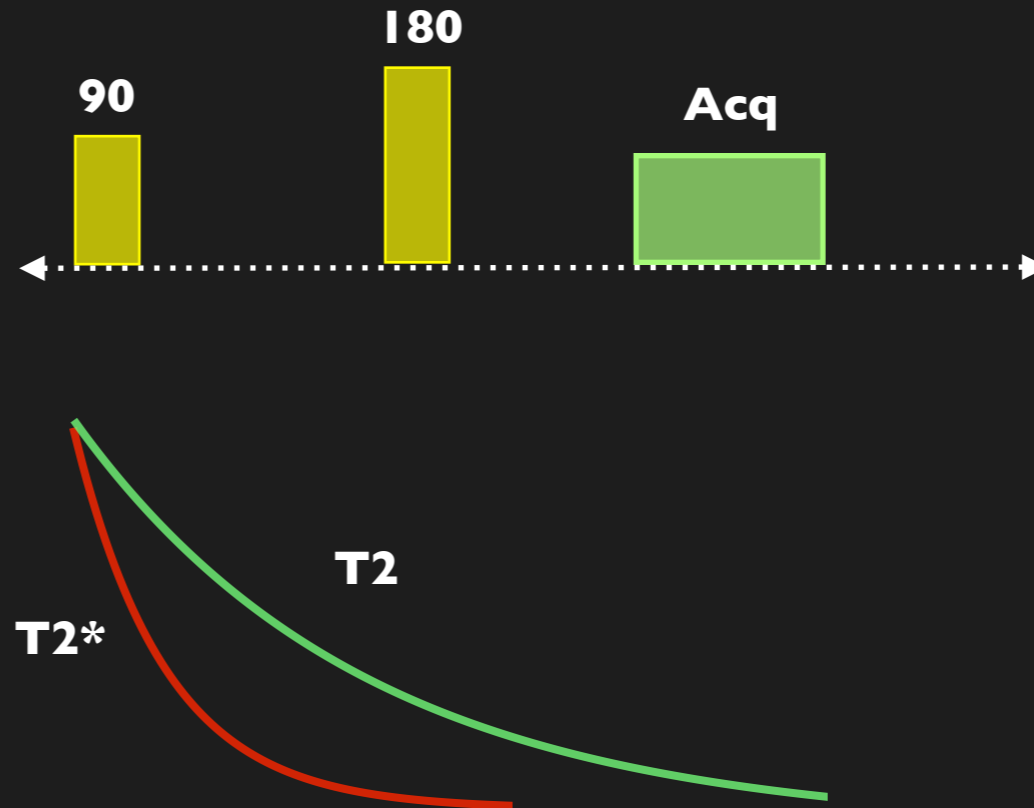
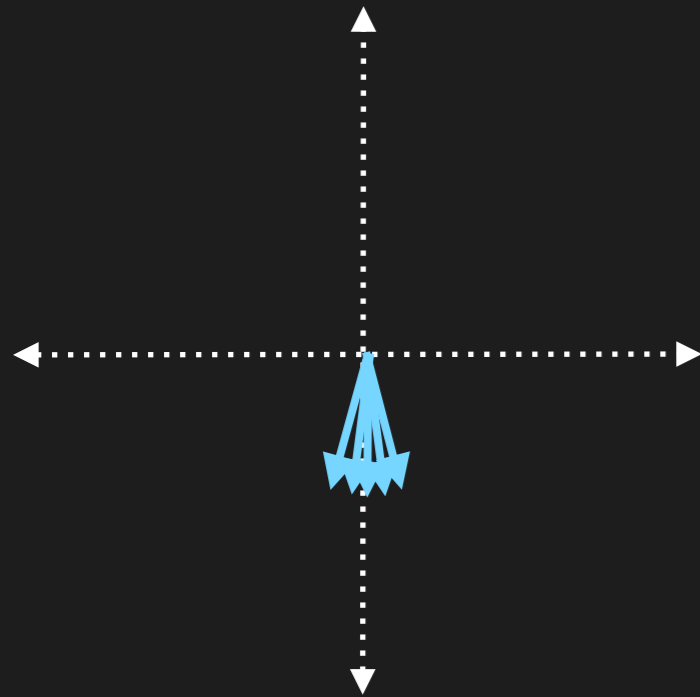


High Signal

Slow

Black blood

Spin Echo

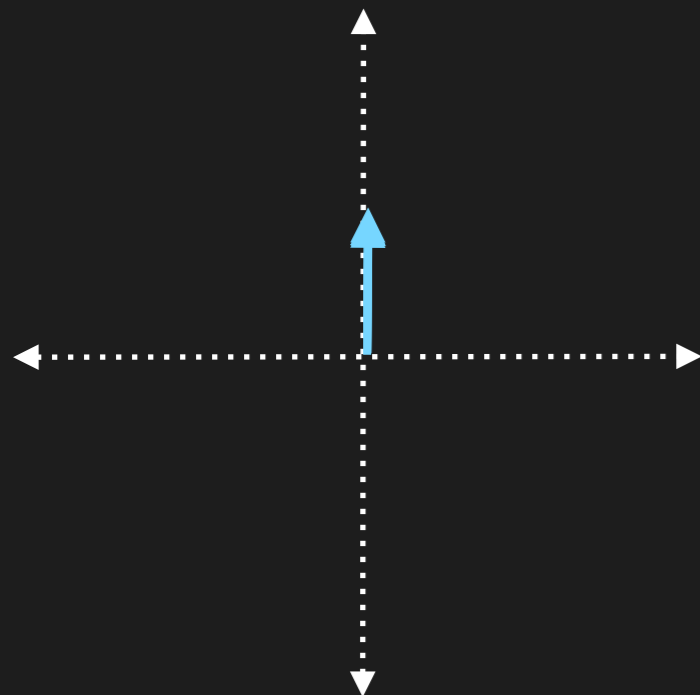


High Signal

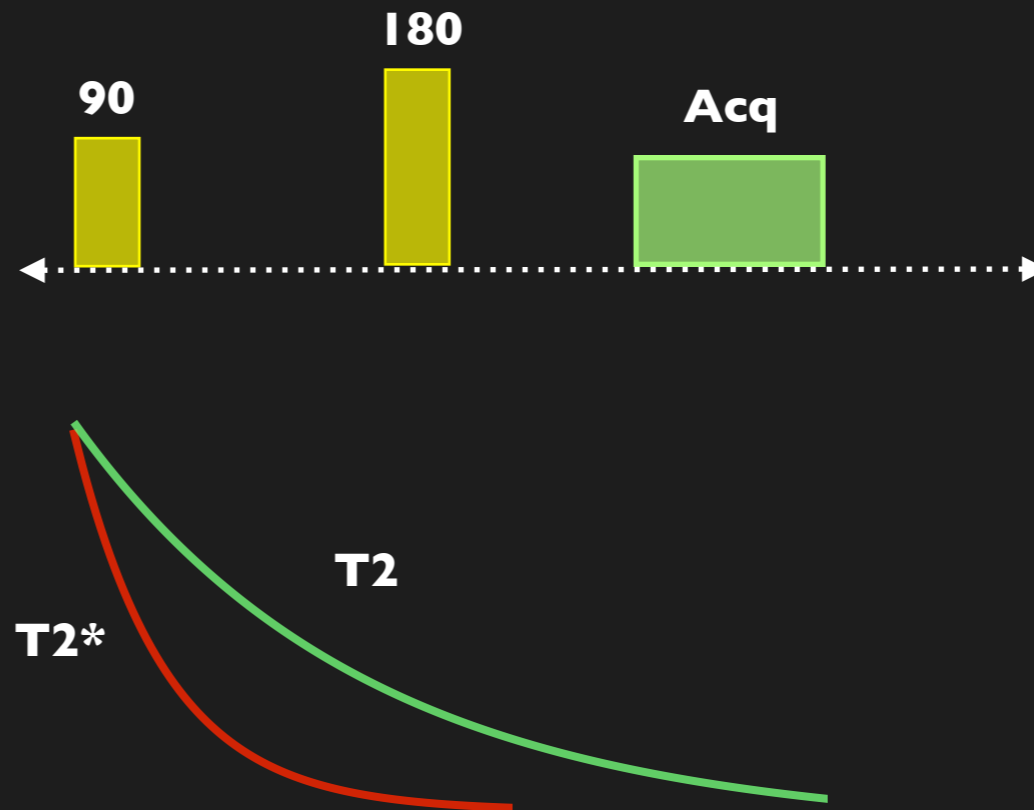
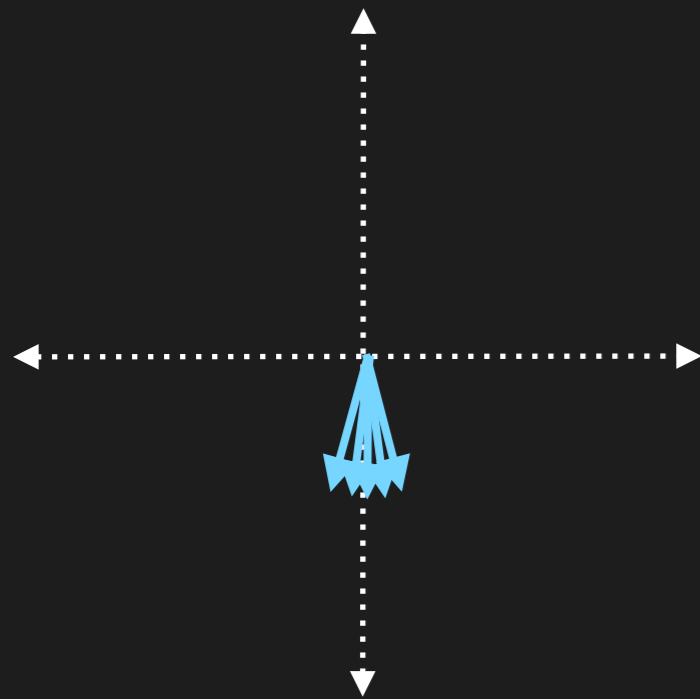
Slow

Black blood

Fast Spin Echo



Spin Echo

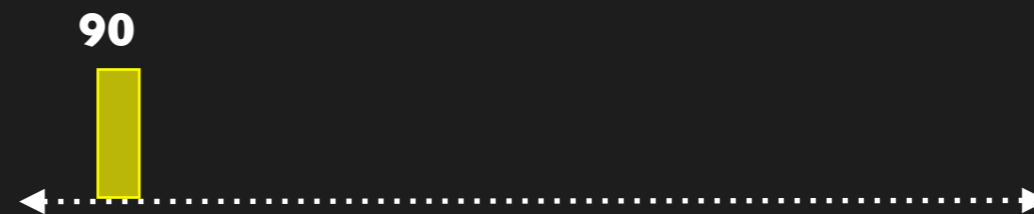
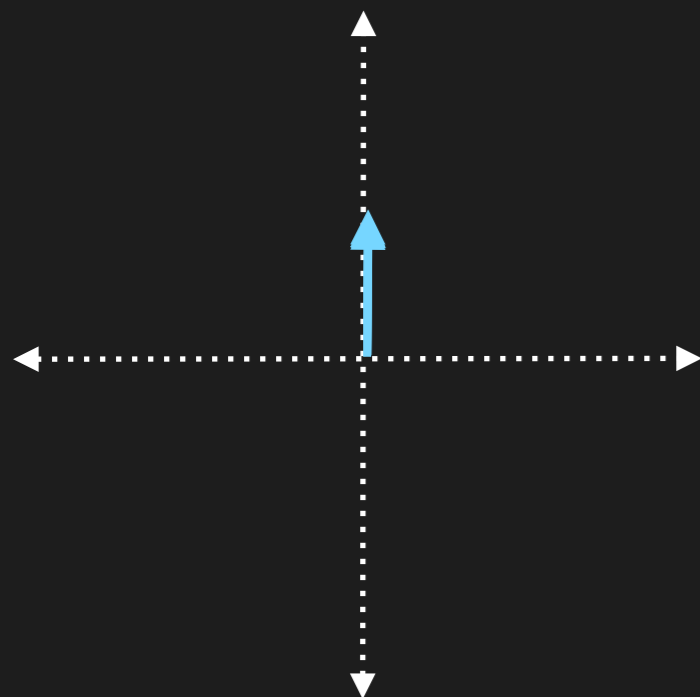


High Signal

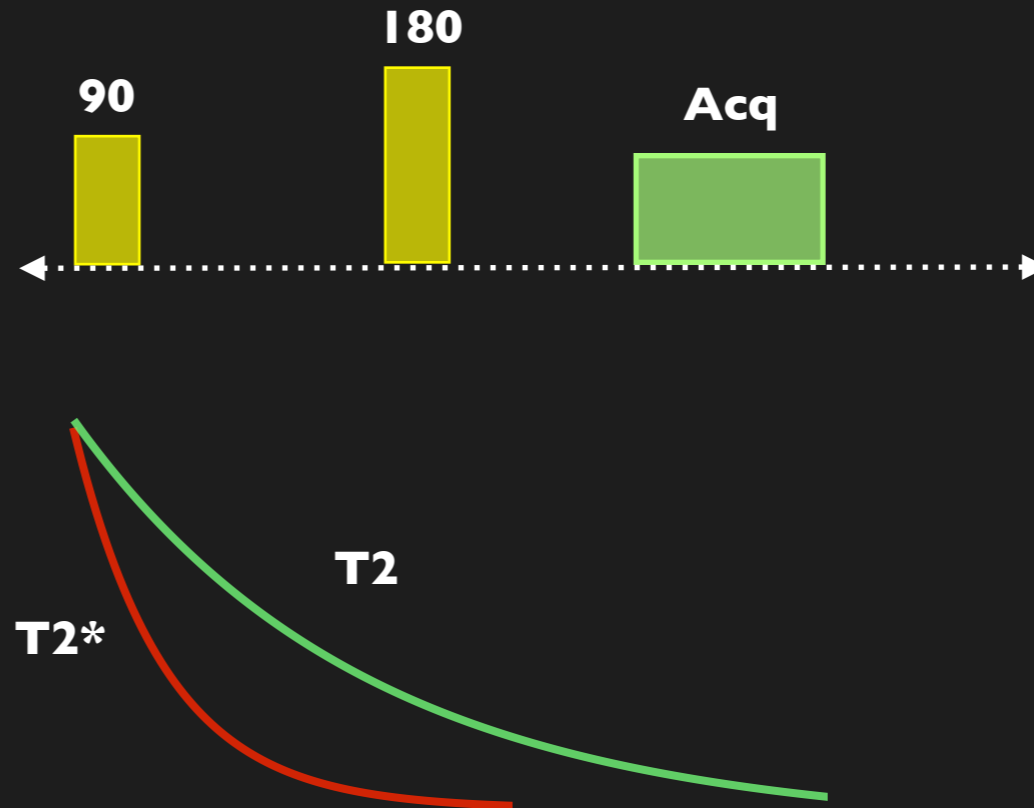
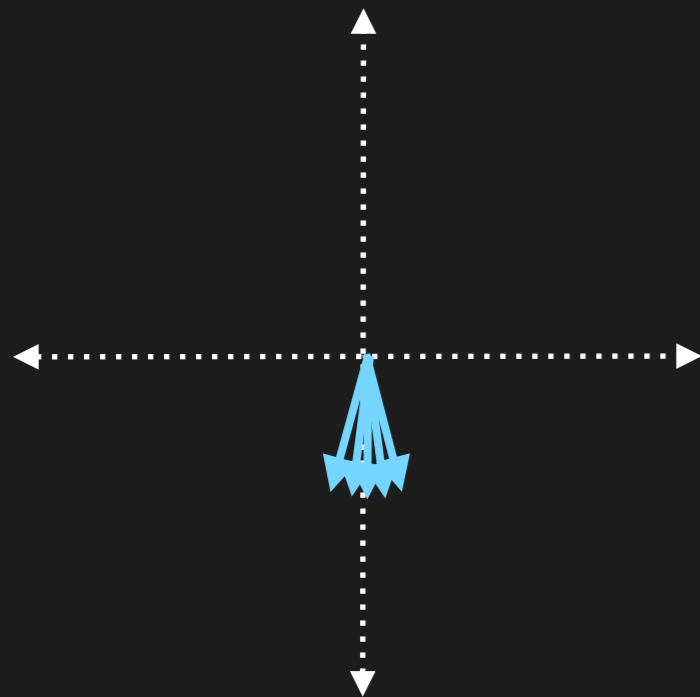
Slow

Black blood

Fast Spin Echo



Spin Echo



High Signal

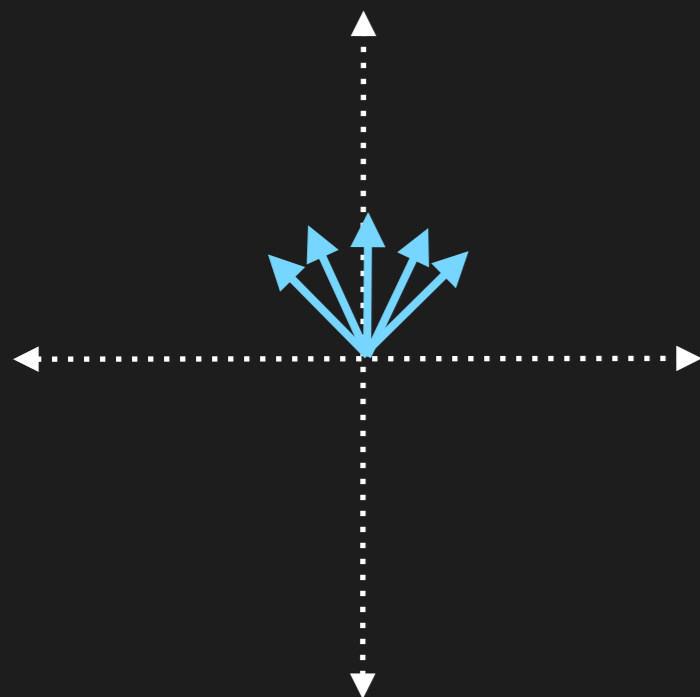
Slow

Black blood

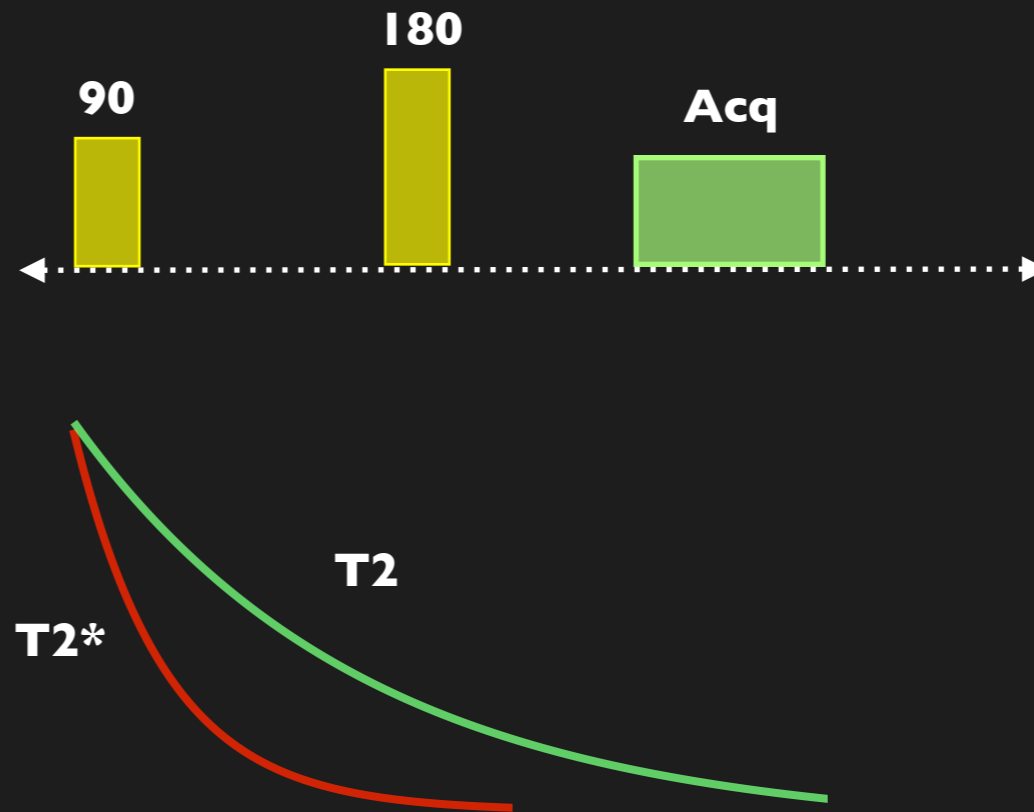
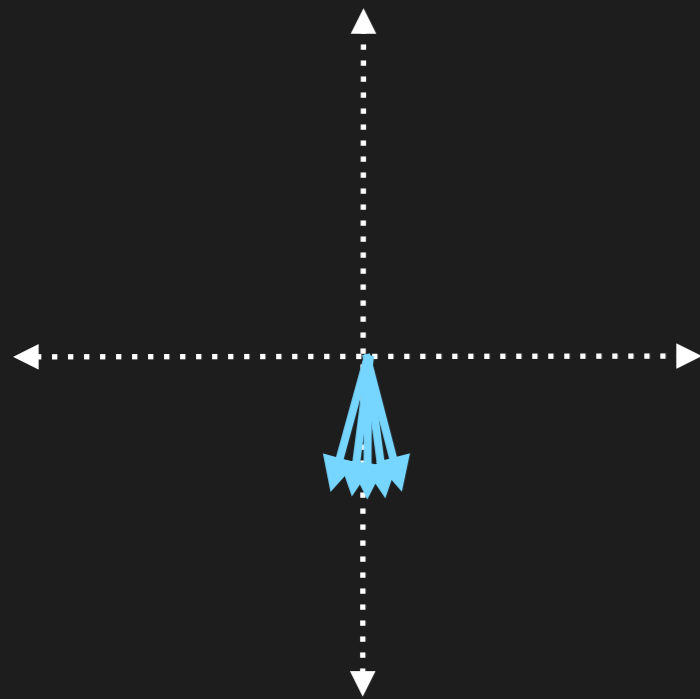
T2*

T2

Fast Spin Echo



Spin Echo

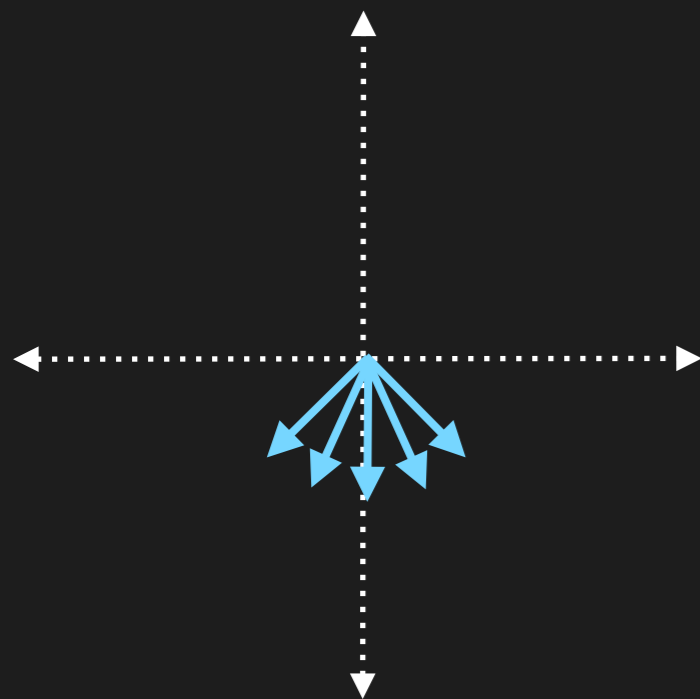


High Signal

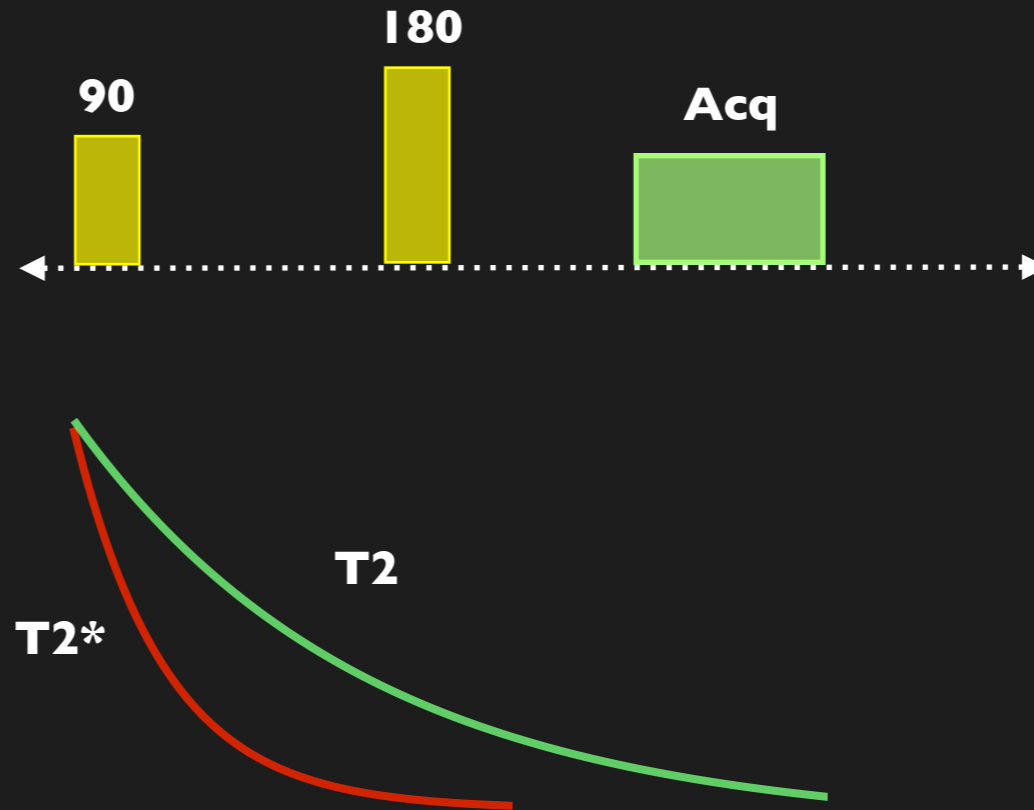
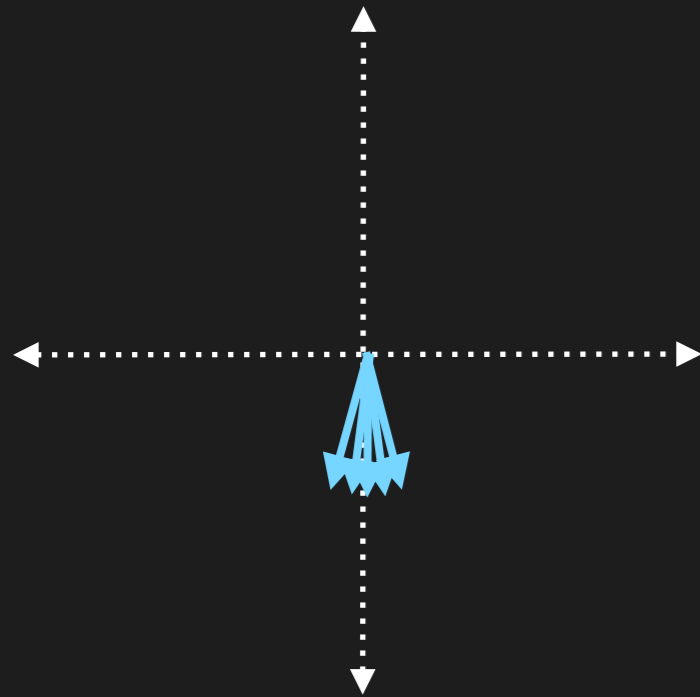
Slow

Black blood

Fast Spin Echo



Spin Echo

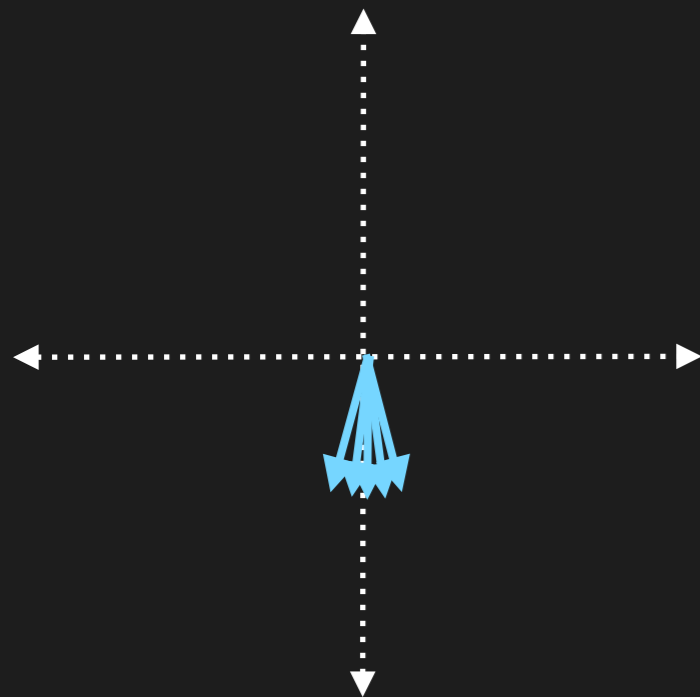


High Signal

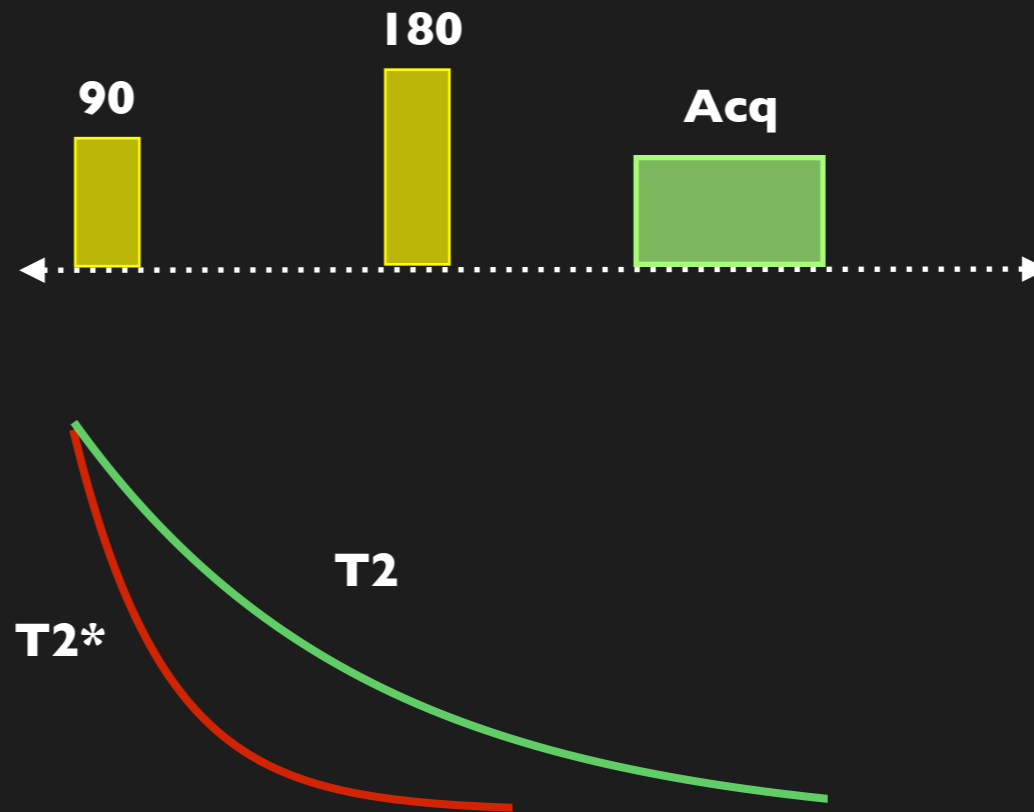
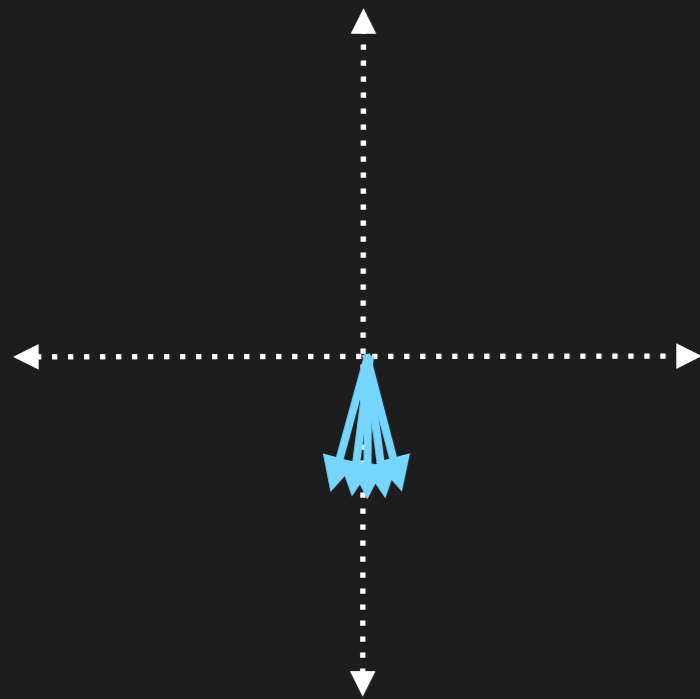
Slow

Black blood

Fast Spin Echo



Spin Echo

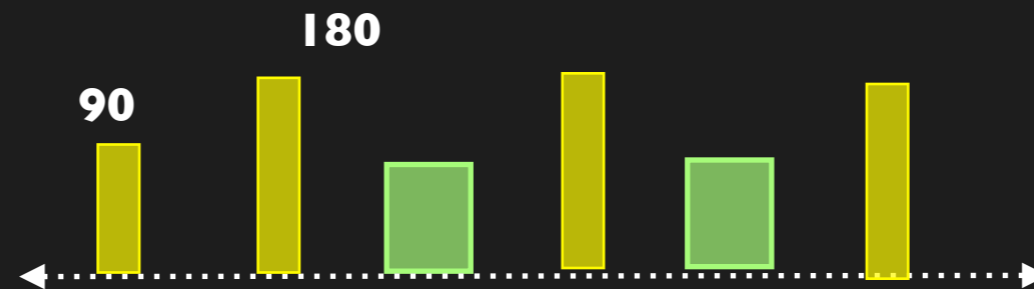
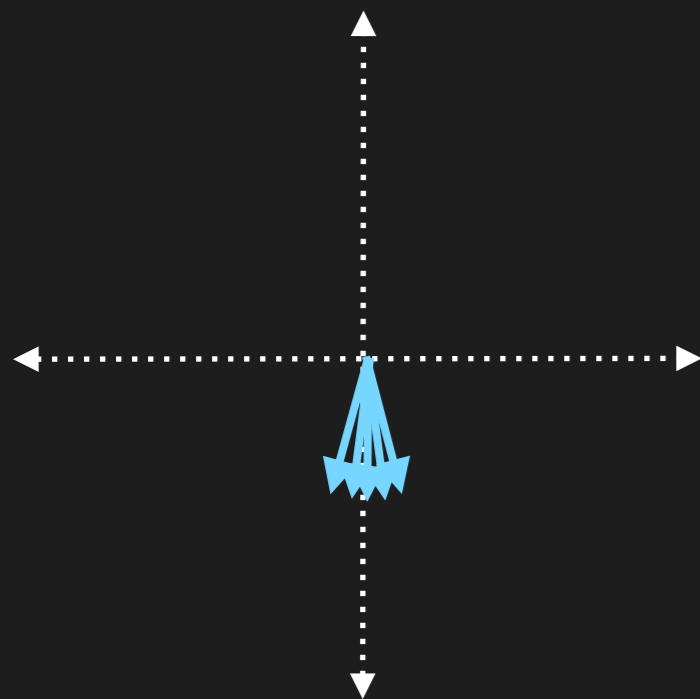


High Signal

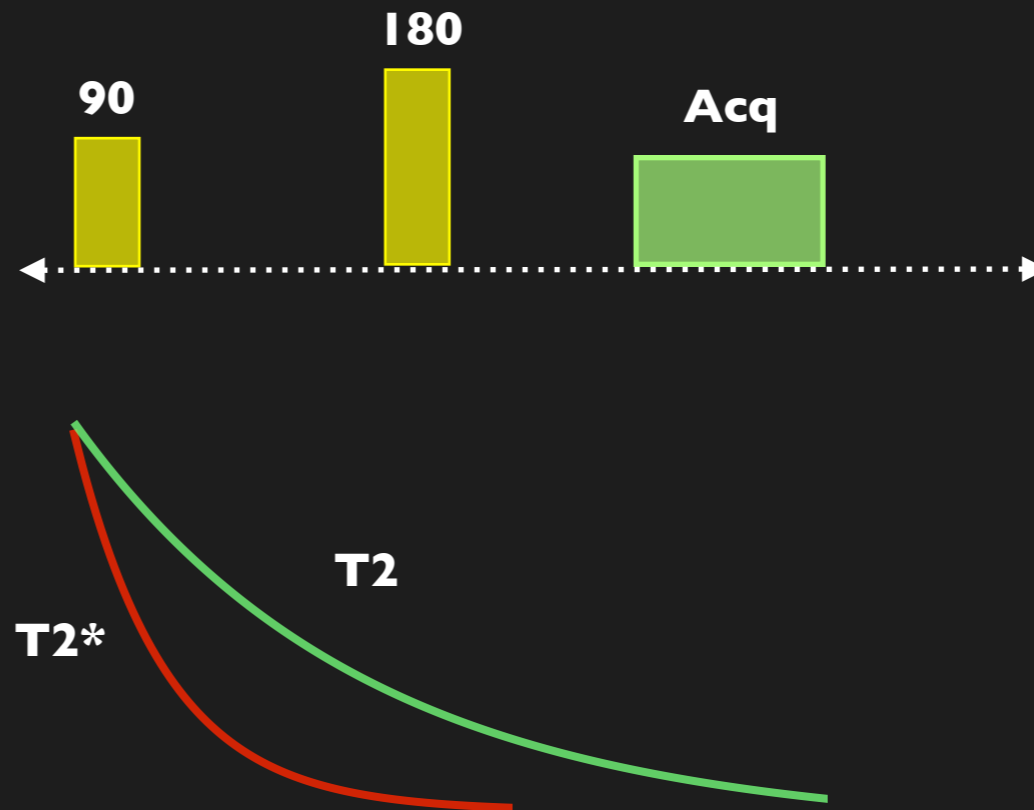
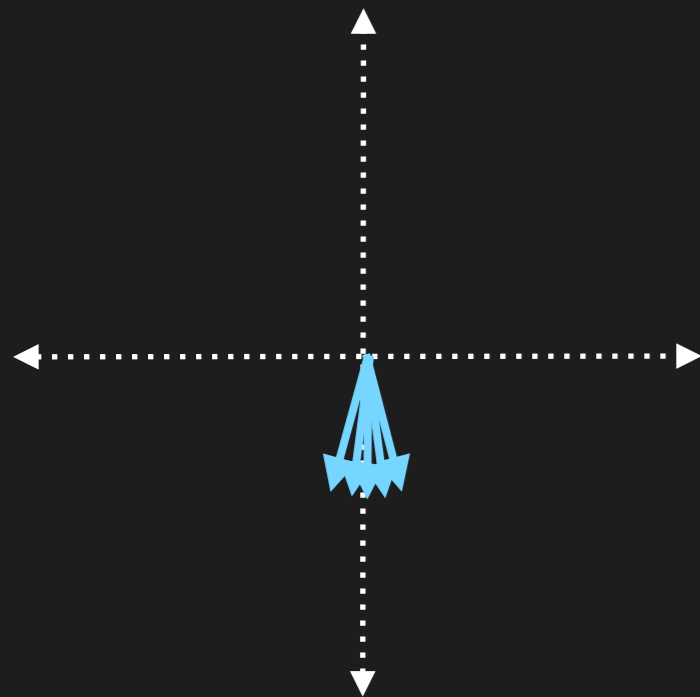
Slow

Black blood

Fast Spin Echo



Spin Echo

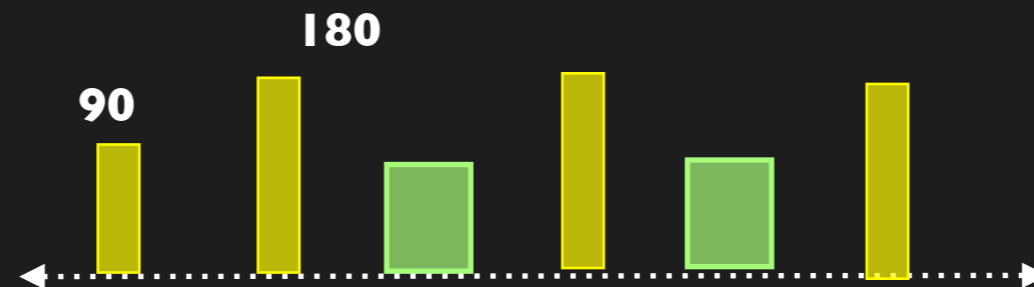
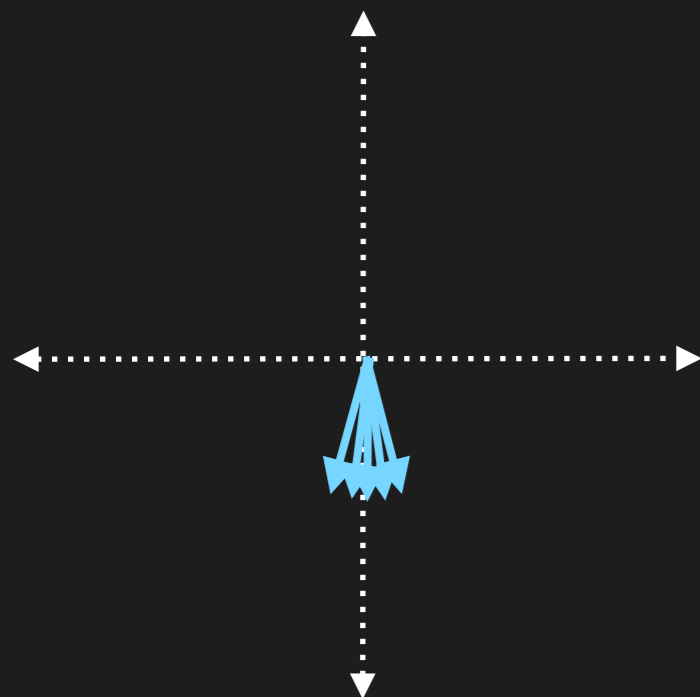


High Signal

Slow

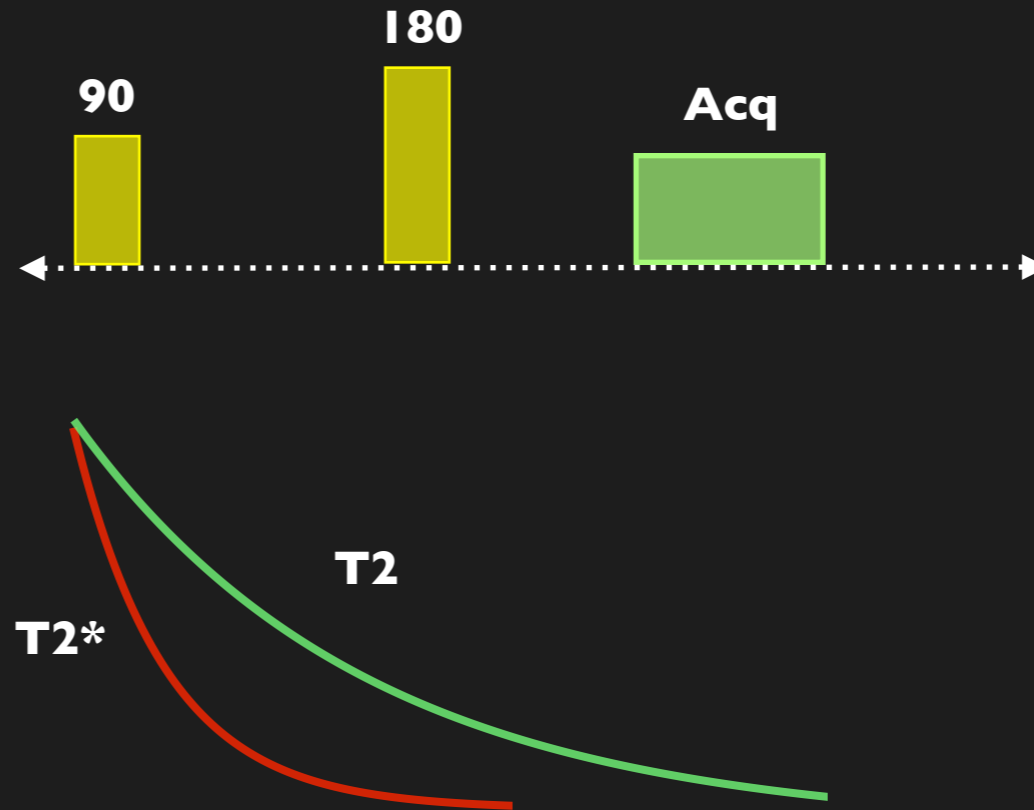
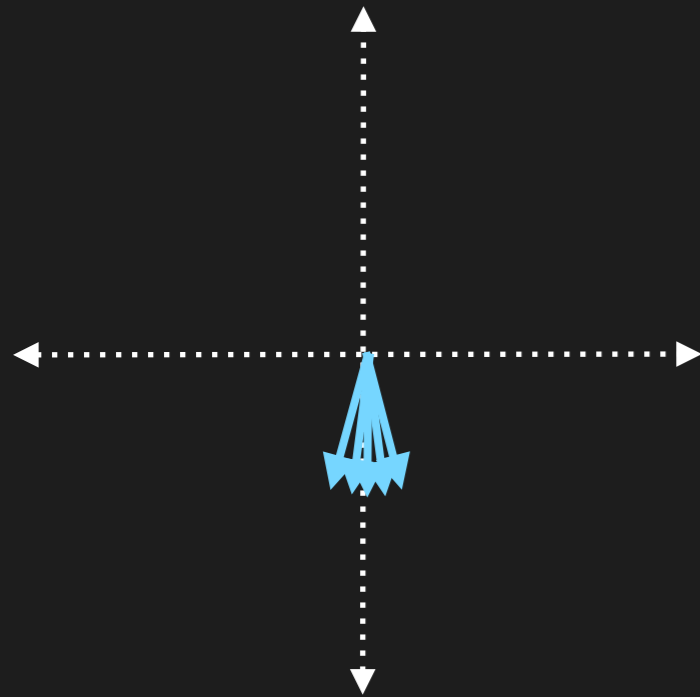
Black blood

Fast Spin Echo



More efficient

Spin Echo

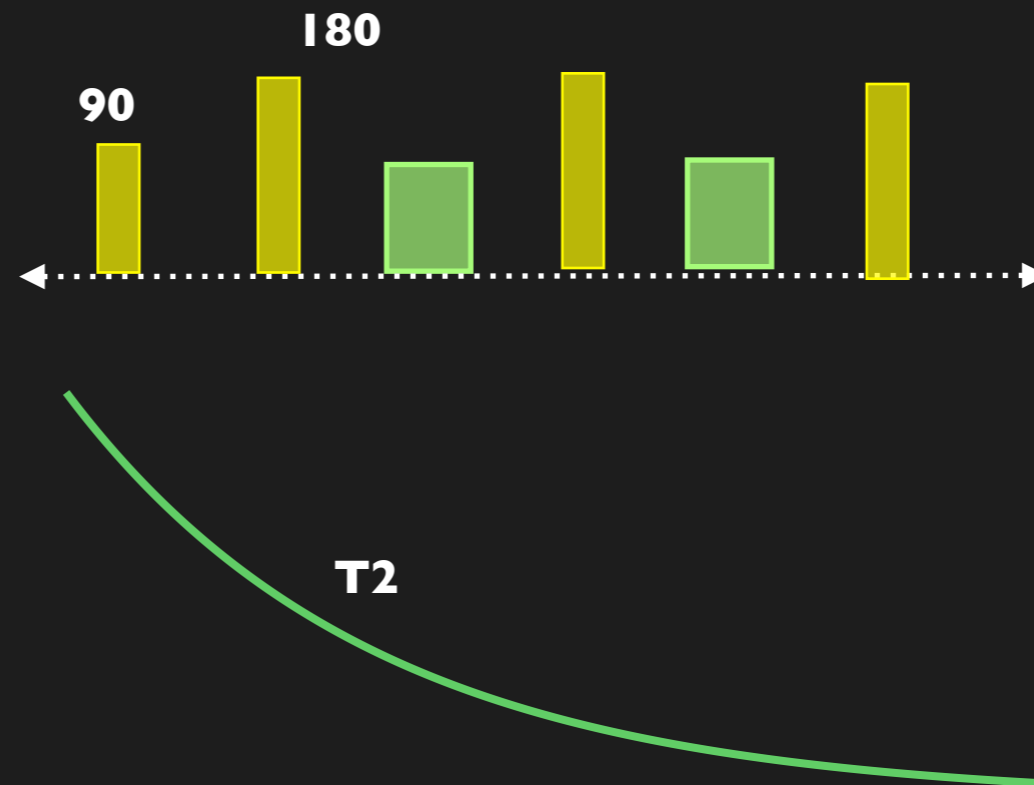
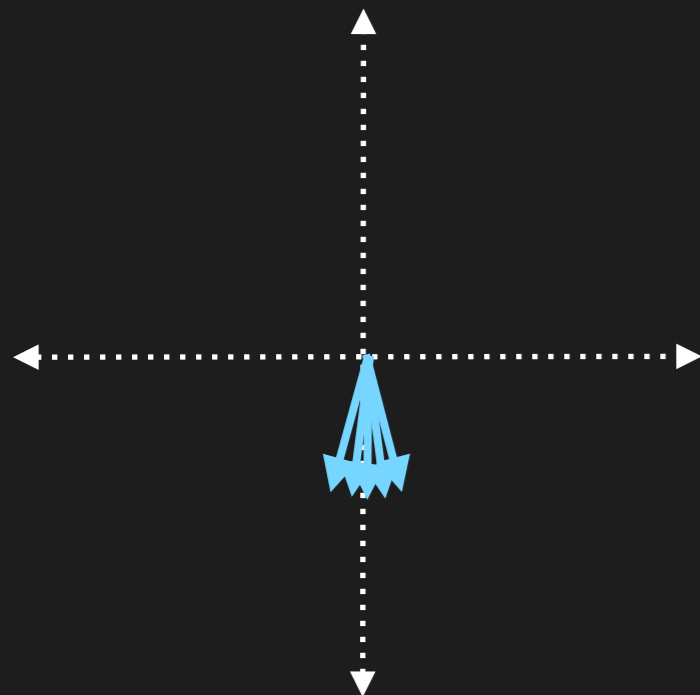


High Signal

Slow

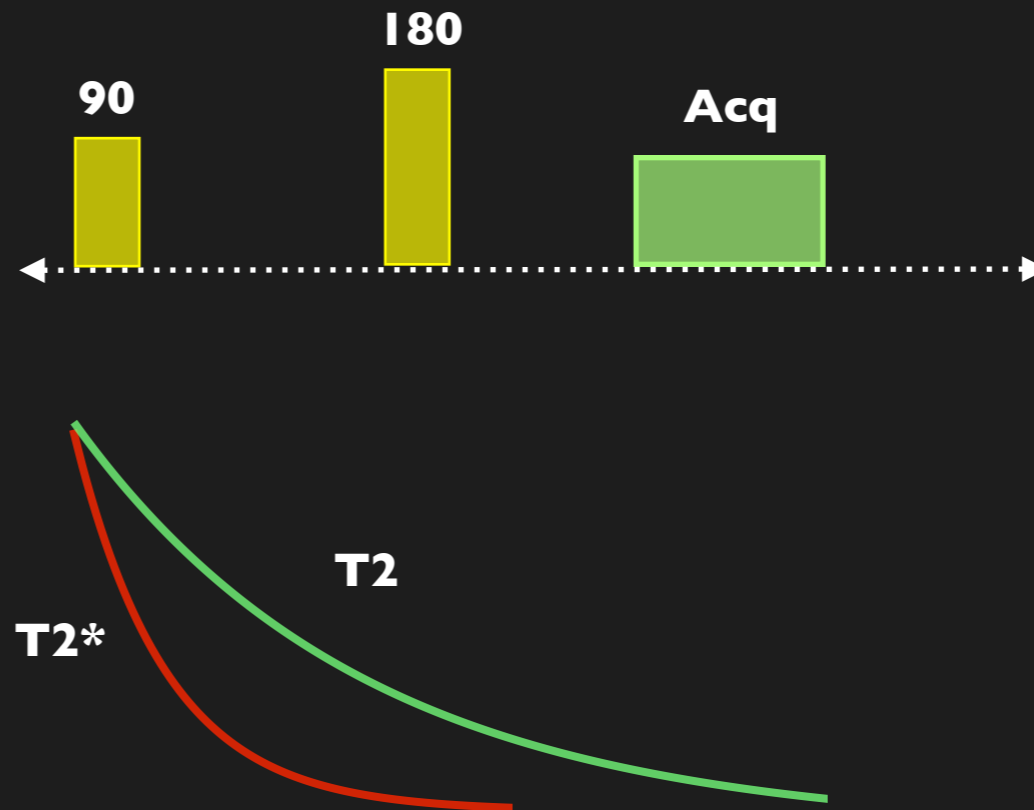
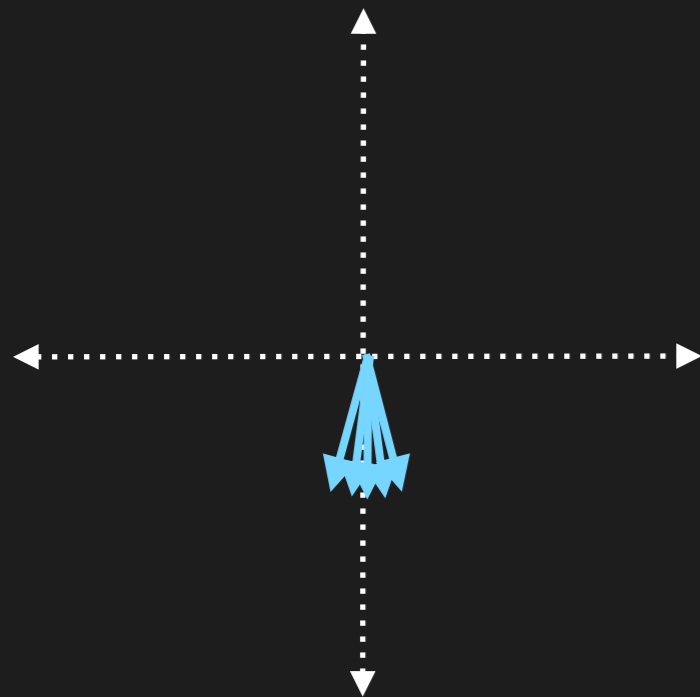
Black blood

Fast Spin Echo



More efficient

Spin Echo

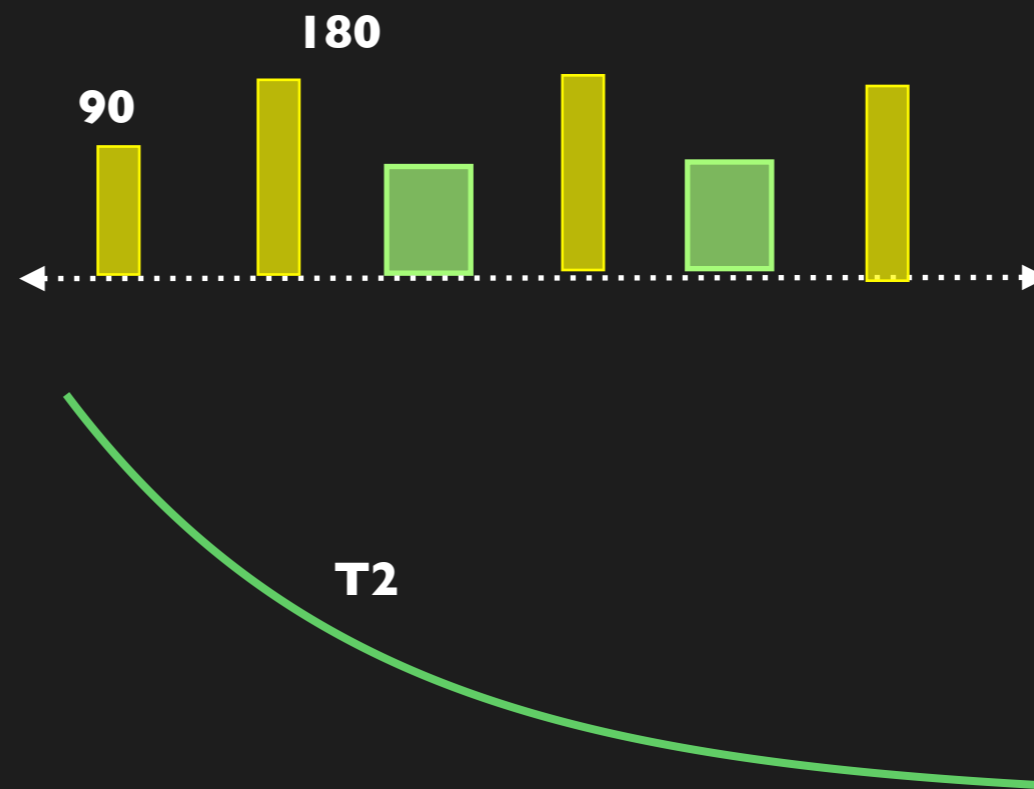
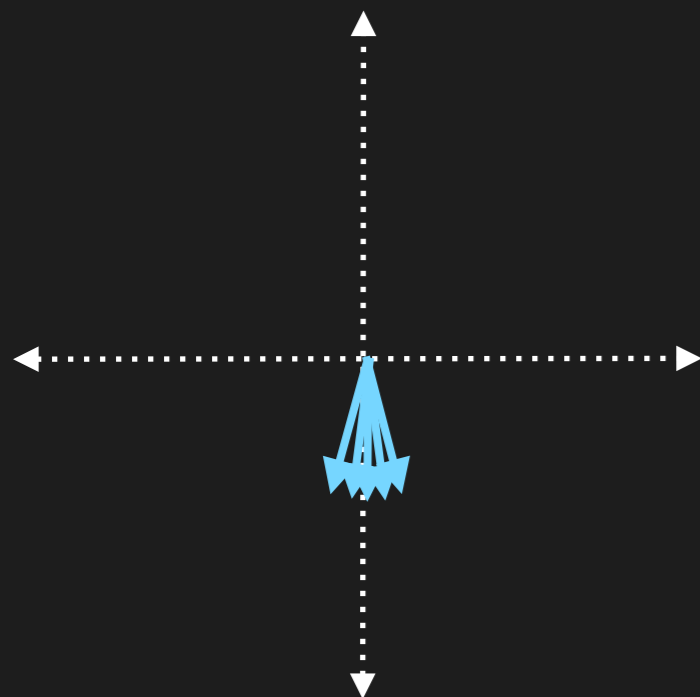


High Signal

Slow

Black blood

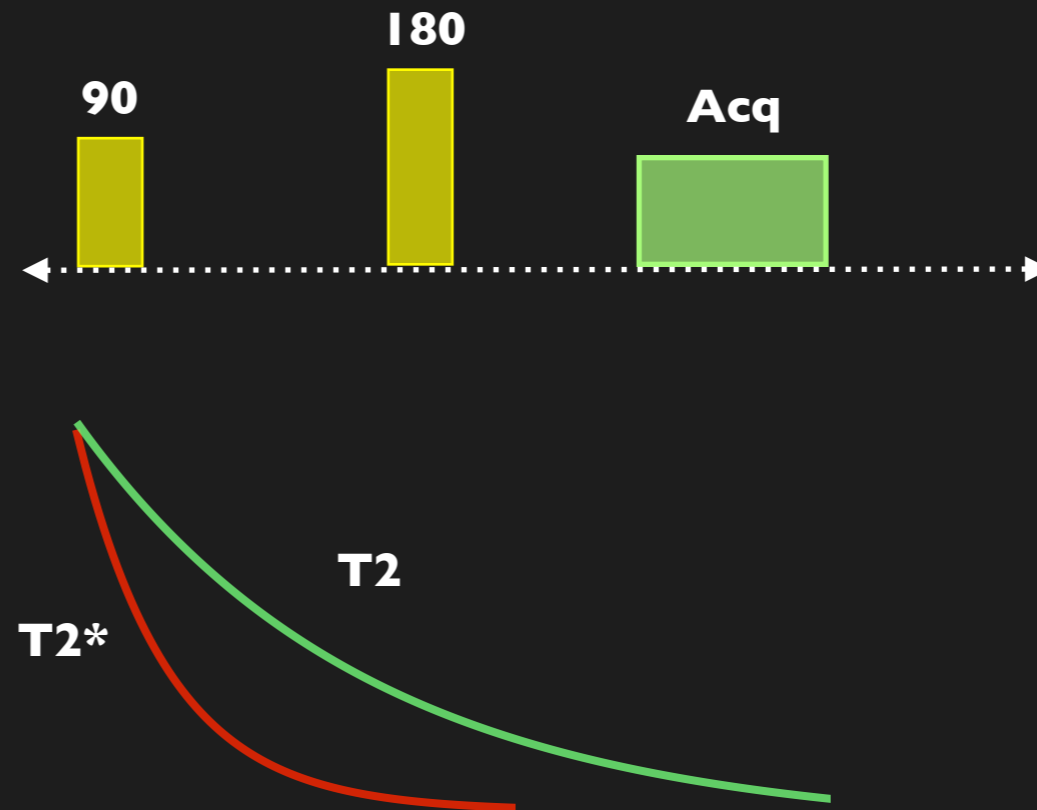
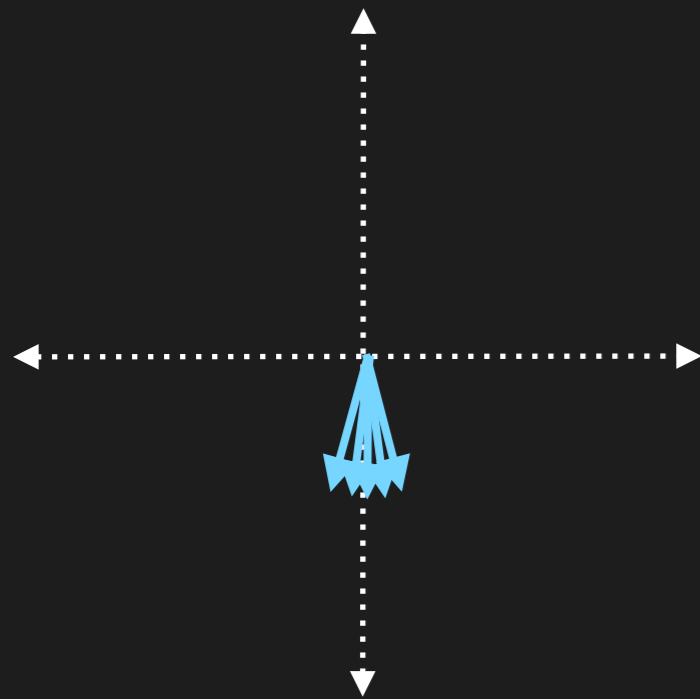
Fast Spin Echo



More efficient

Cardiac

Spin Echo

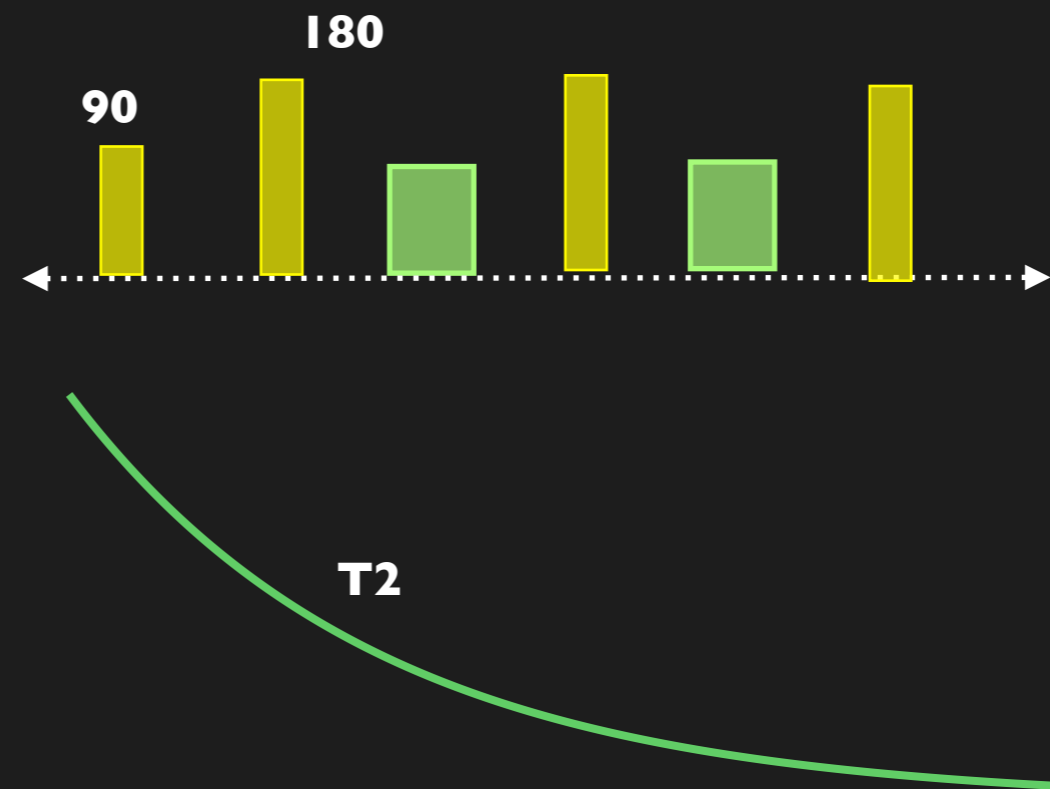
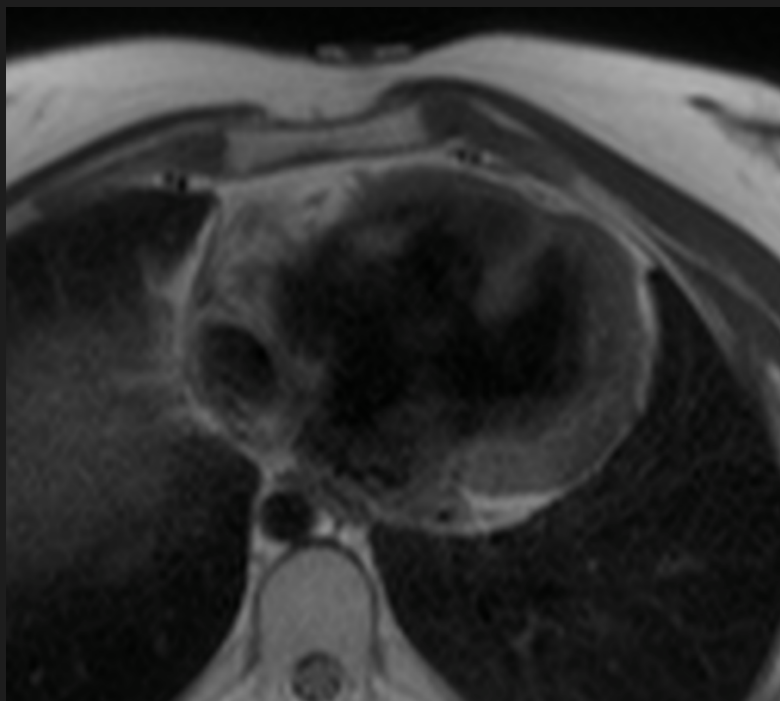


High Signal

Slow

Black blood

Fast Spin Echo



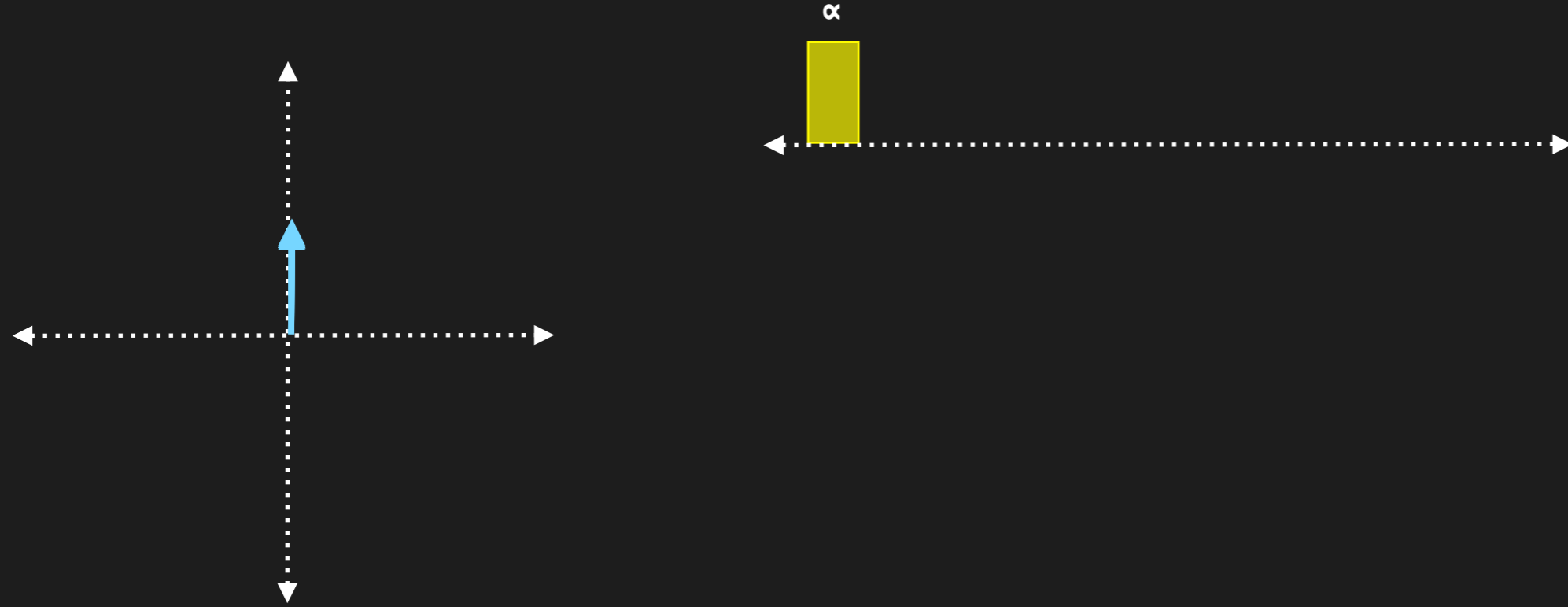
More efficient

Cardiac

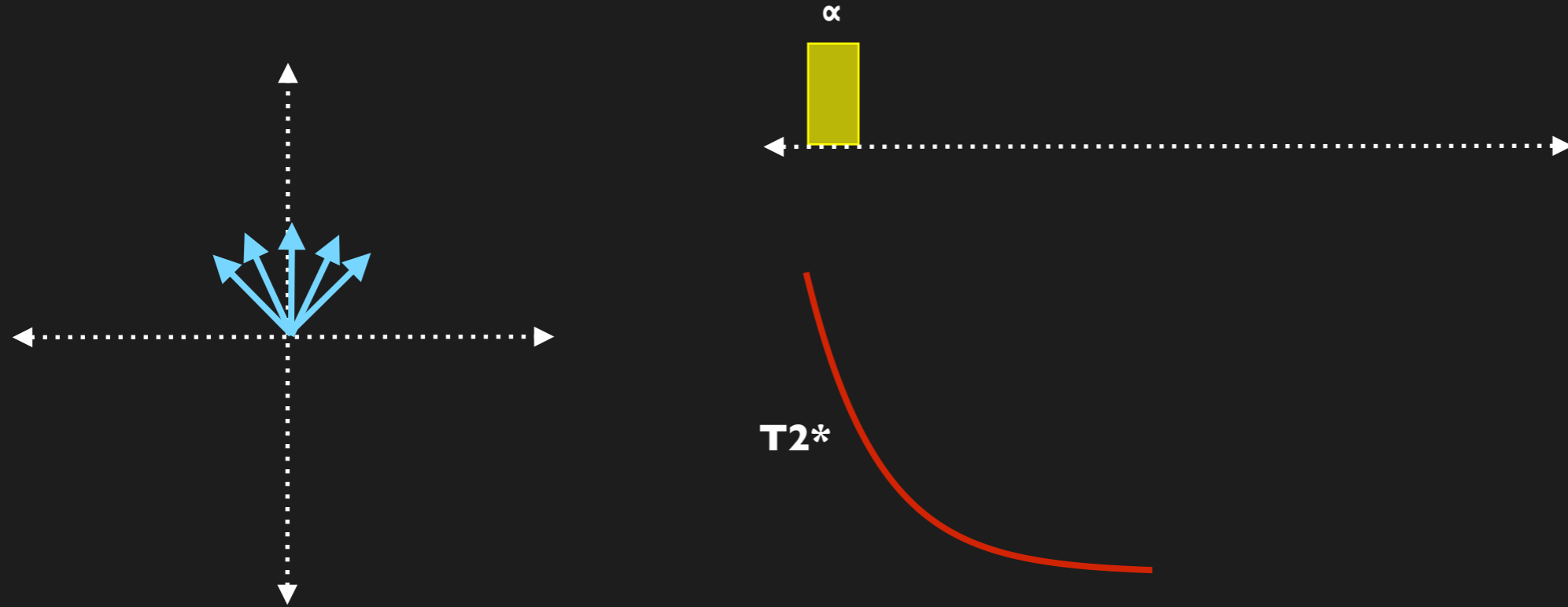
HASTE

Gradient Echo

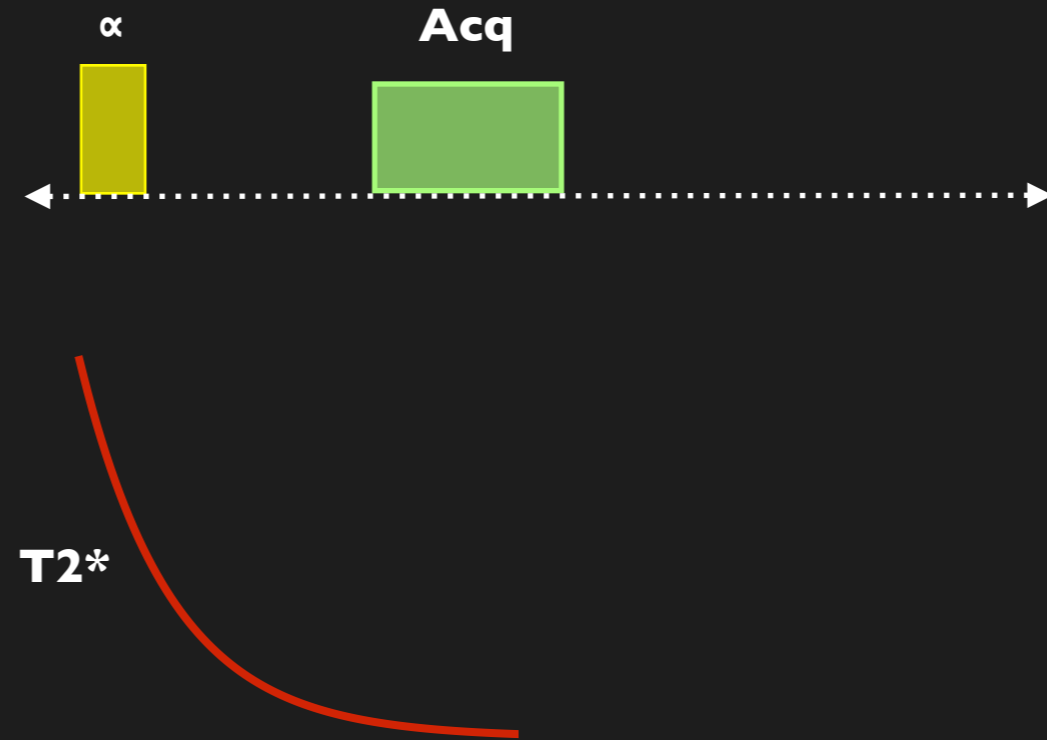
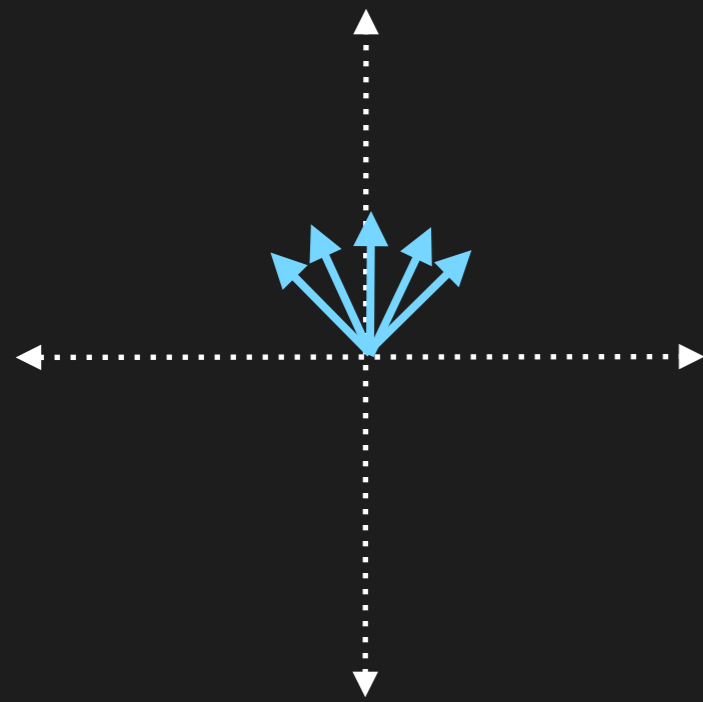
Gradient Echo



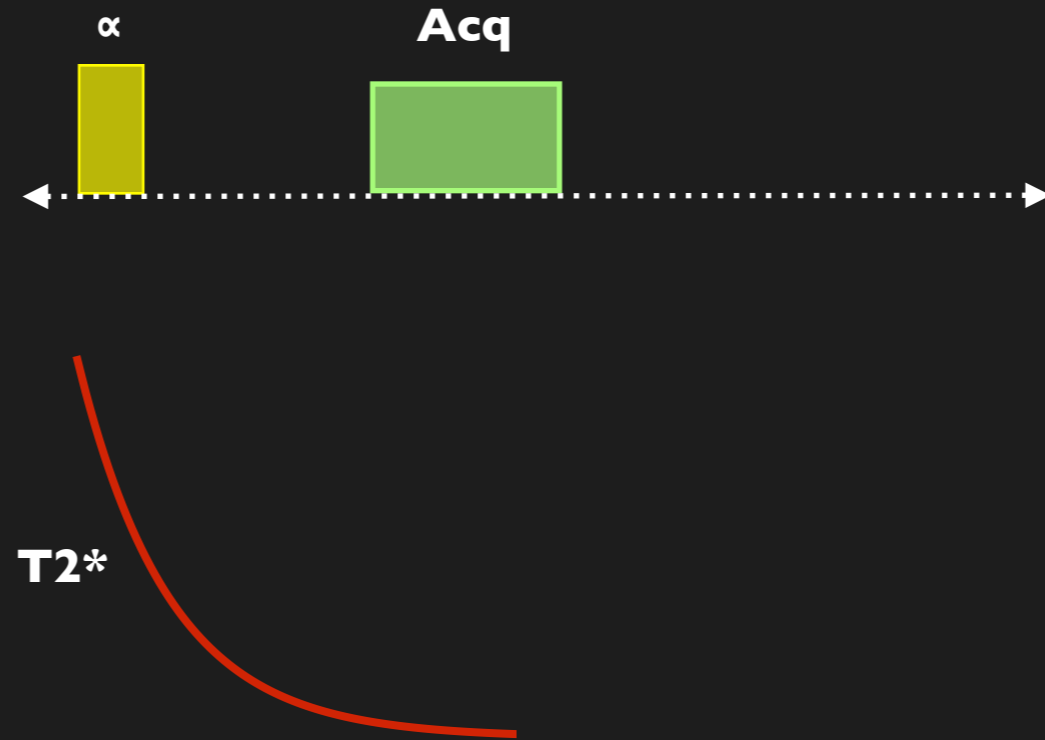
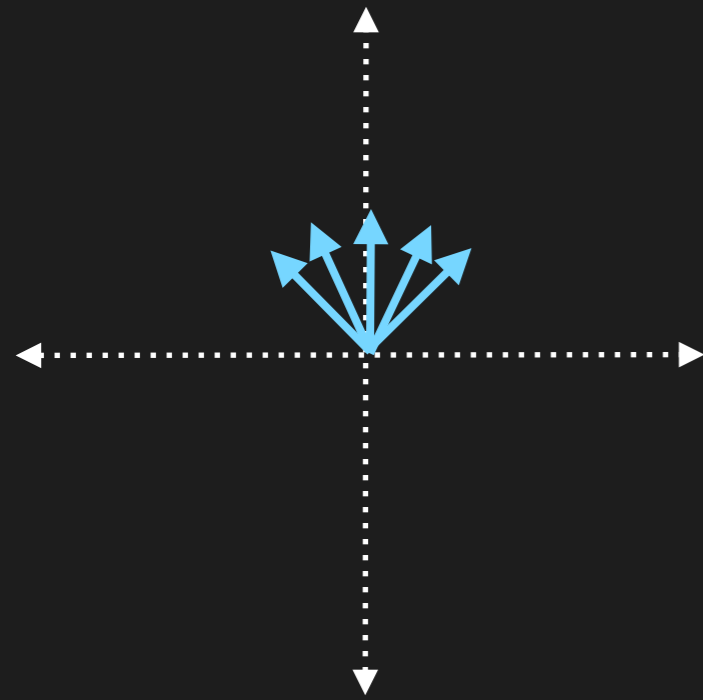
Gradient Echo



Gradient Echo

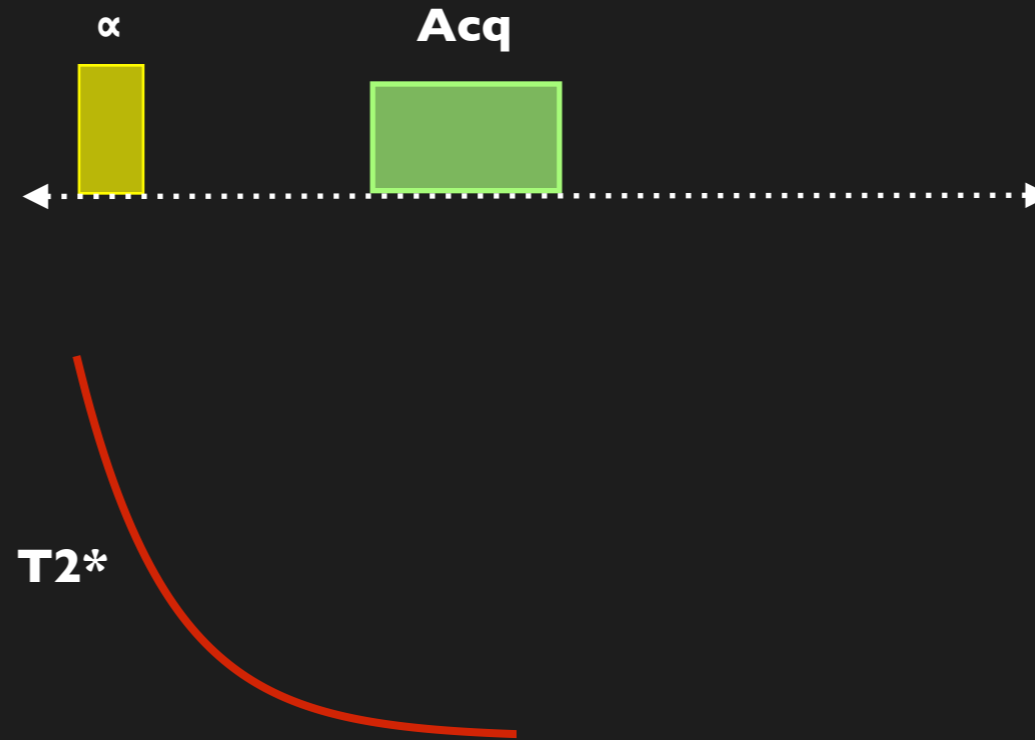
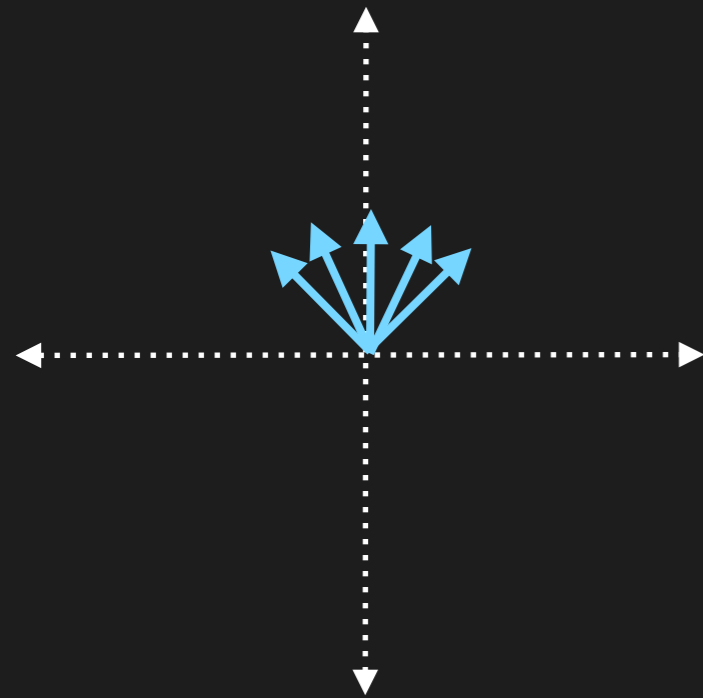


Gradient Echo



T2* not T2

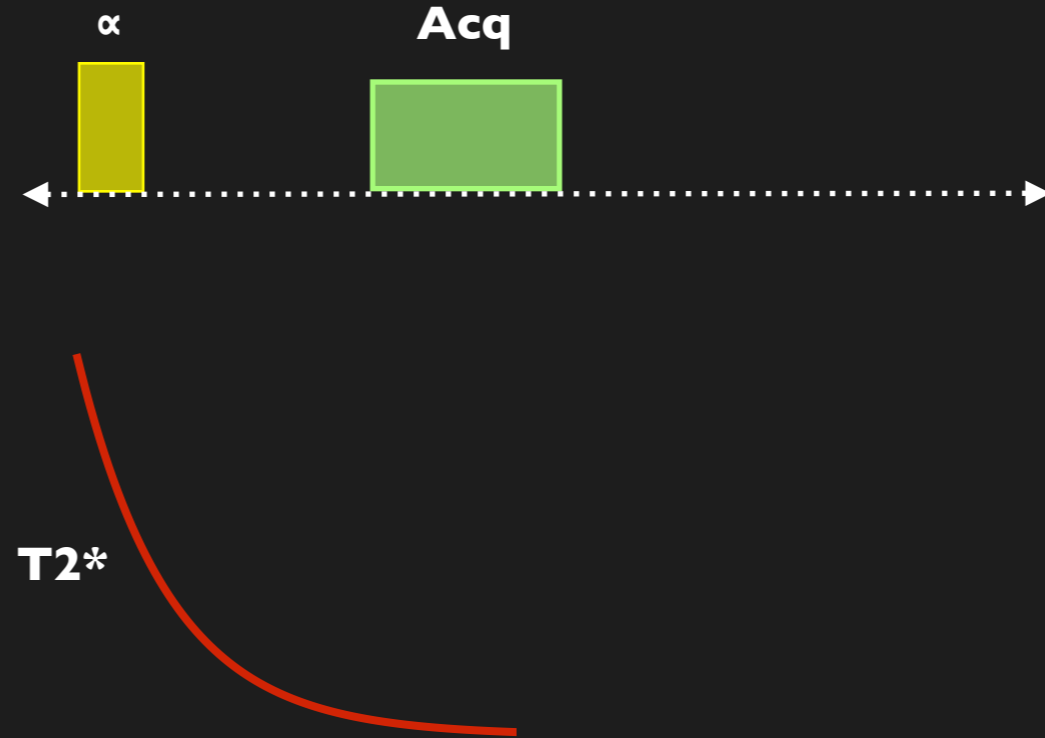
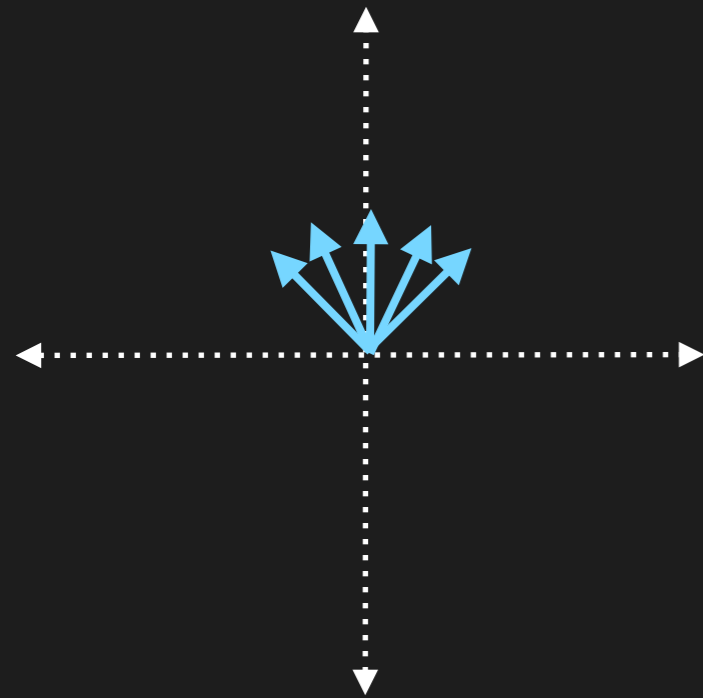
Gradient Echo



T2* not T2

Fast - cardiac

Gradient Echo

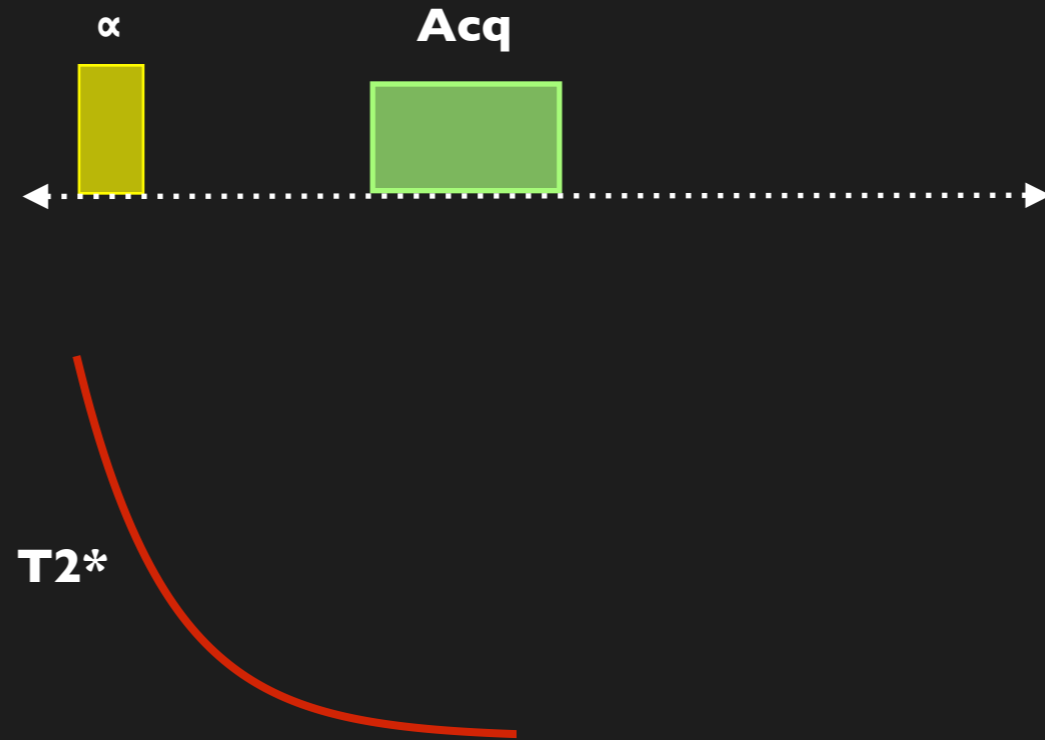
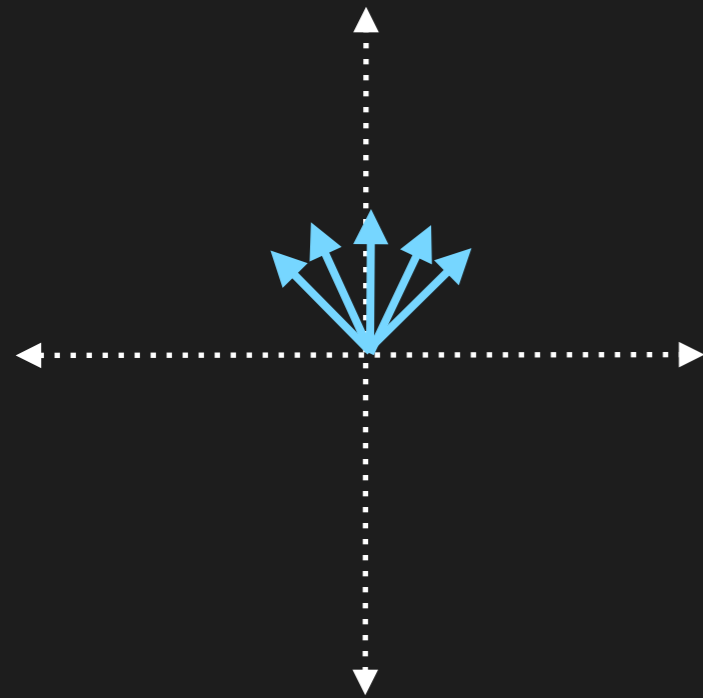


$T2^*$ not $T2$

Fast - cardiac

Bright blood

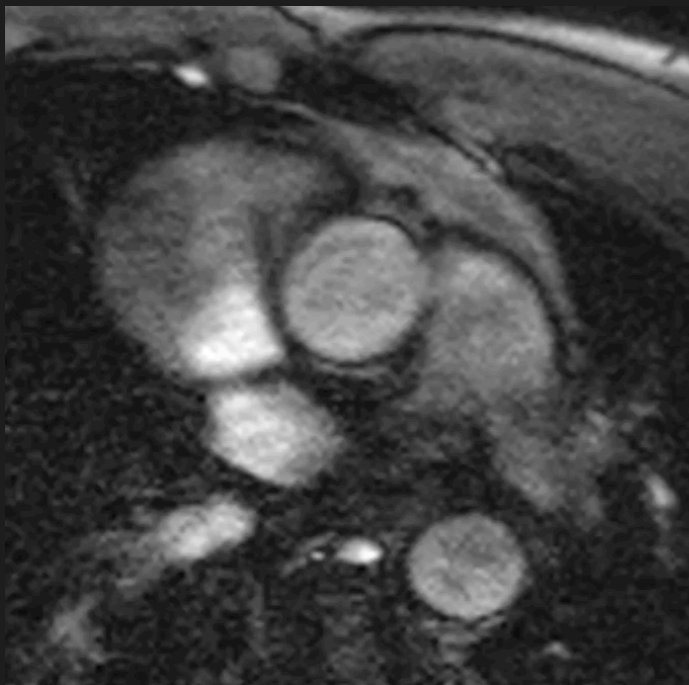
Gradient Echo



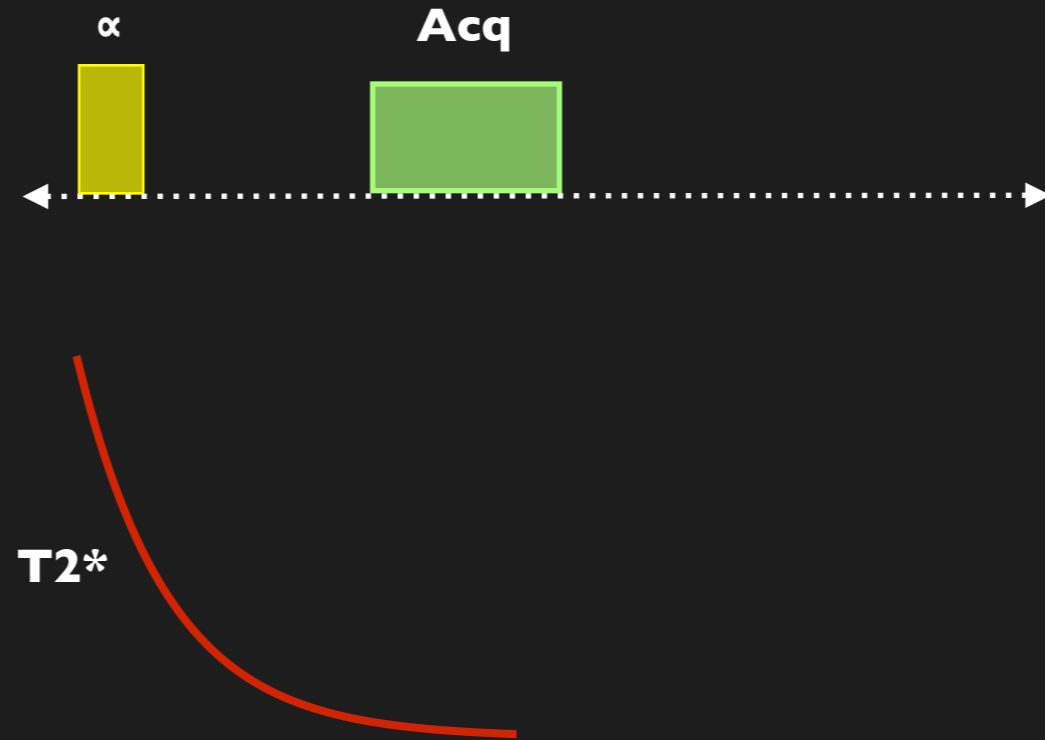
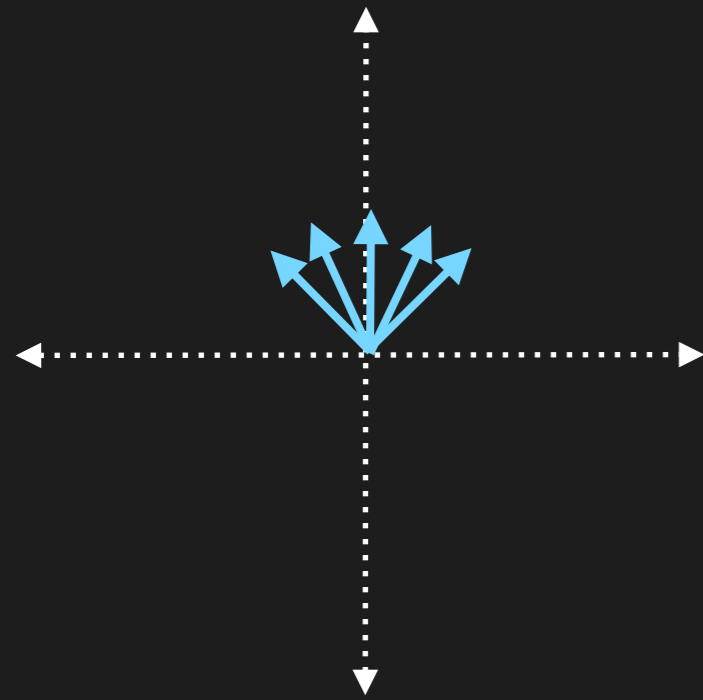
T2* not T2

Fast - cardiac

Bright blood



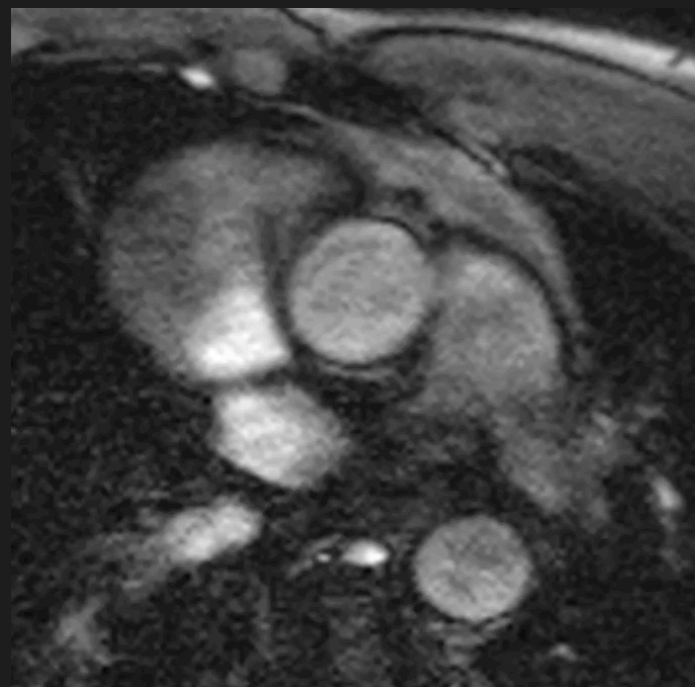
Gradient Echo



T2* not T2

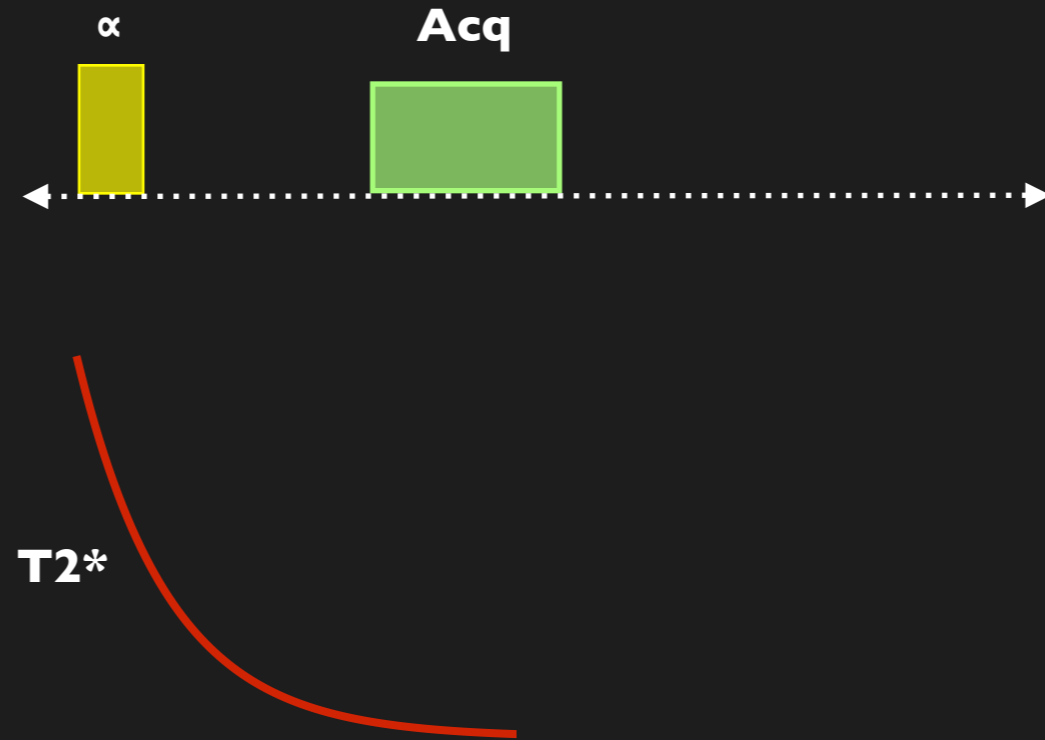
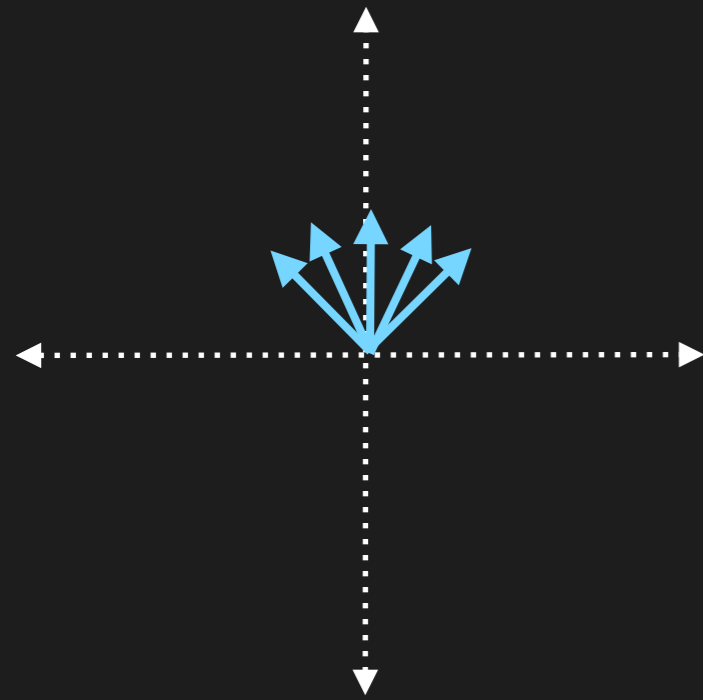
Fast - cardiac

Bright blood



Saturated blood

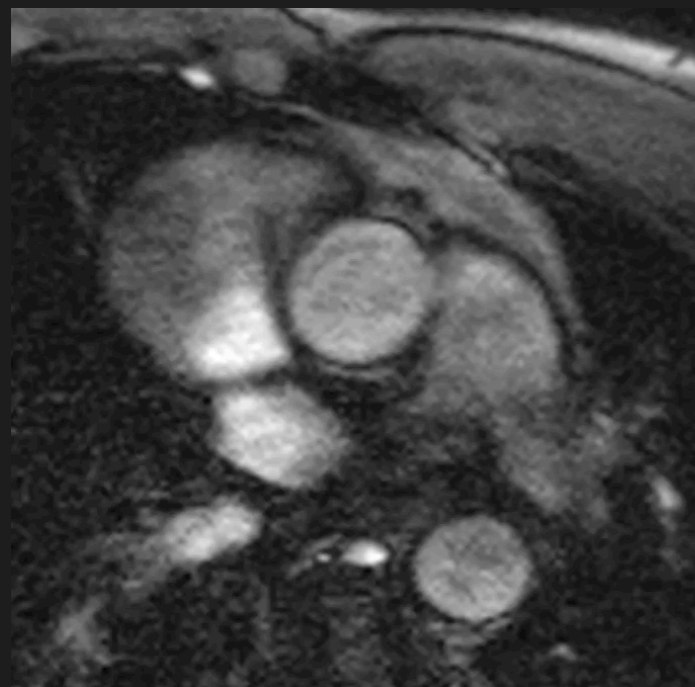
Gradient Echo



T2* not T2

Fast - cardiac

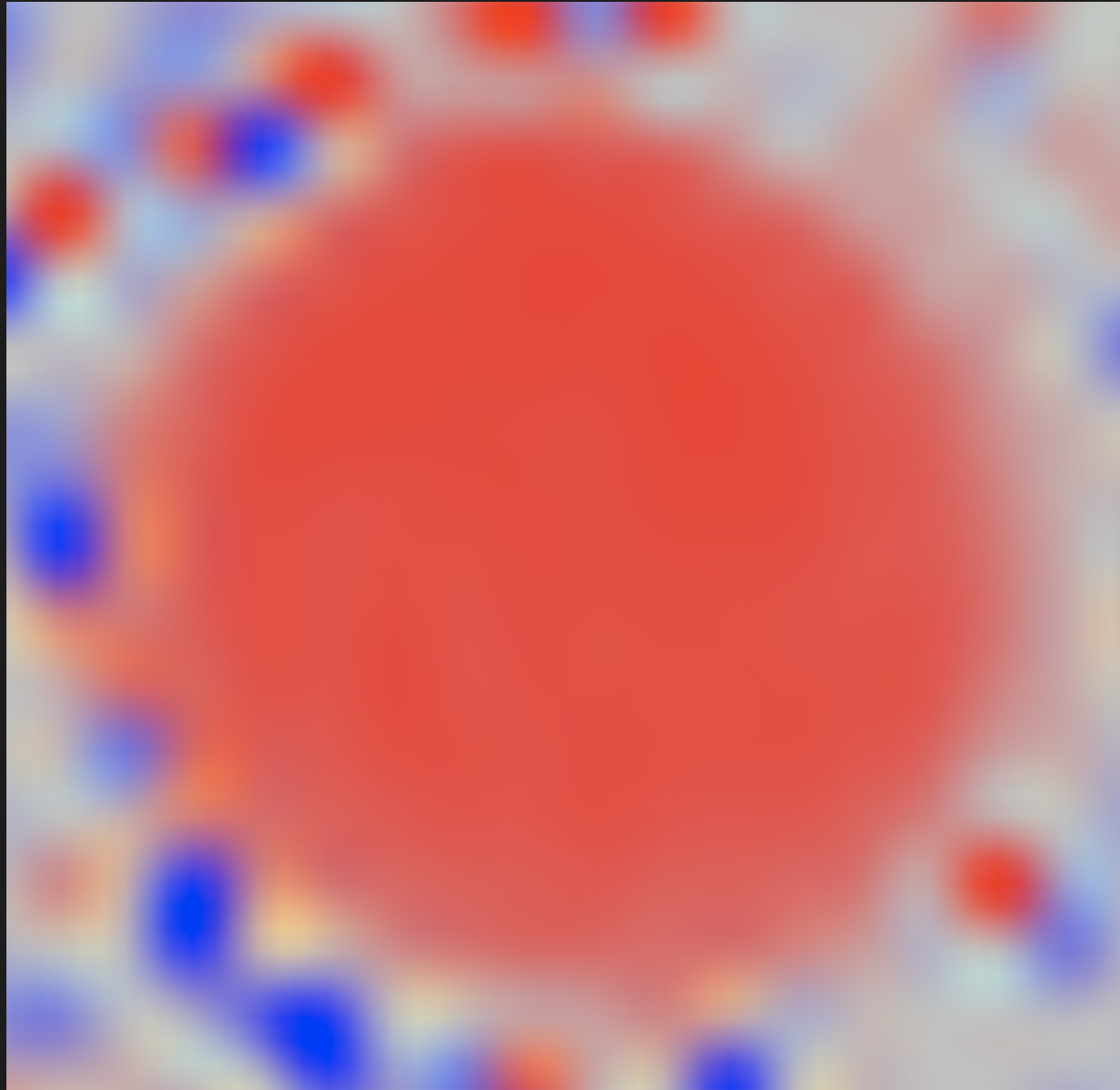
Bright blood



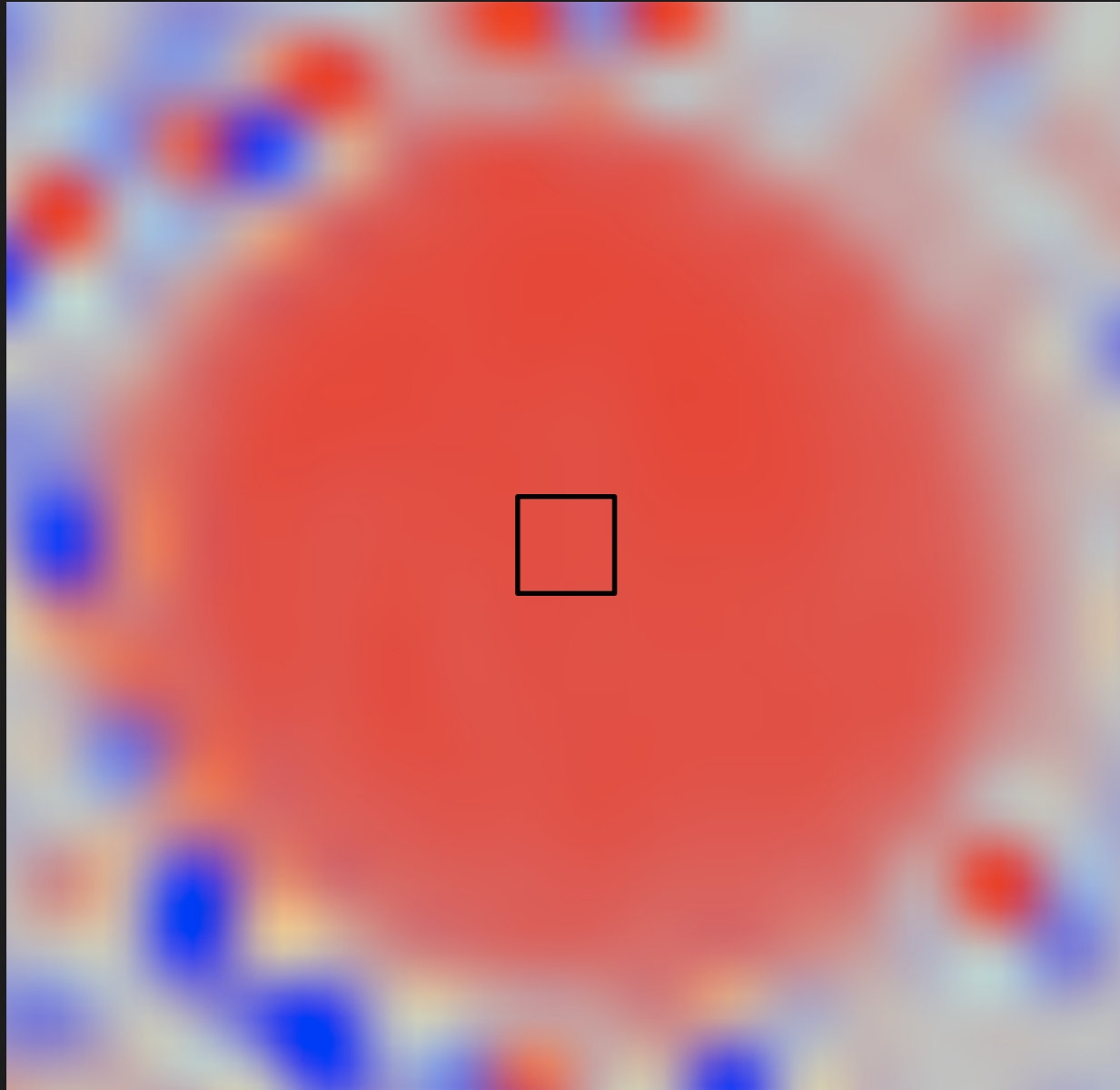
Saturated blood

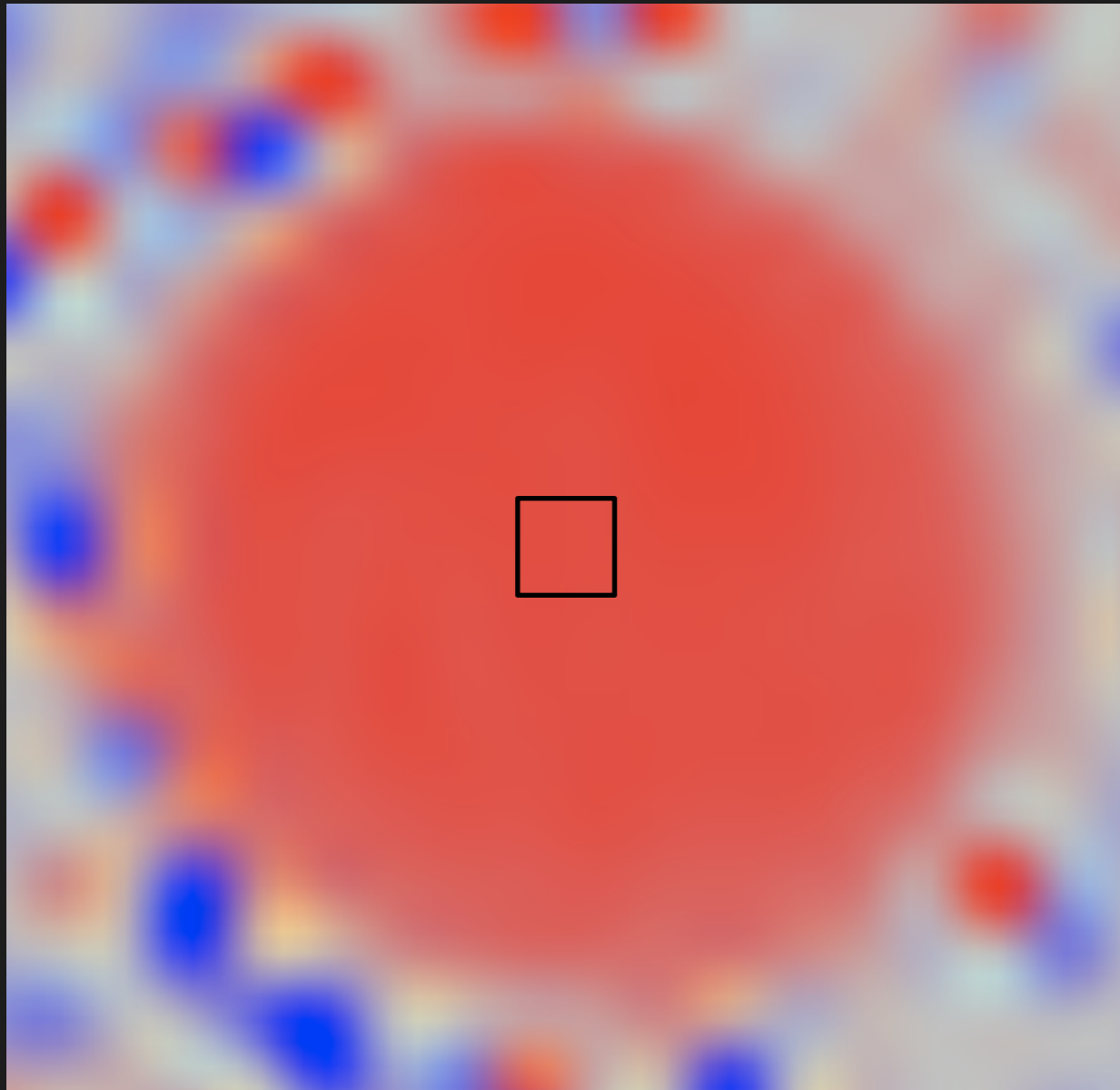
In-flow enhancement

Spatial resolution

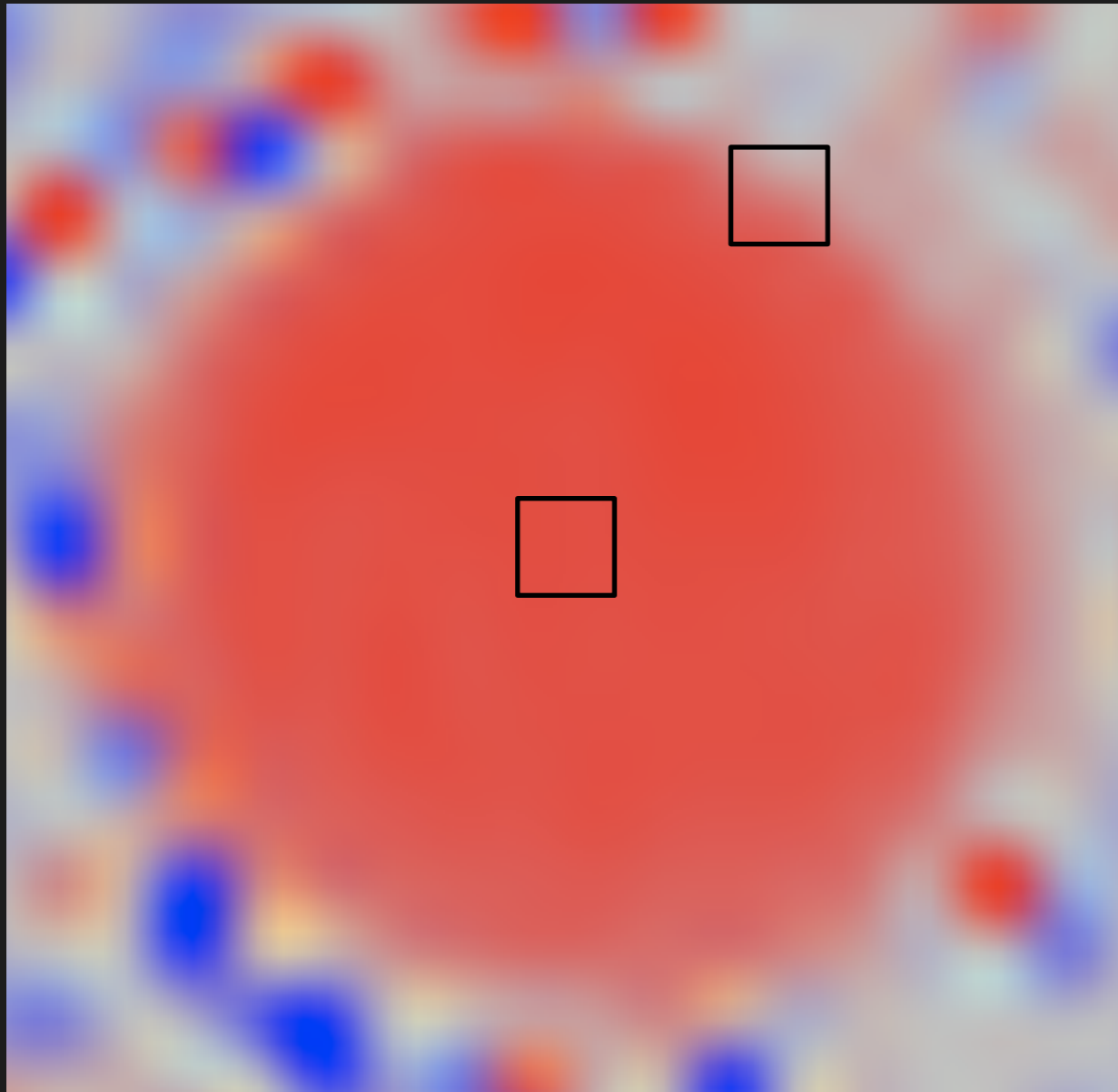


Spatial resolution

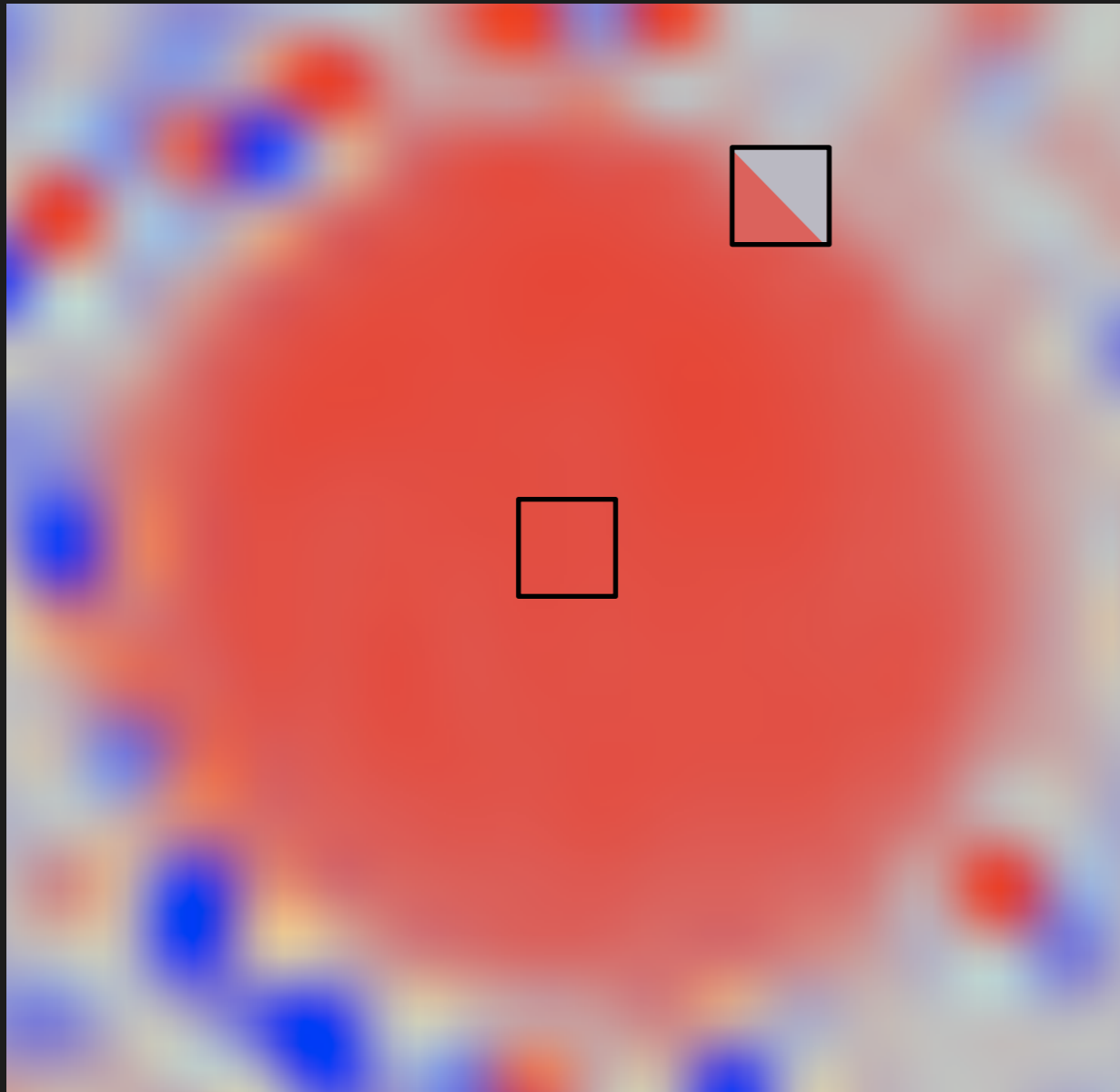




$$Q = V \times A$$



$$Q = V \times A$$

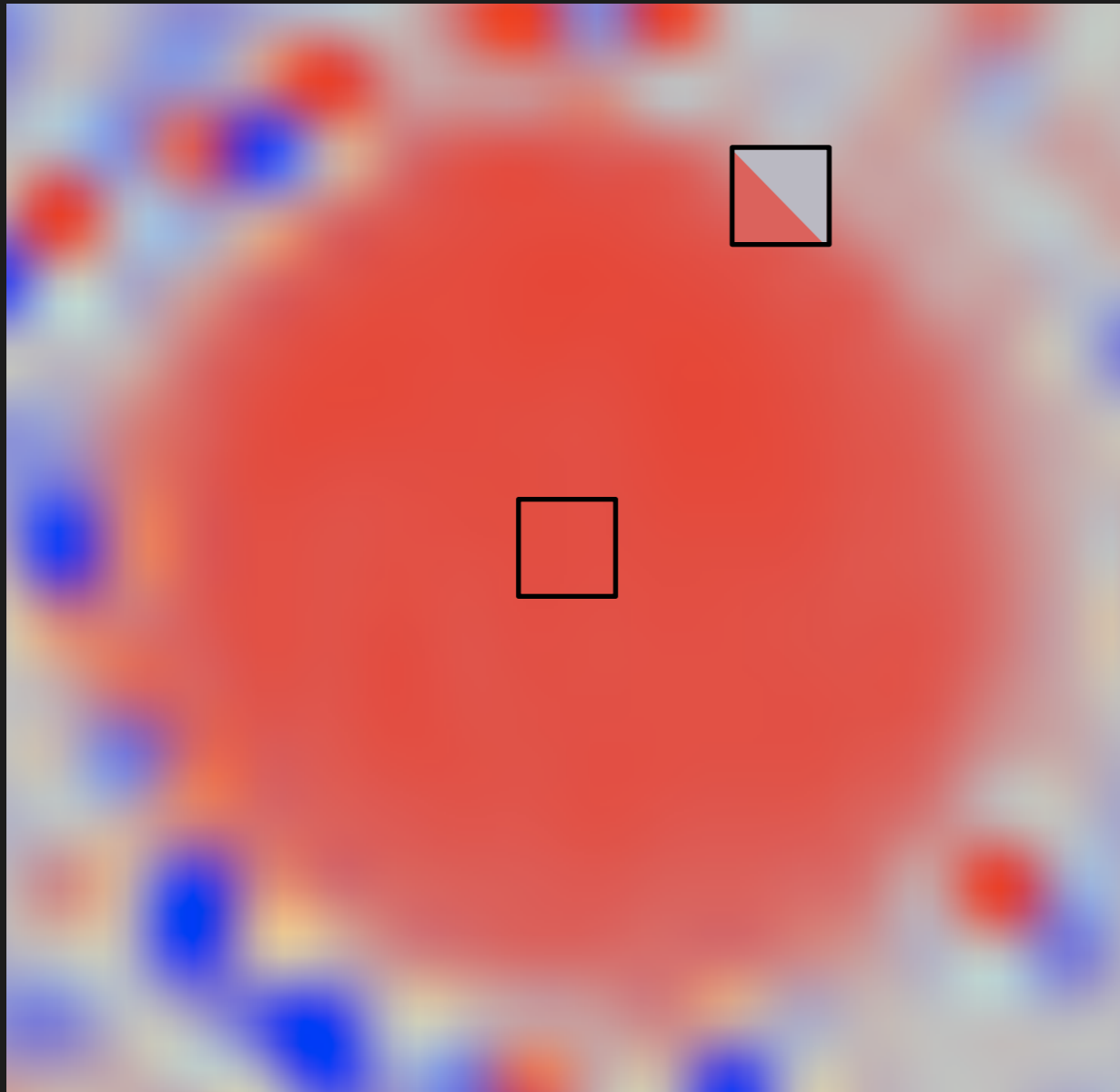


$$Q = V \times A$$

Half pixel moving

Half pixel stationary

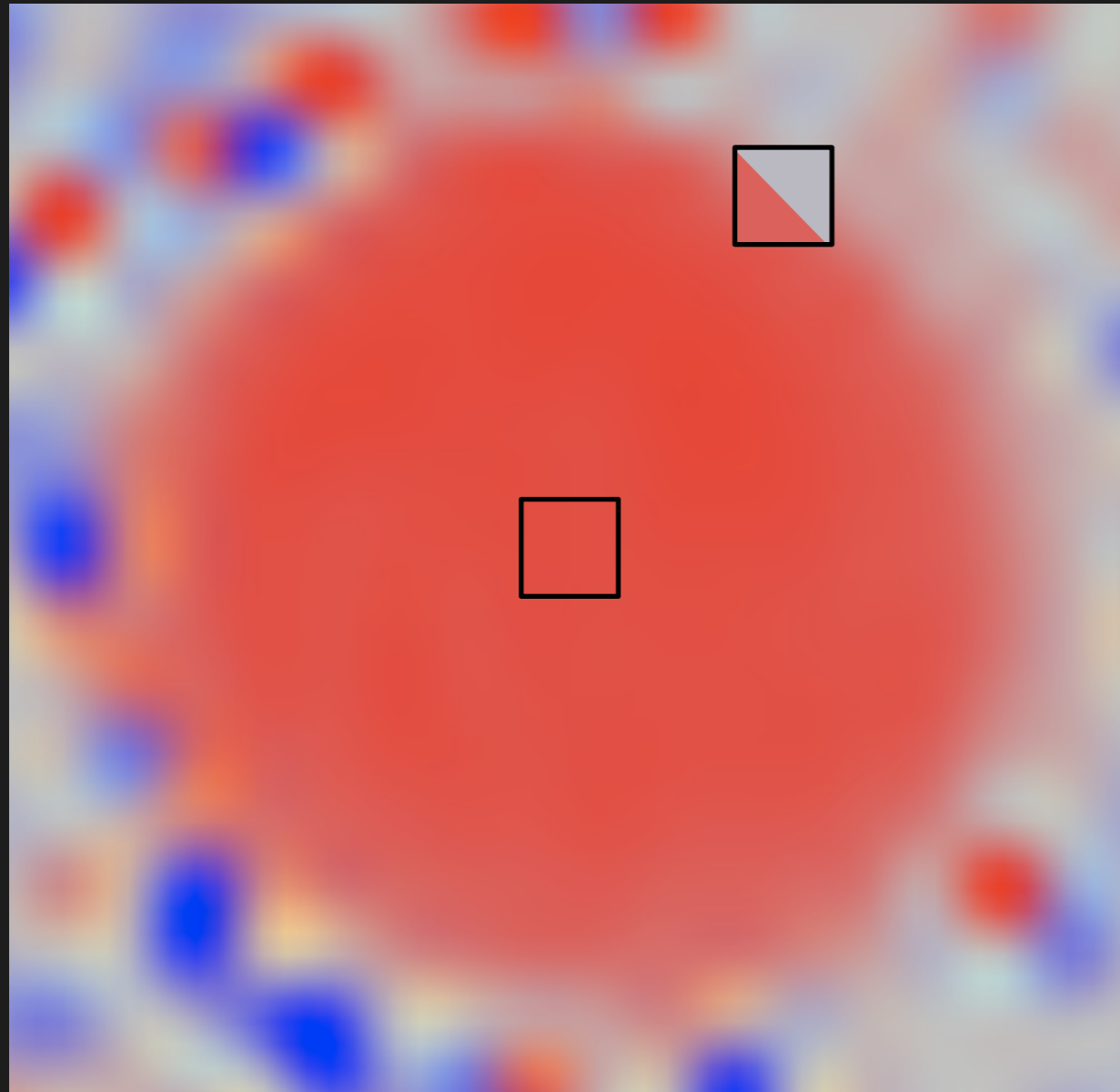
Whats the flow



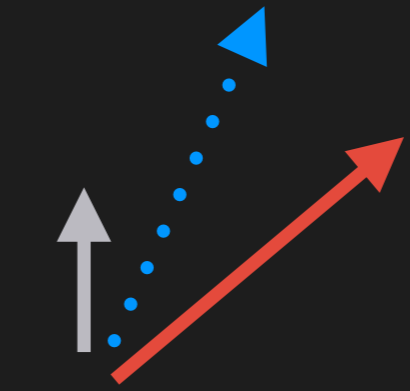
$$Q = V \times A$$

Half pixel moving

Half pixel stationary



Whats the flow

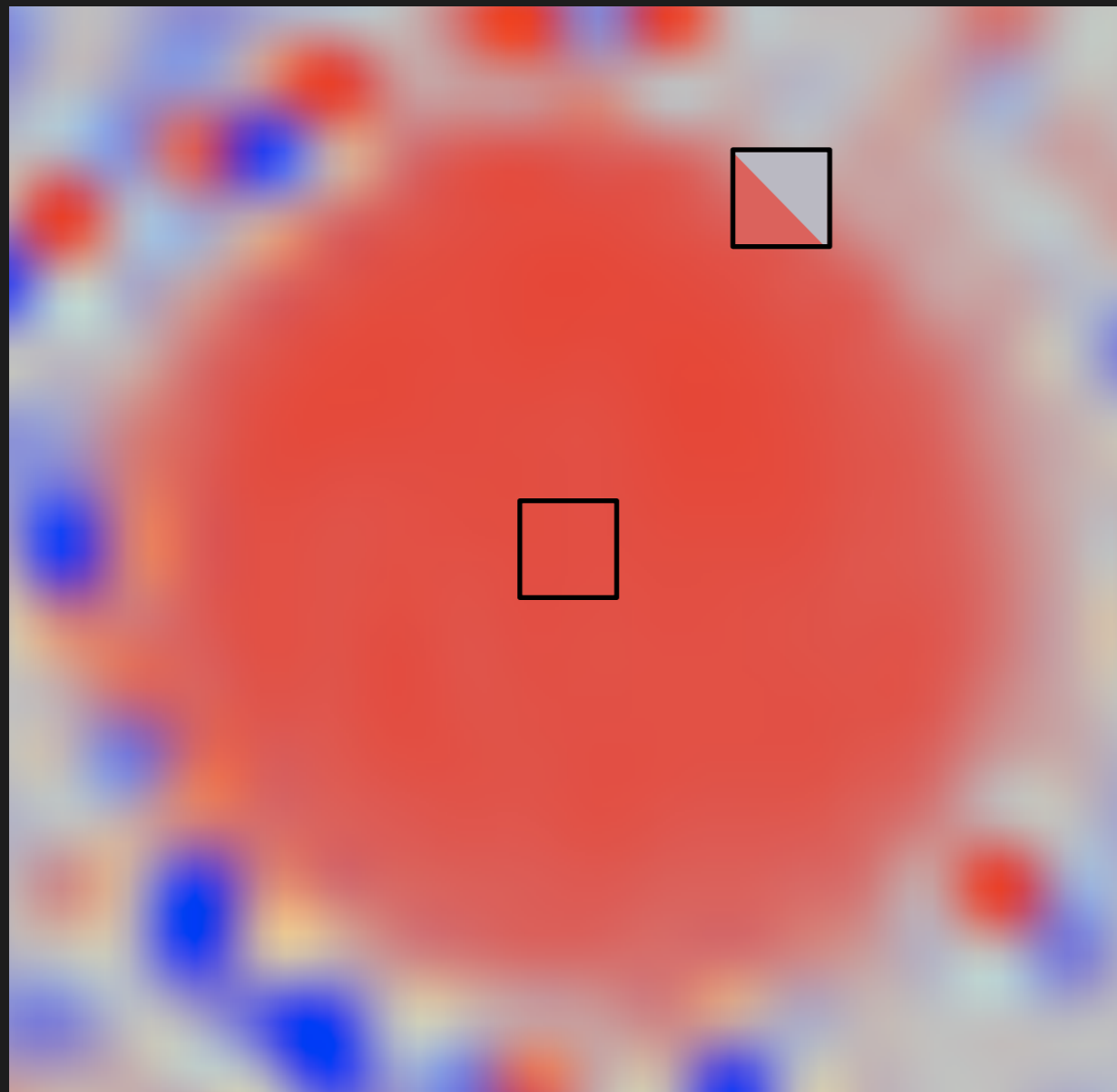


Simple average

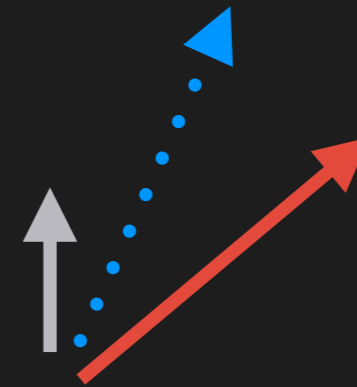
$Q = V \times A$

Half pixel moving

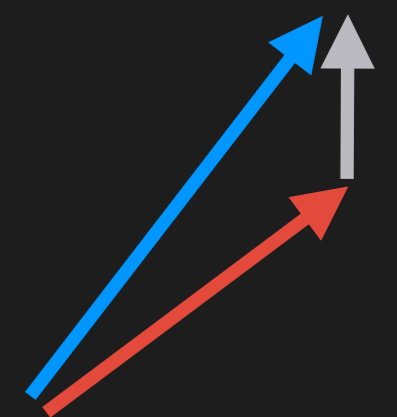
Half pixel stationary



Whats the flow



Simple
average

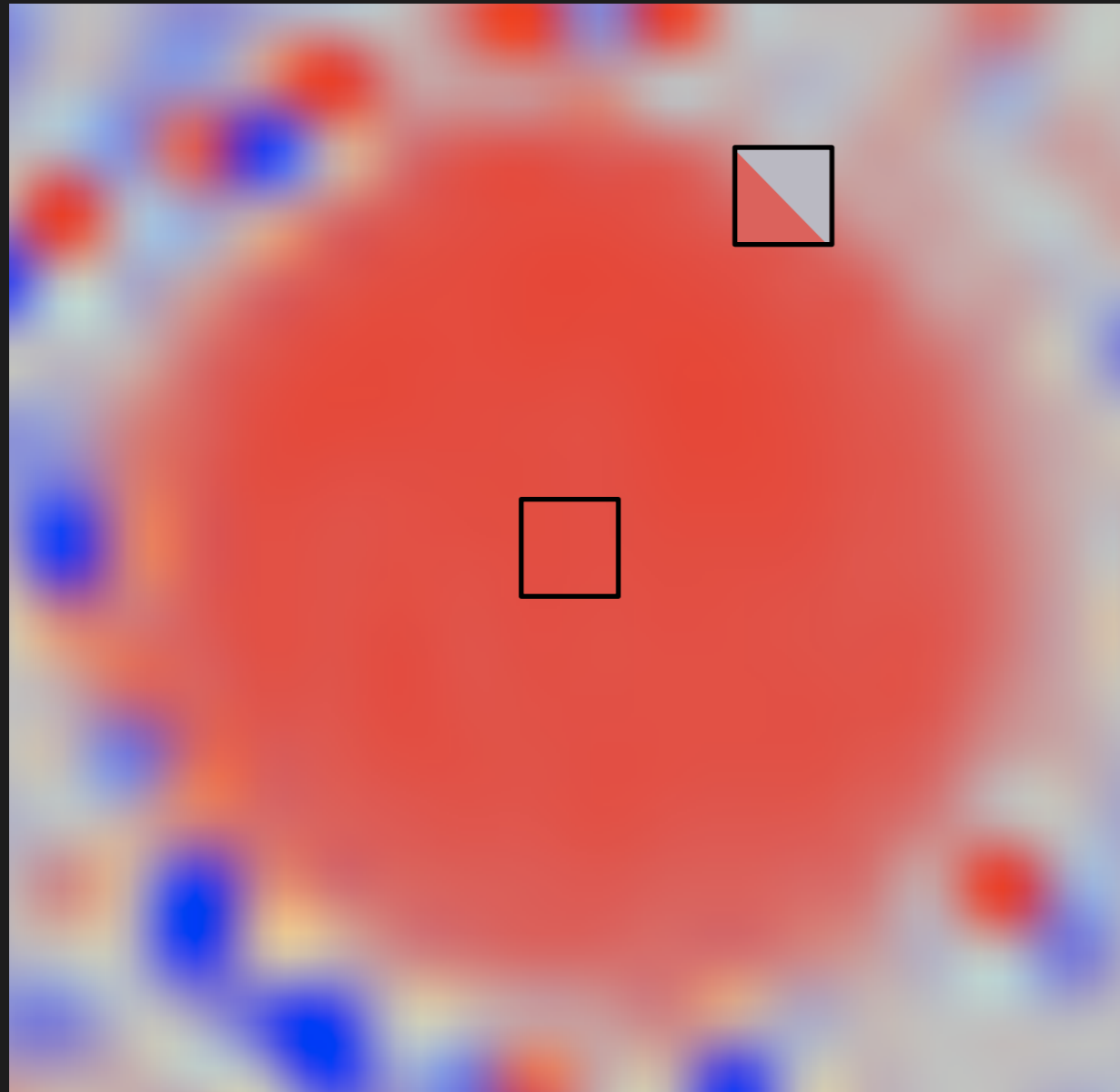


Vectorial
sum

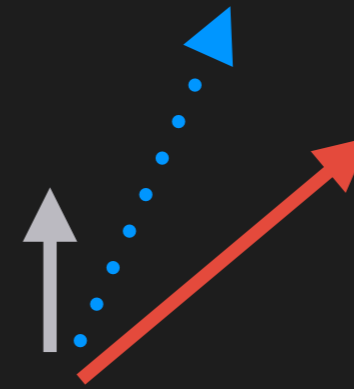
$$Q = V \times A$$

Half pixel moving

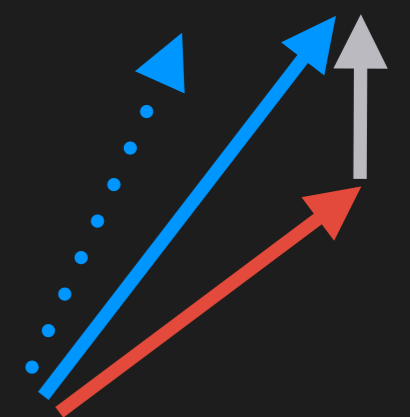
Half pixel stationary



Whats the flow



Simple
average

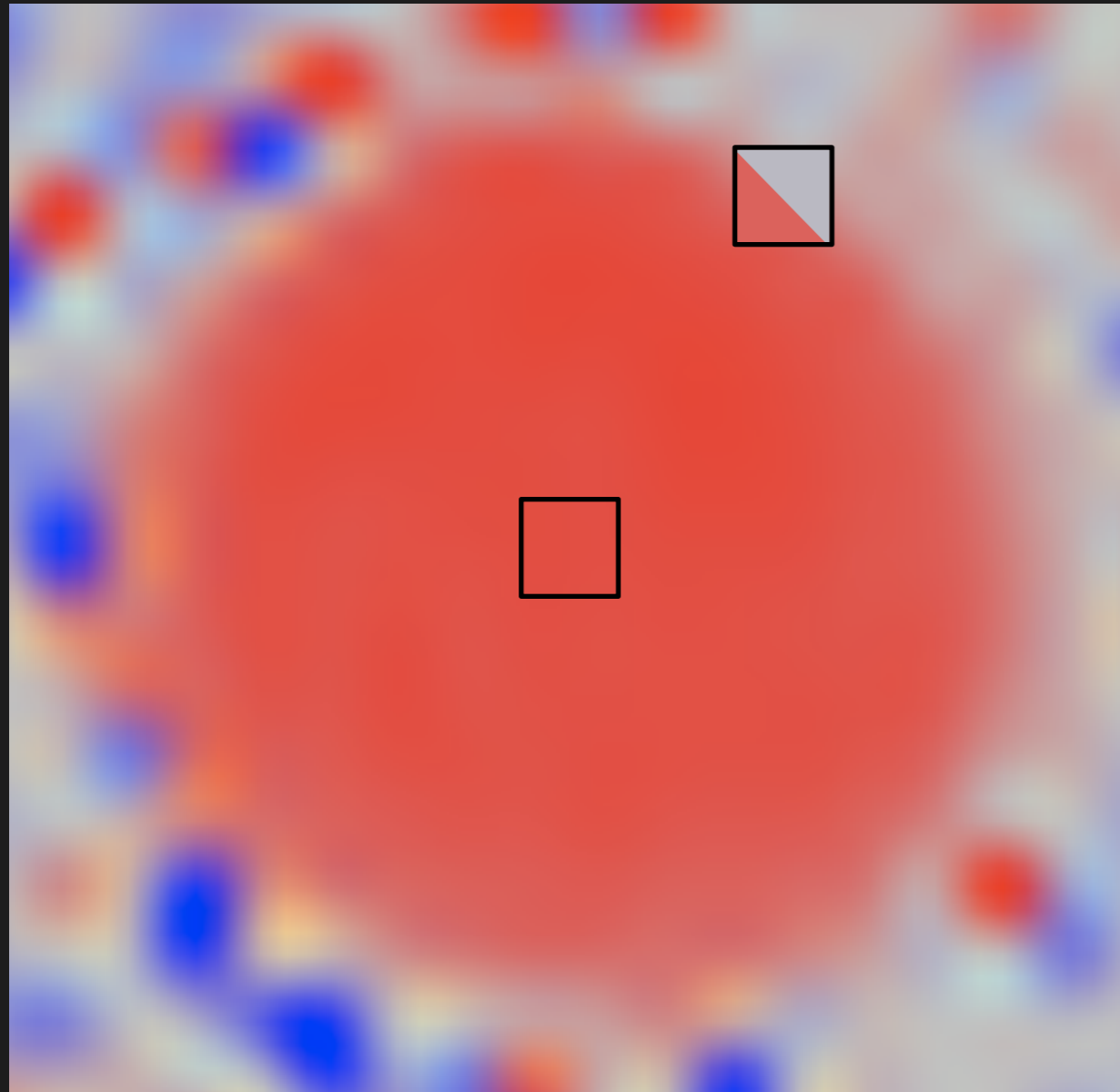


Vectorial
sum

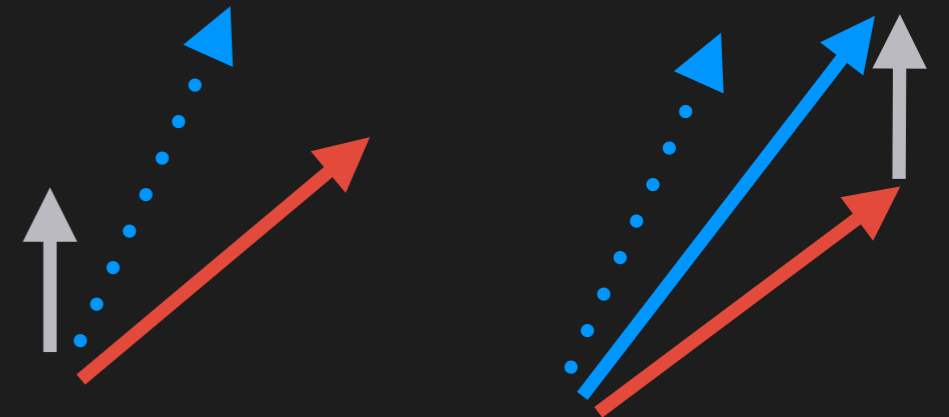
$$Q = V \times A$$

Half pixel moving

Half pixel stationary



Whats the flow



Simple
average

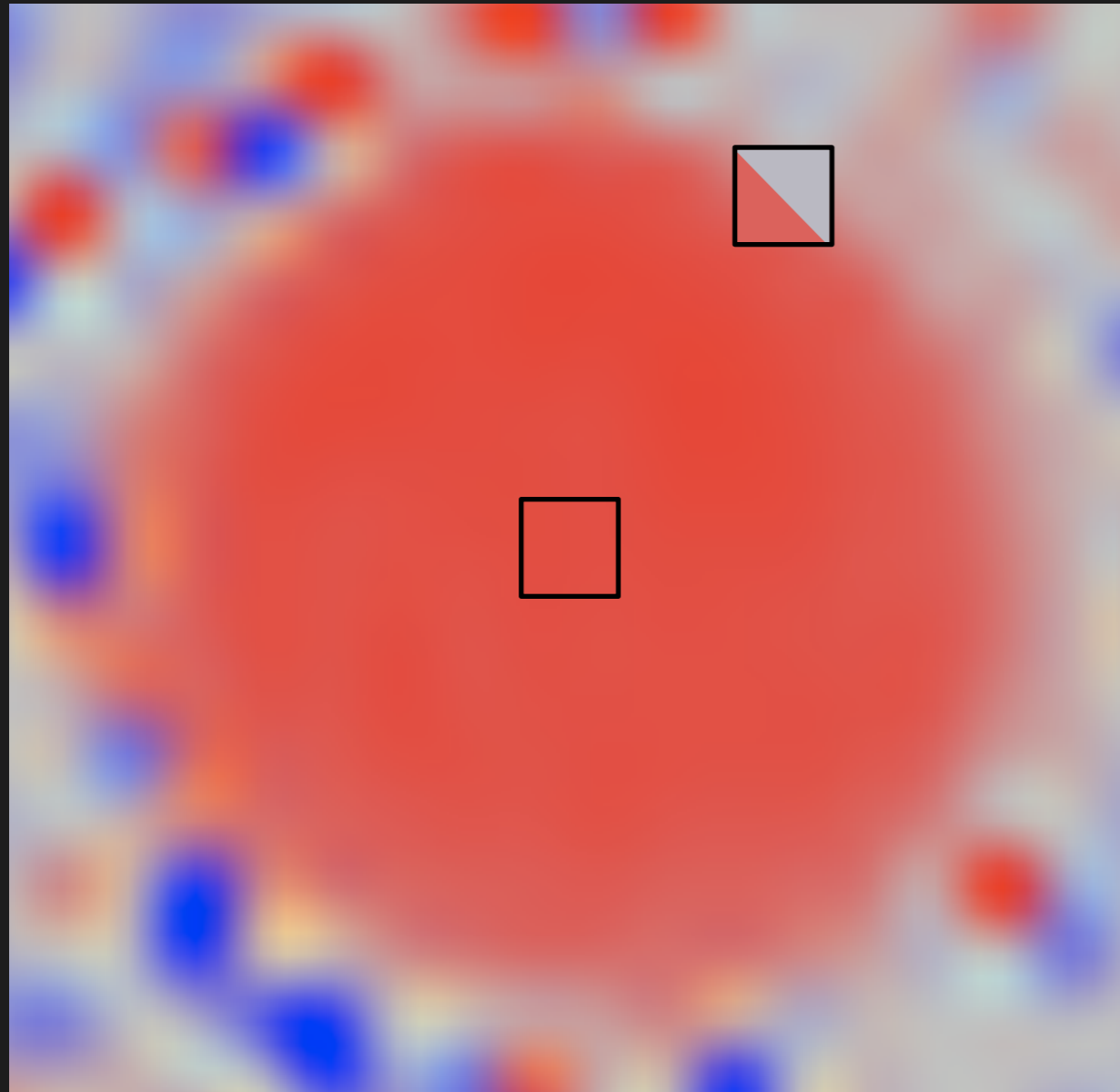
Vectorial
sum

Edge pixels

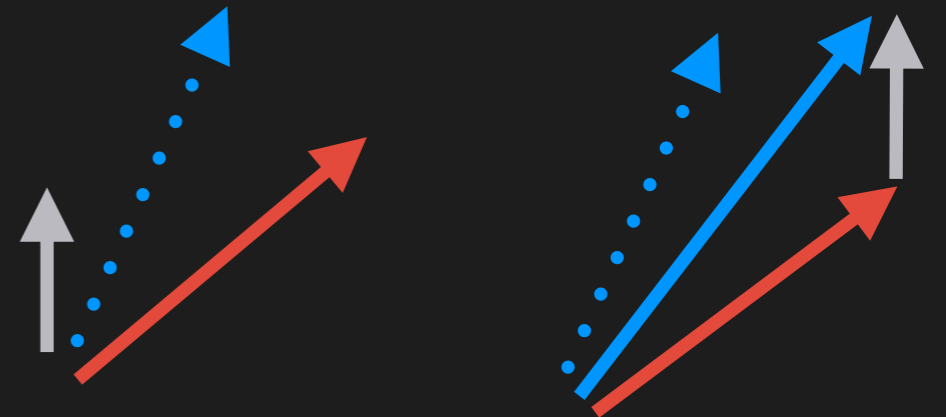
$$Q = V \times A$$

Half pixel moving

Half pixel stationary



Whats the flow



Simple
average

Vectorial
sum

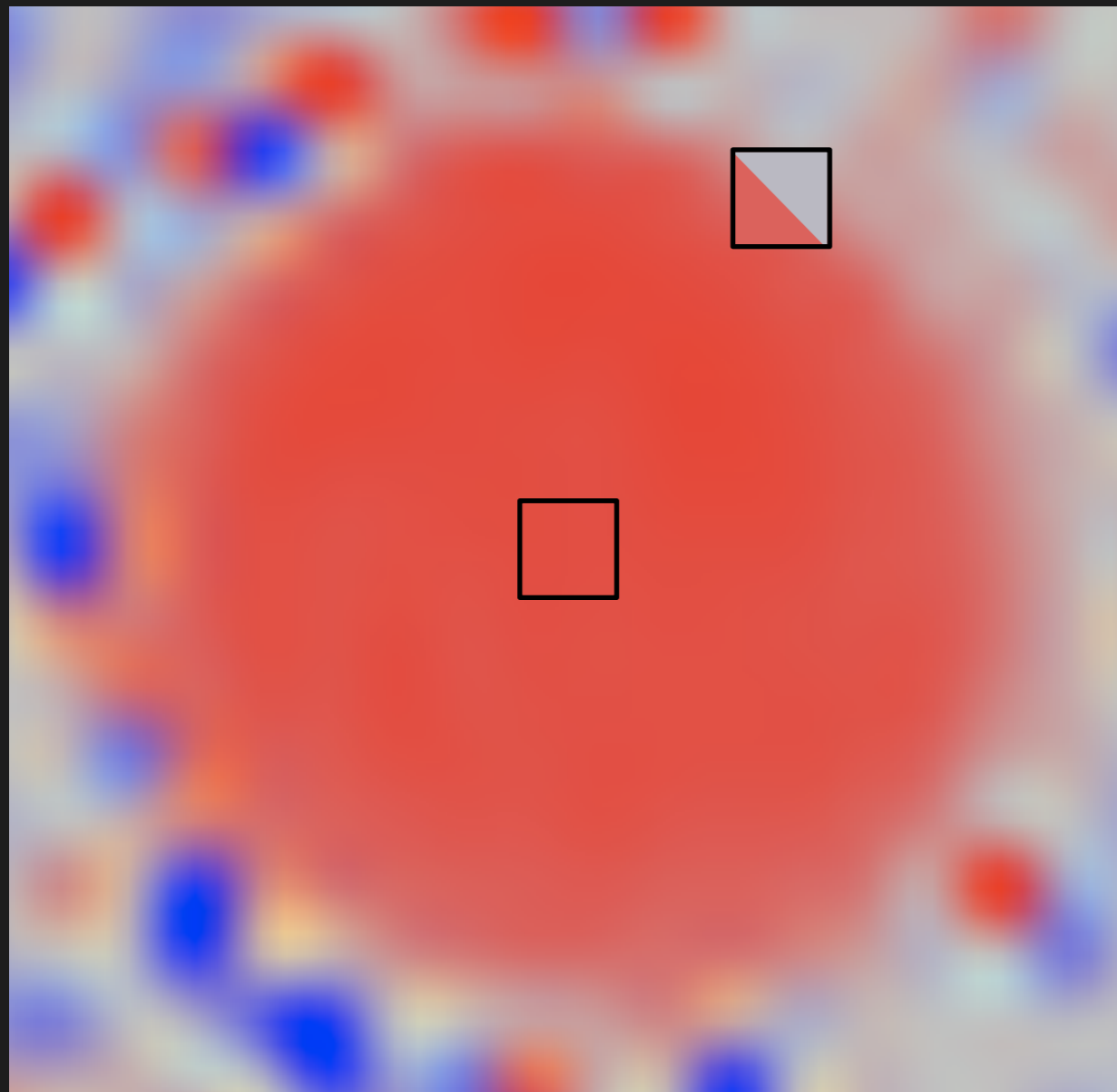
Edge pixels

Overestimate flow

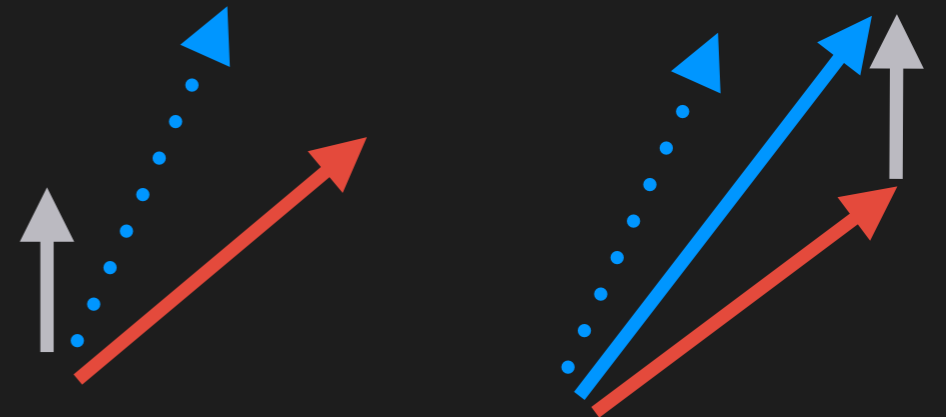
$$Q = V \times A$$

Half pixel moving

Half pixel stationary



Whats the flow



Simple
average

Vectorial
sum

Edge pixels

Overestimate flow

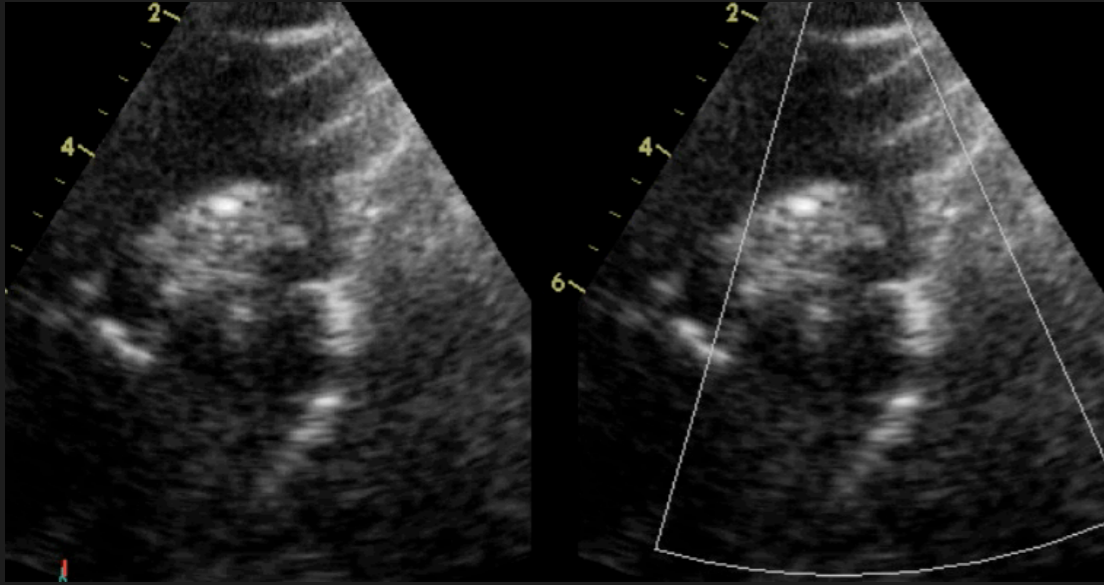
16 pixels minimum

$$Q = V \times A$$

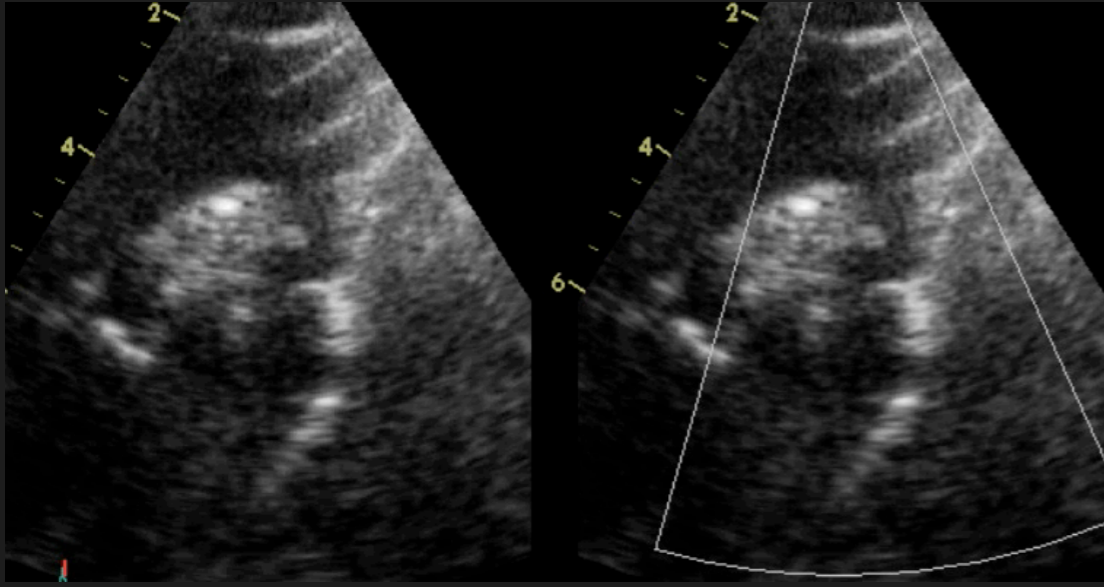
Half pixel moving

Half pixel stationary

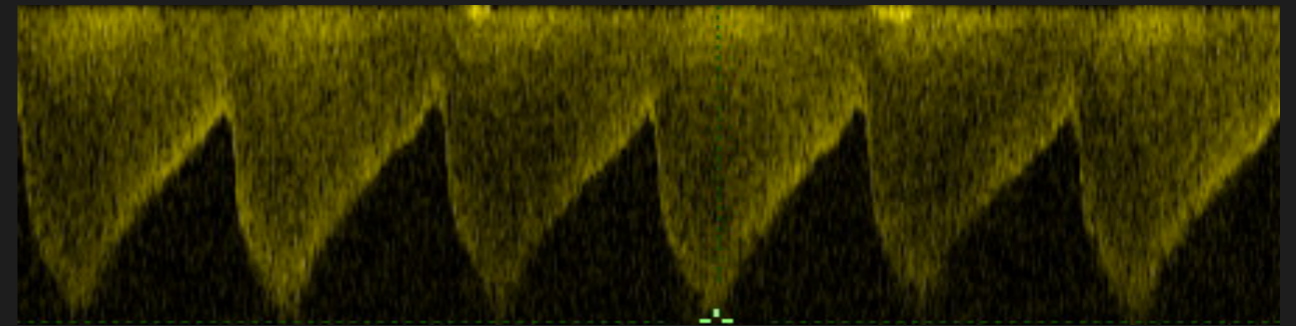
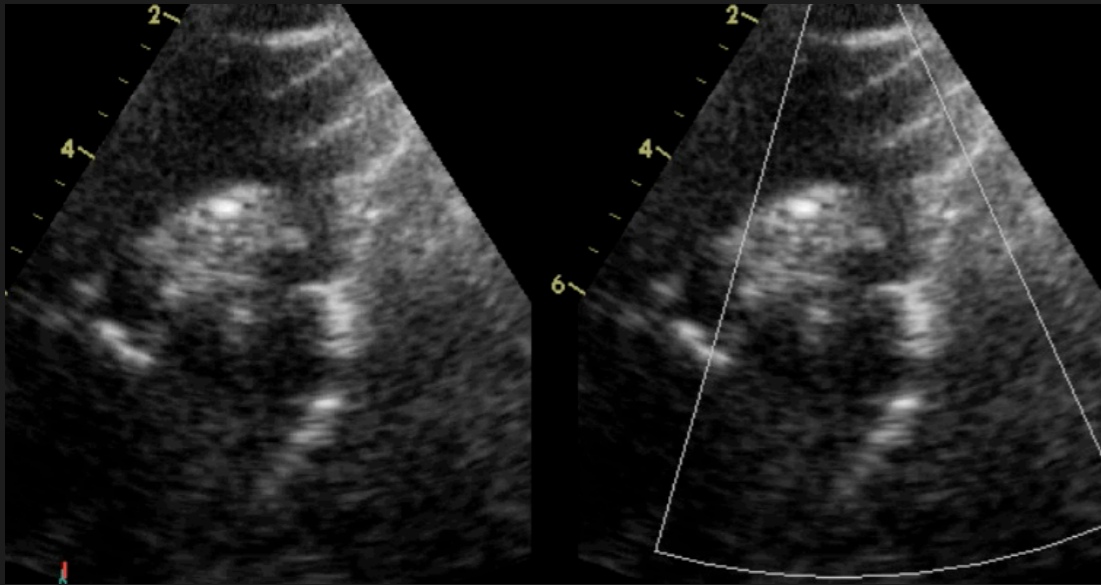
Peak Velocity



Peak Velocity

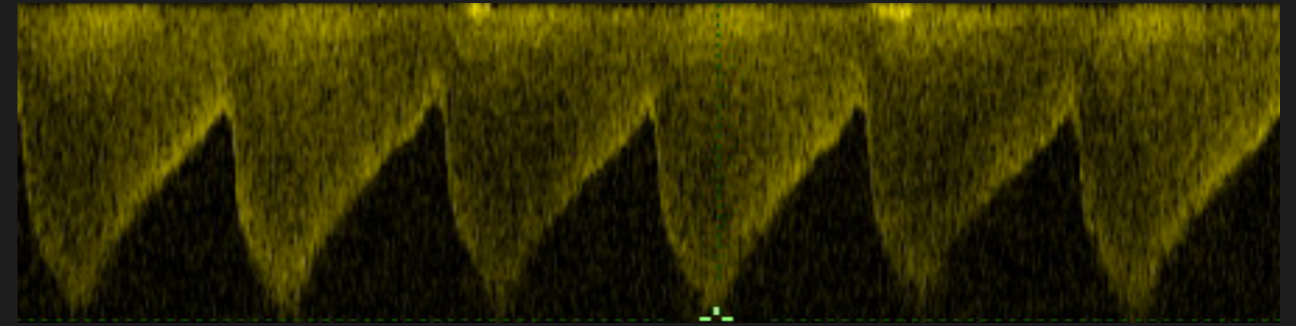
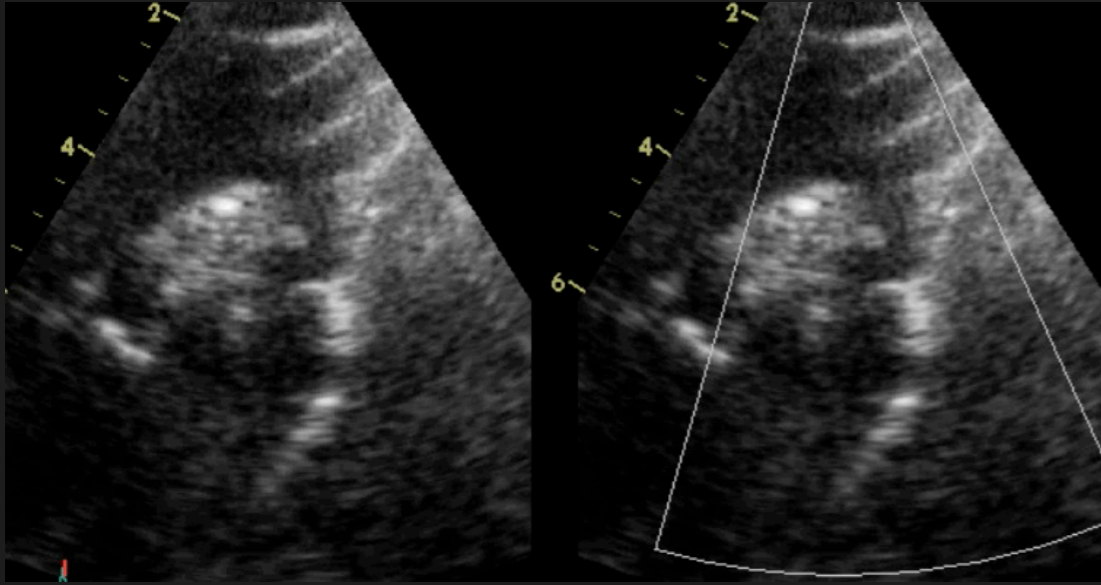


Peak Velocity

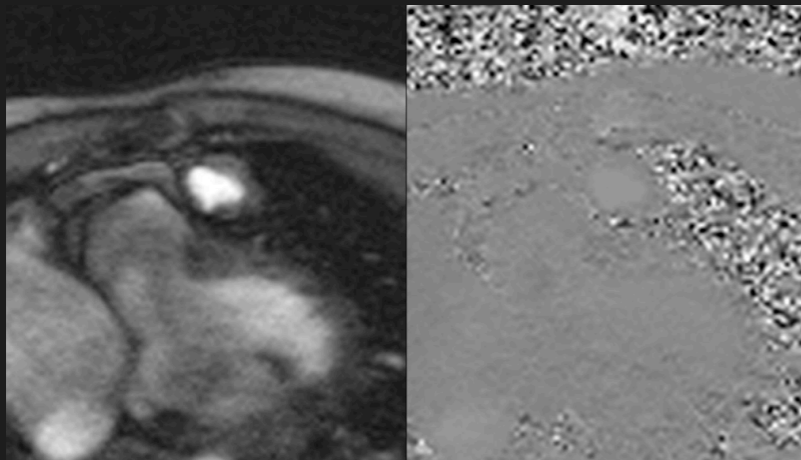


Doppler Reference

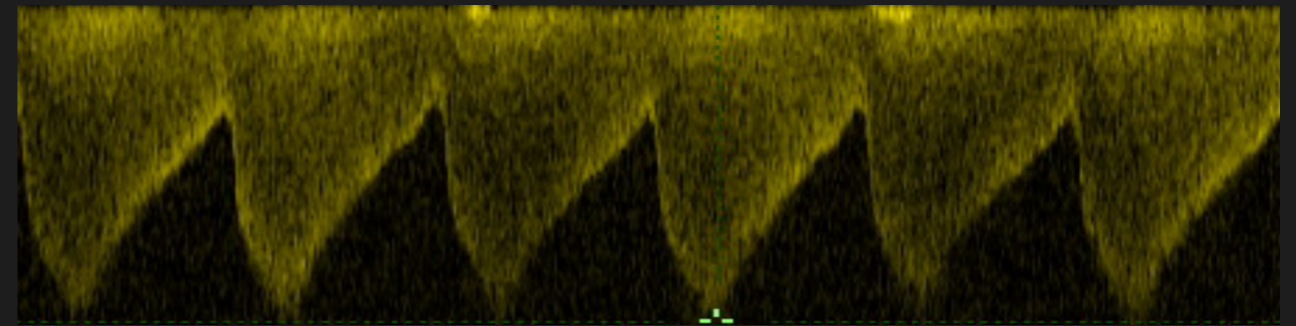
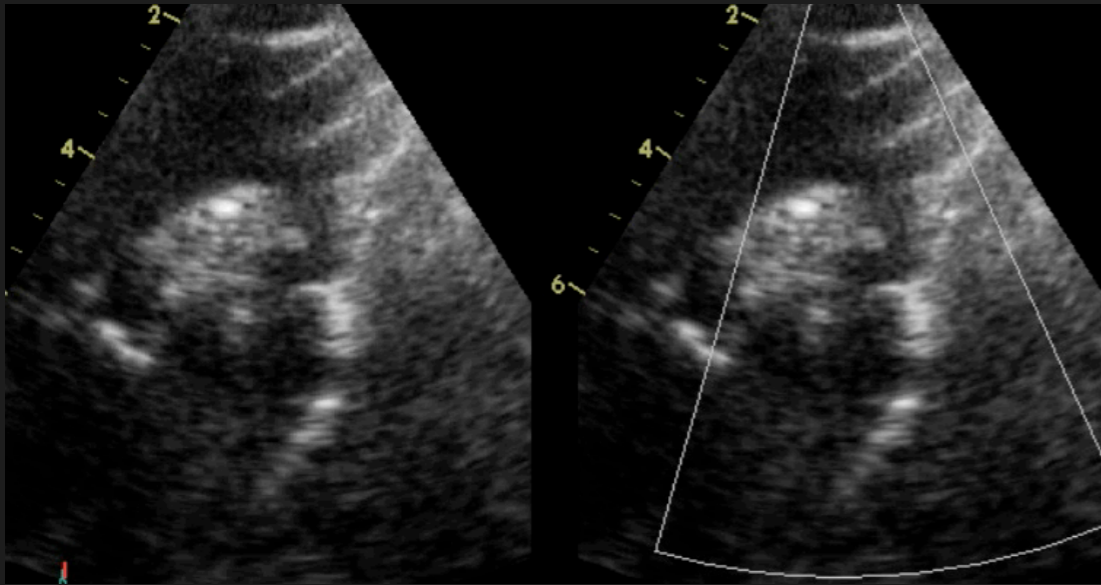
Peak Velocity



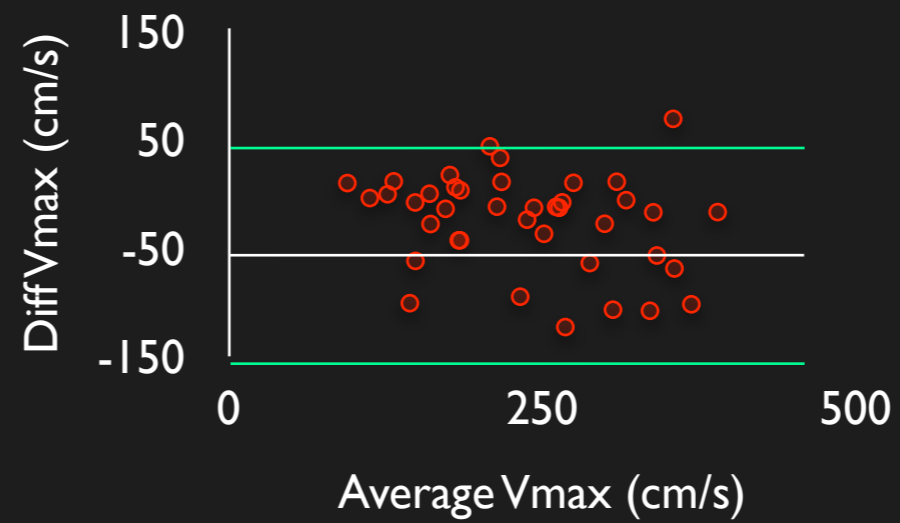
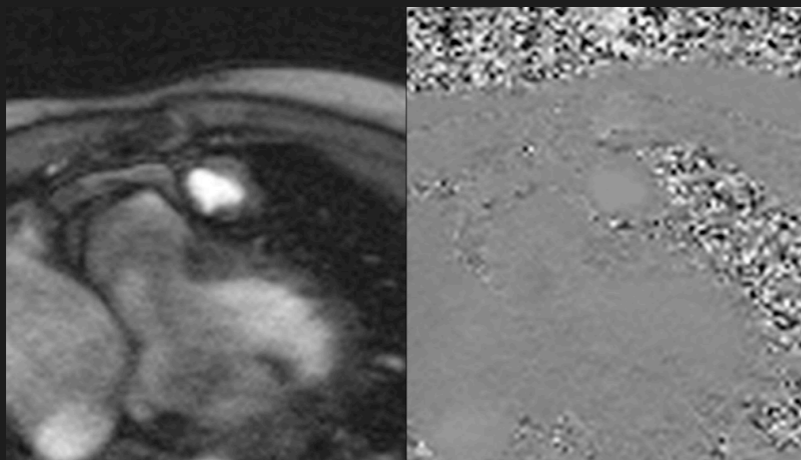
Doppler Reference



Peak Velocity

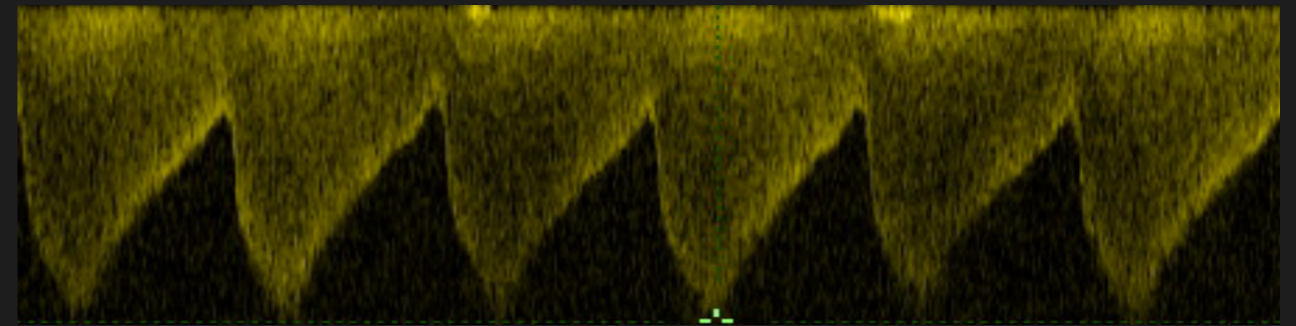
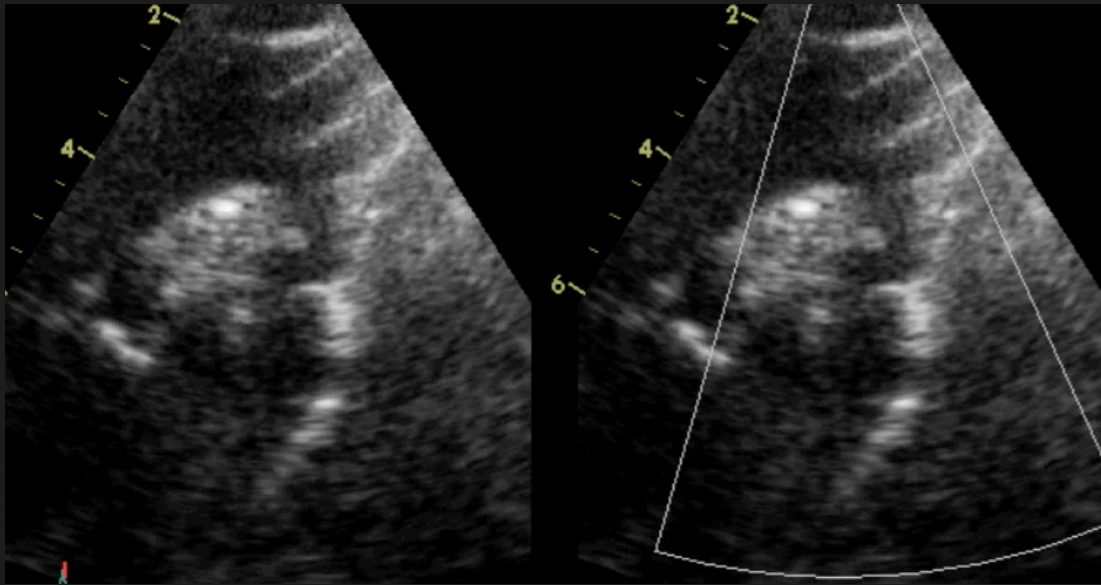


Doppler Reference

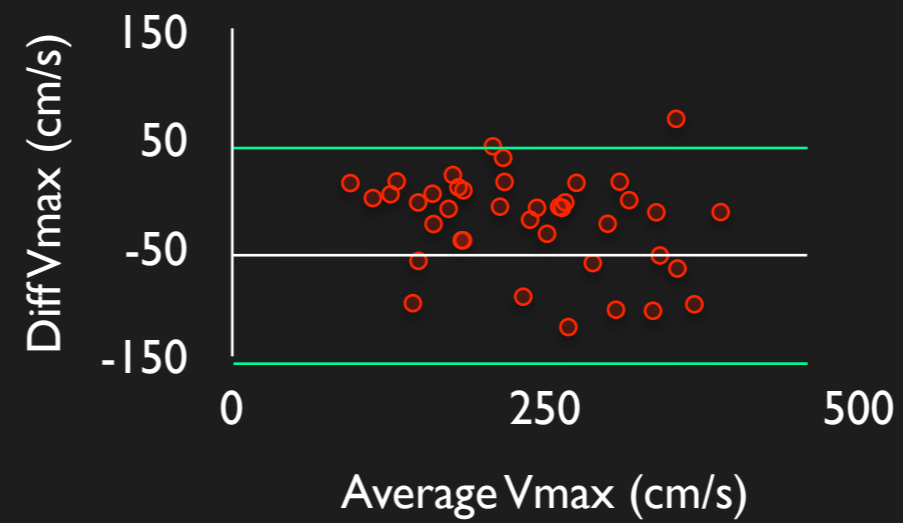
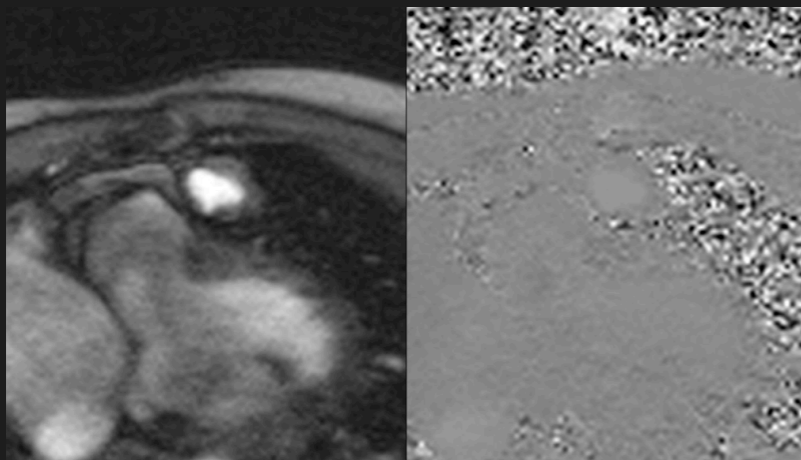


Bias 0.4m/s

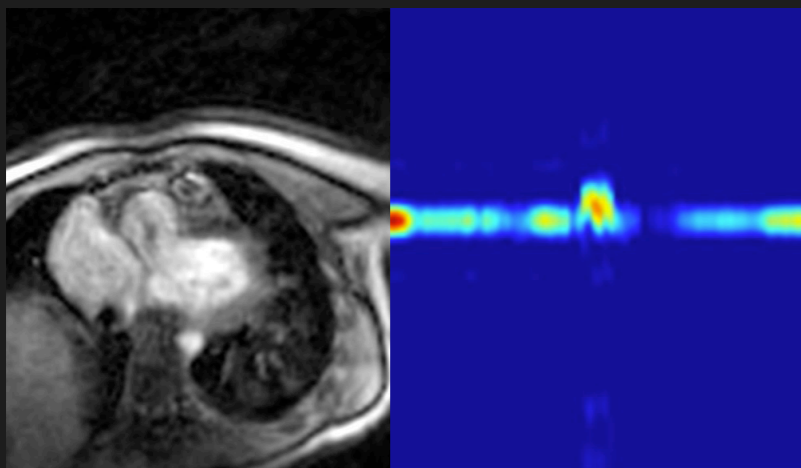
Peak Velocity



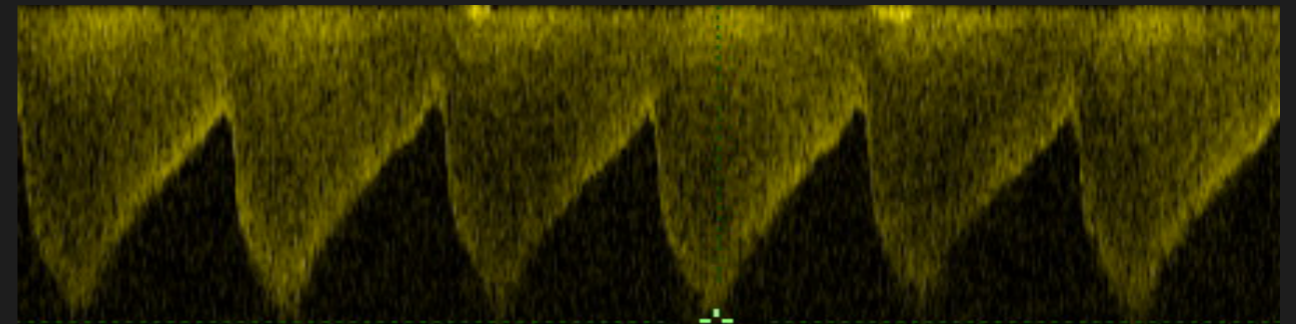
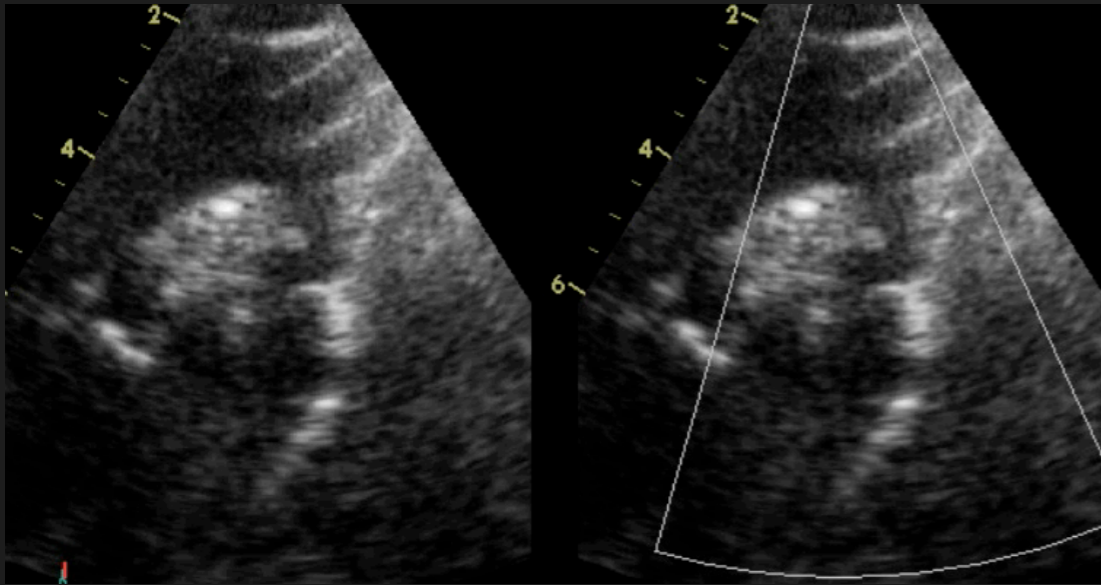
Doppler Reference



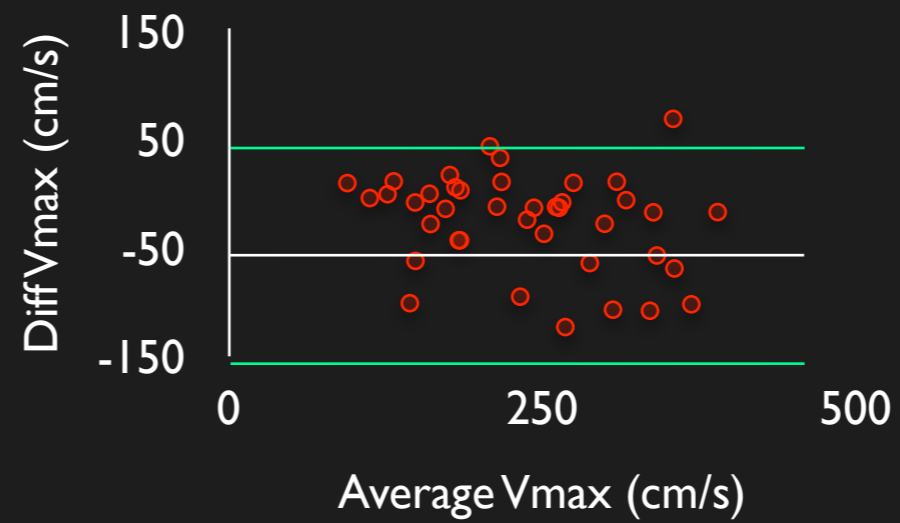
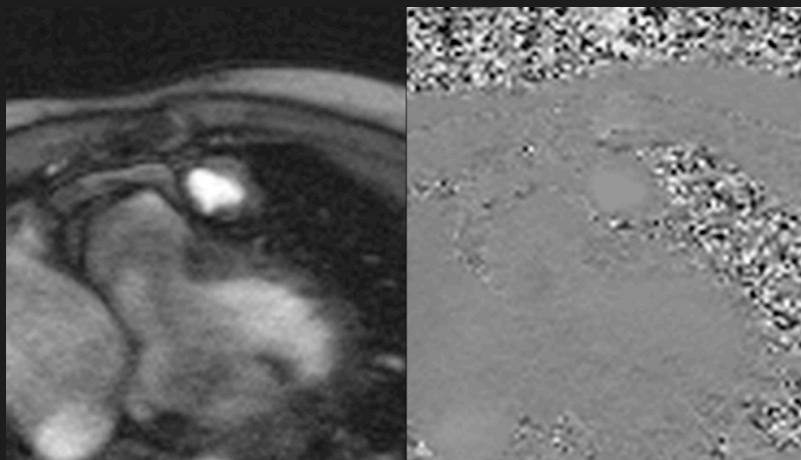
Bias 0.4m/s



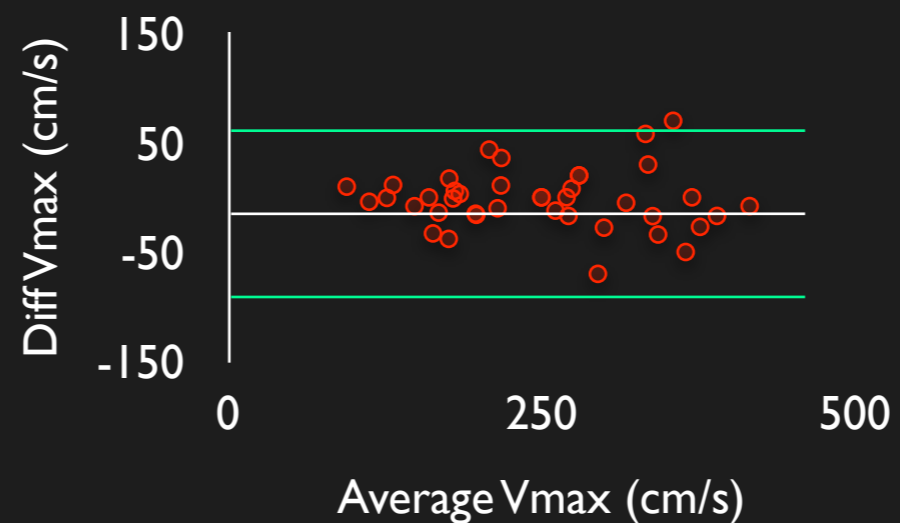
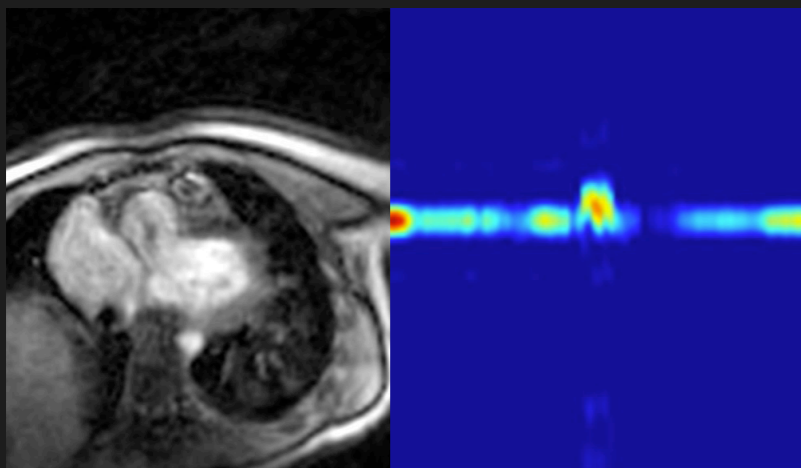
Peak Velocity



Doppler Reference

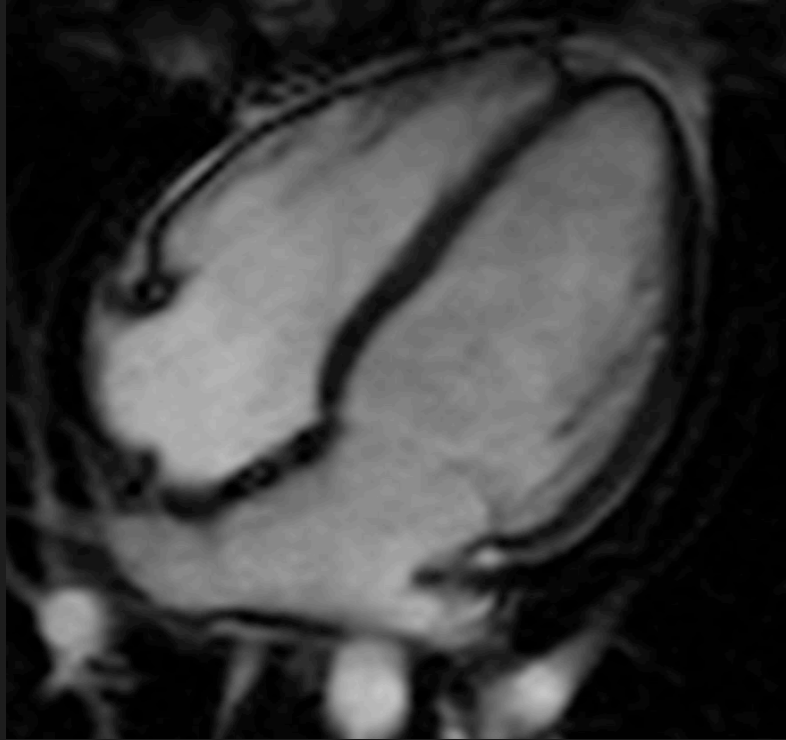


Bias 0.4m/s

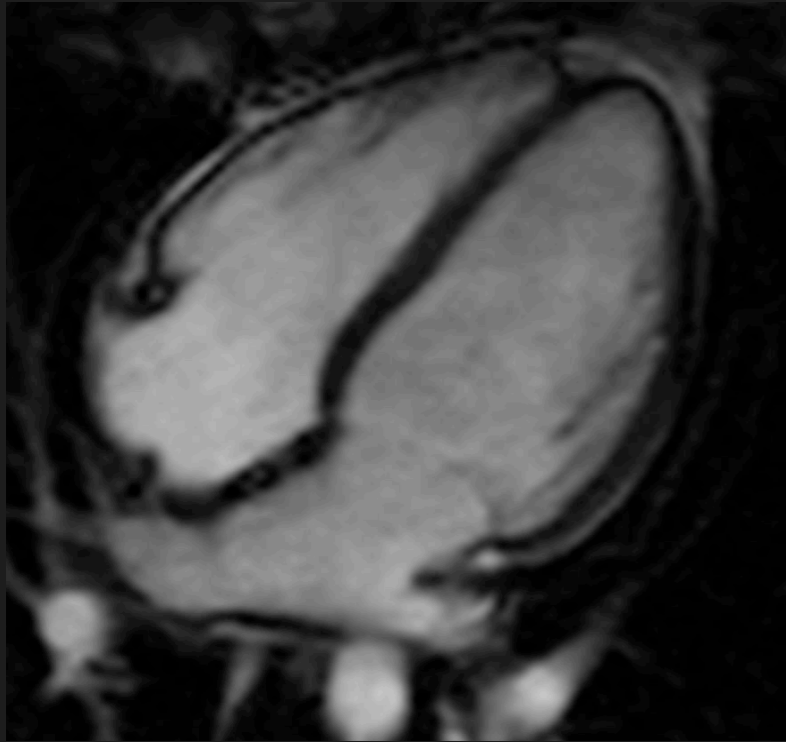


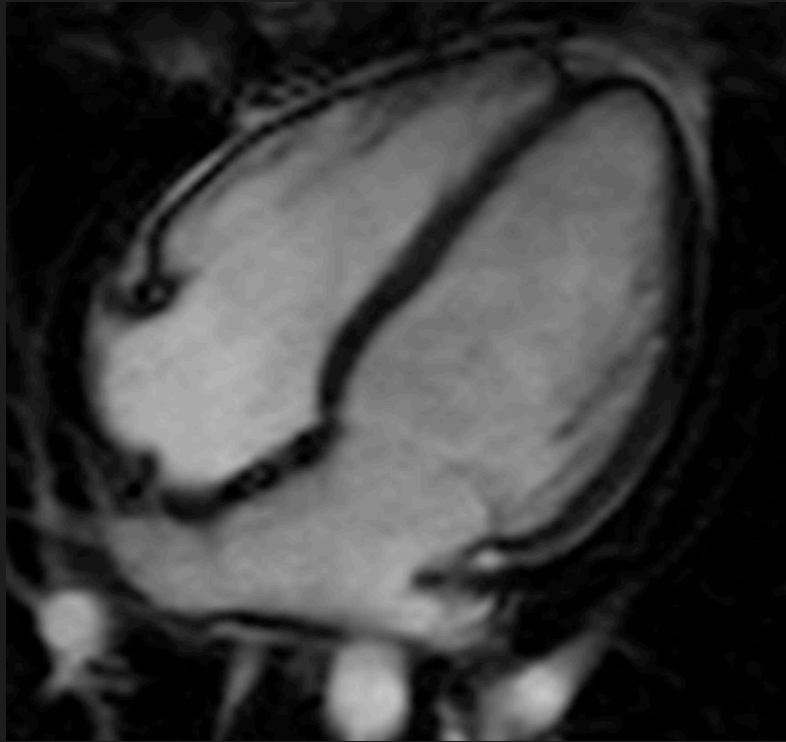
No bias

balanced steady state free precession

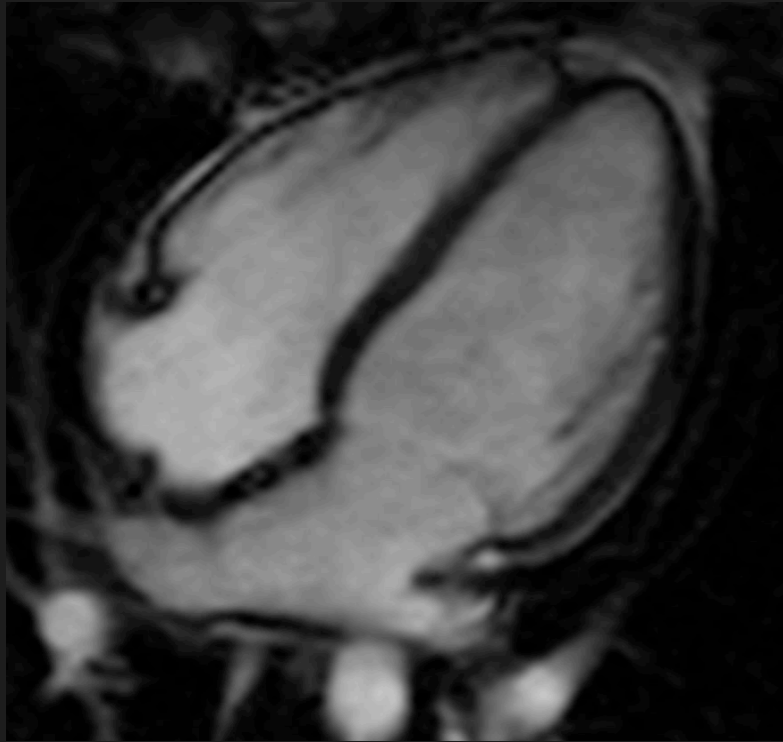


balanced steady state free precession



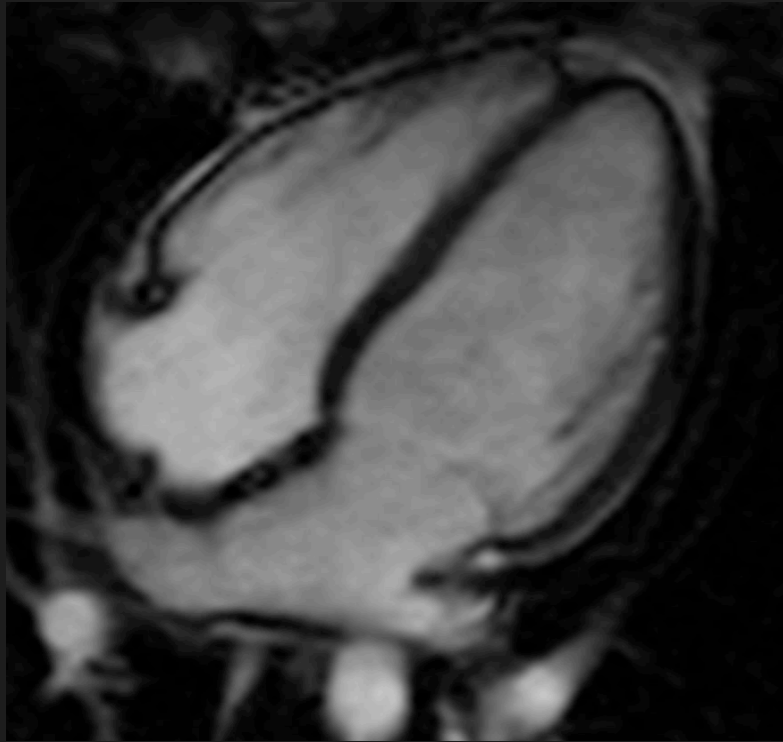


Type of GRE



Type of GRE

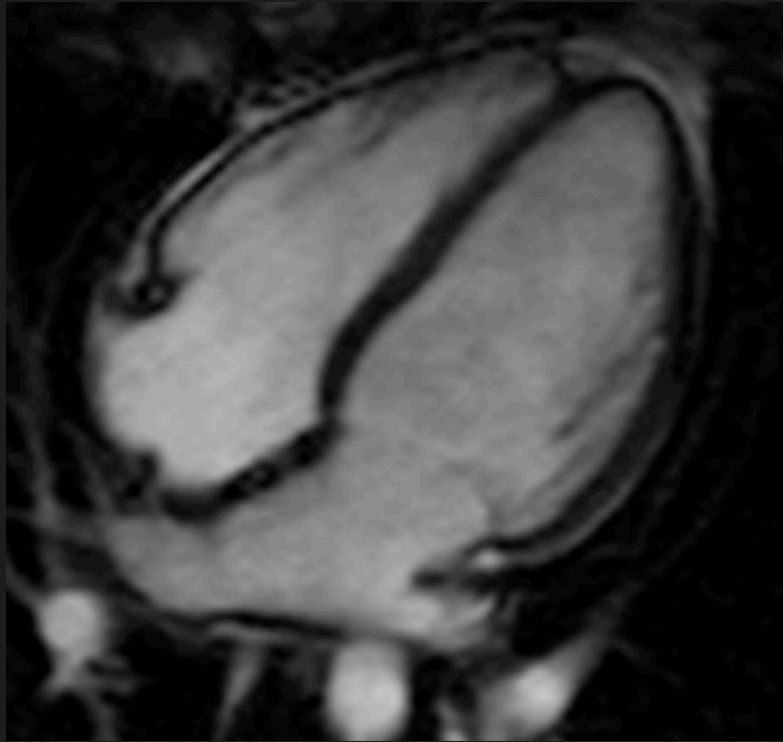
Flow indépendant



Type of GRE

Flow indépendant

High contrast



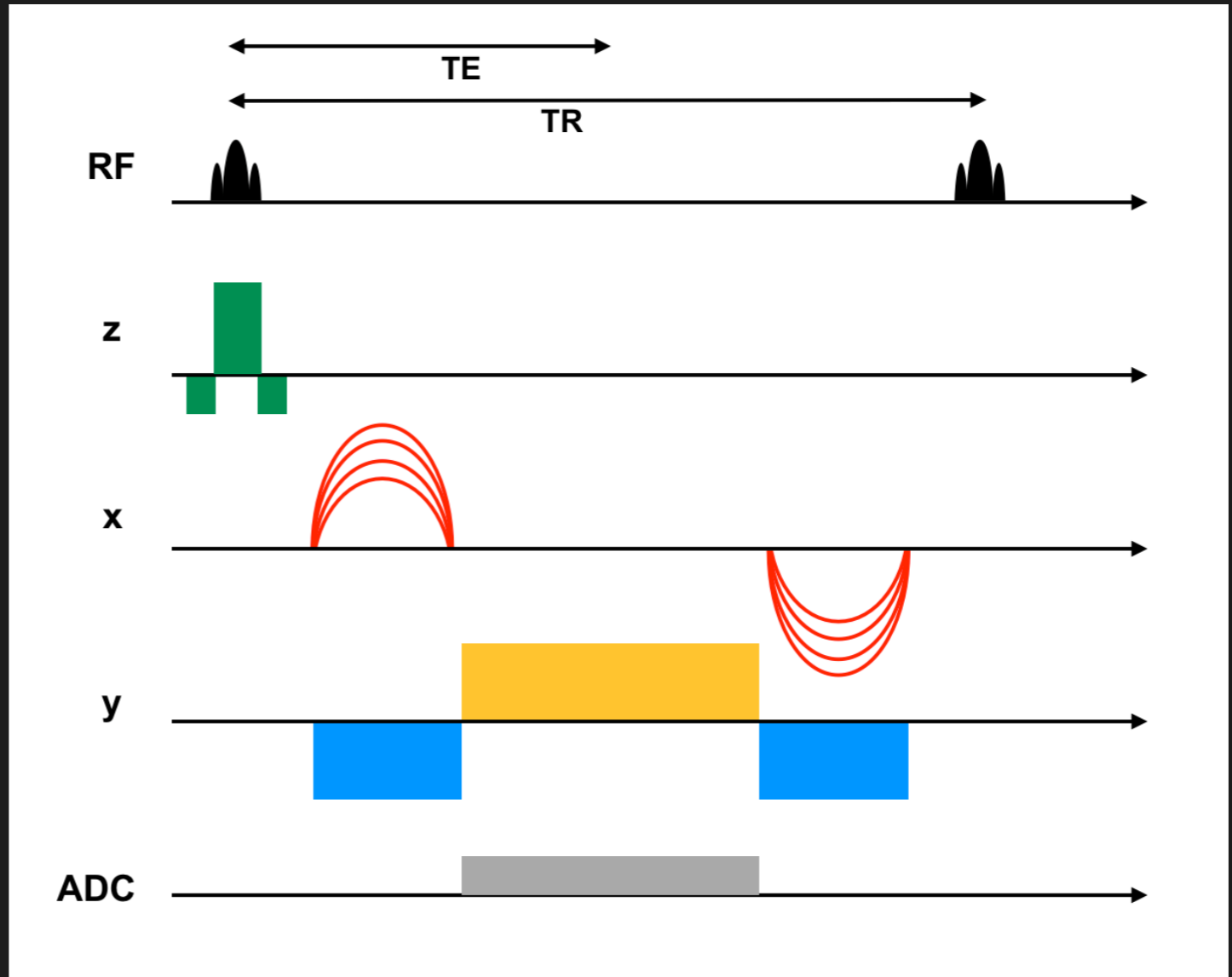
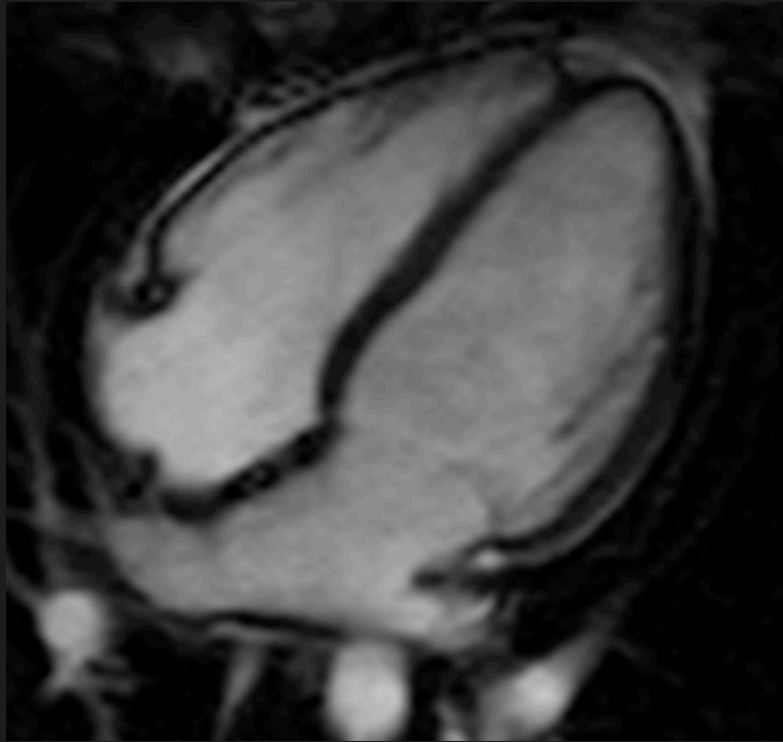
Type of GRE

Flow indépendant

High contrast

Work horse

balanced steady state free precession

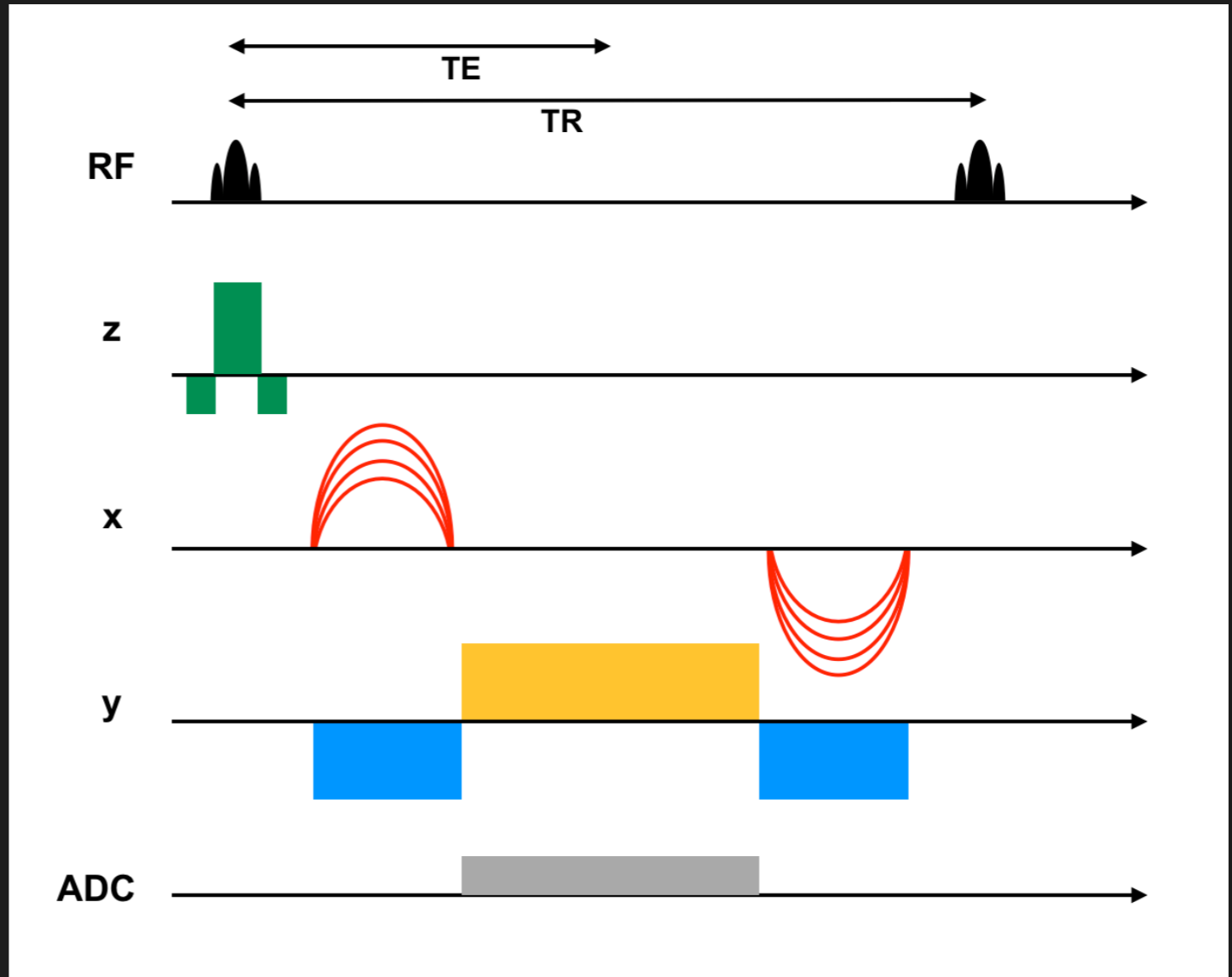
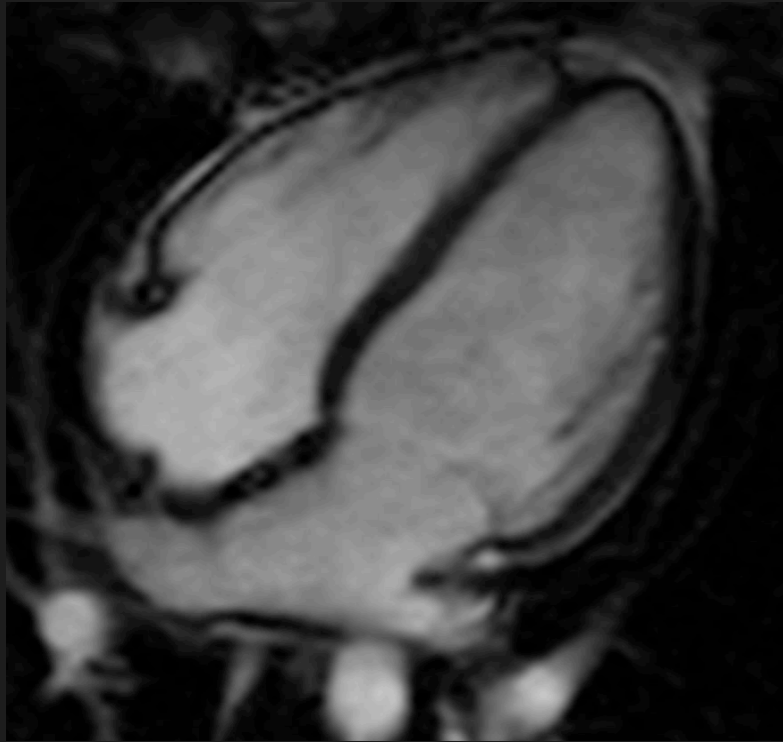


Type of GRE

Flow indépendant

High contrast

Work horse



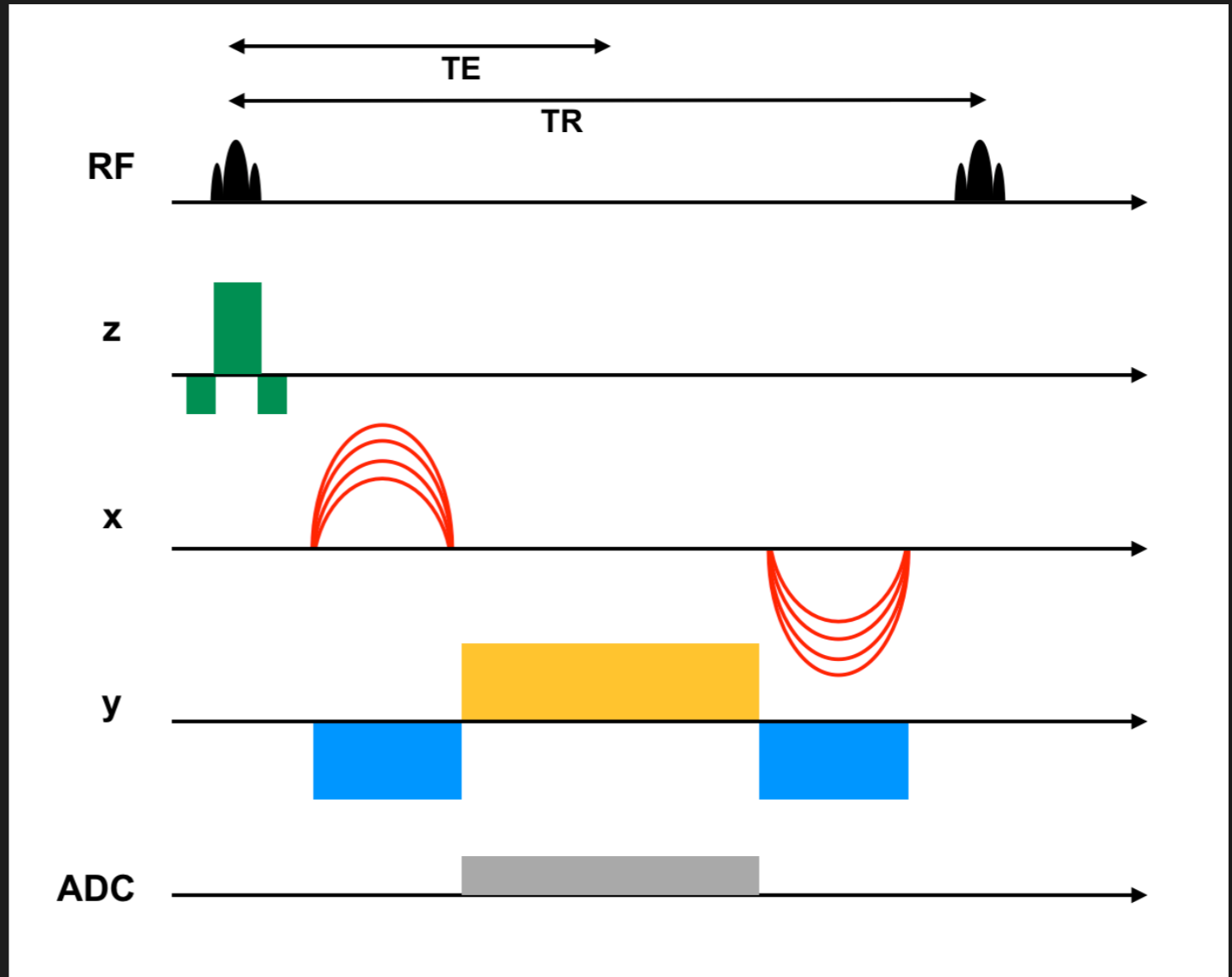
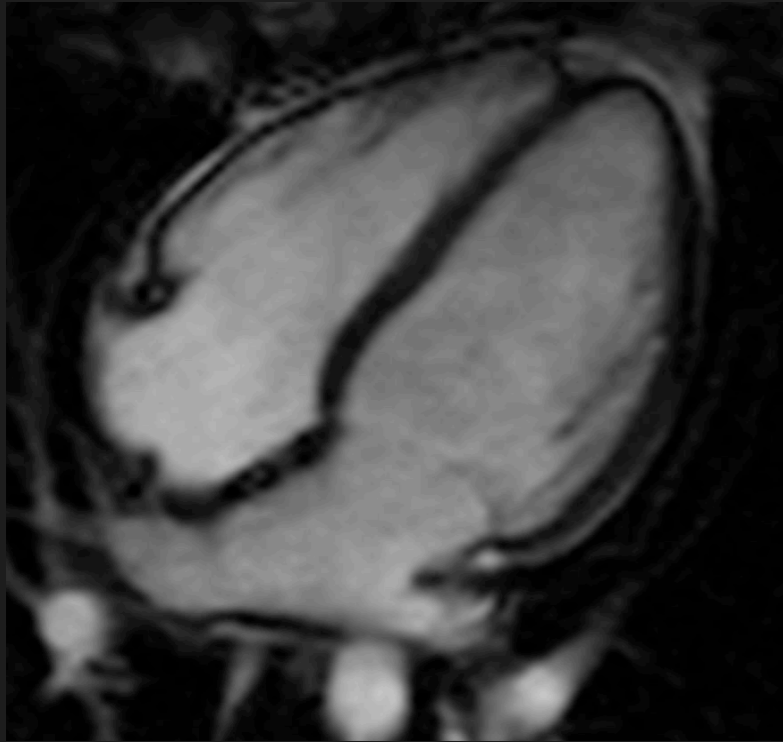
Type of GRE

Flow independent

High contrast

Work horse

Gradients balanced



Type of GRE

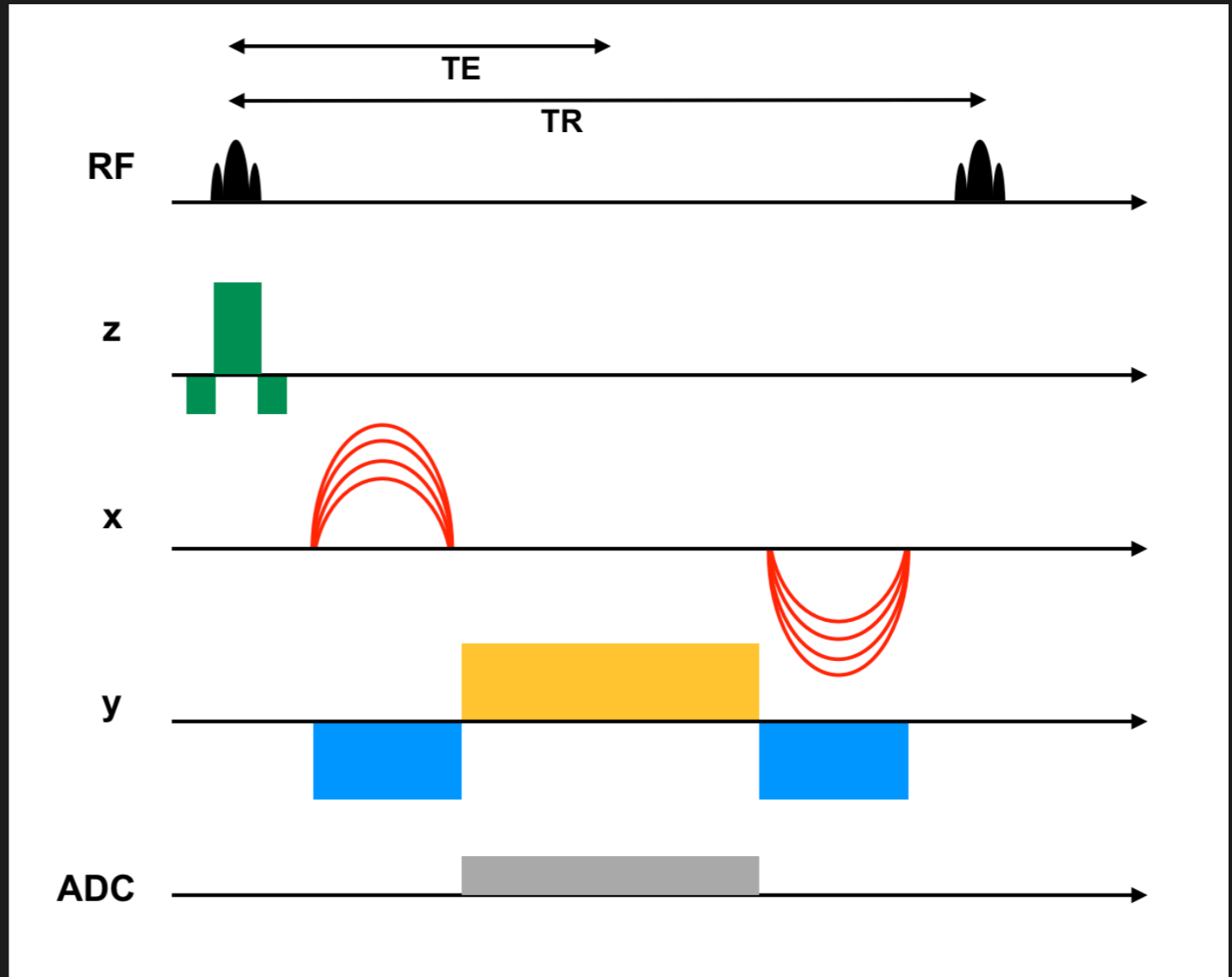
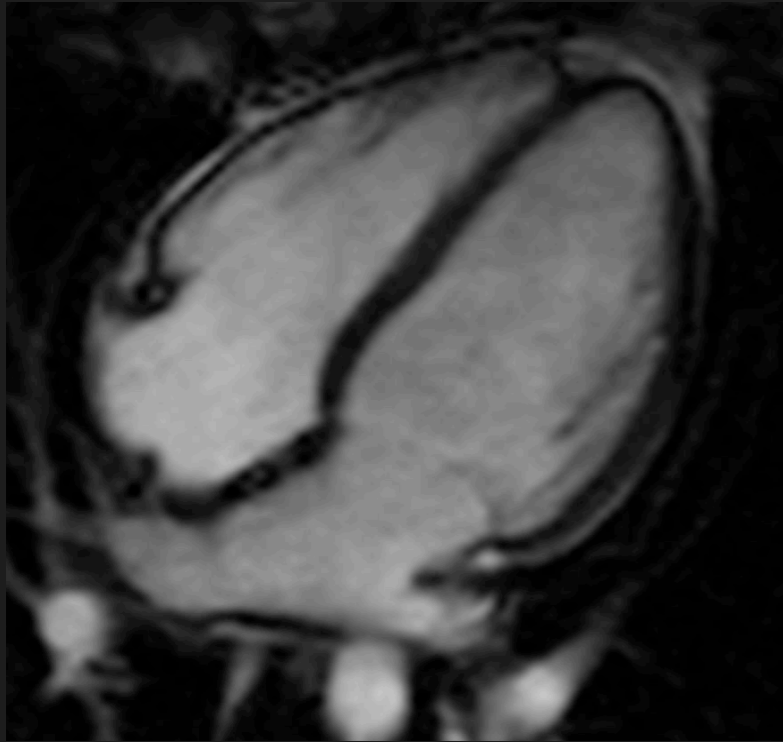
Flow indépendant

High contrast

Work horse

Gradients balanced

Flipping magnetisation



Type of GRE

Flow independent

High contrast

Work horse

Gradients balanced

Flipping magnetisation

T2 weighted not T2*

Dark band b-SSFP artefact

Sensitive to off resonance

Sensitive to off resonance

Magnetic field inhomogeneity

Sensitive to off resonance

Magnetic field inhomogeneity

Time is a factor = TR

Sensitive to off resonance

Magnetic field inhomogeneity

Time is a factor = TR

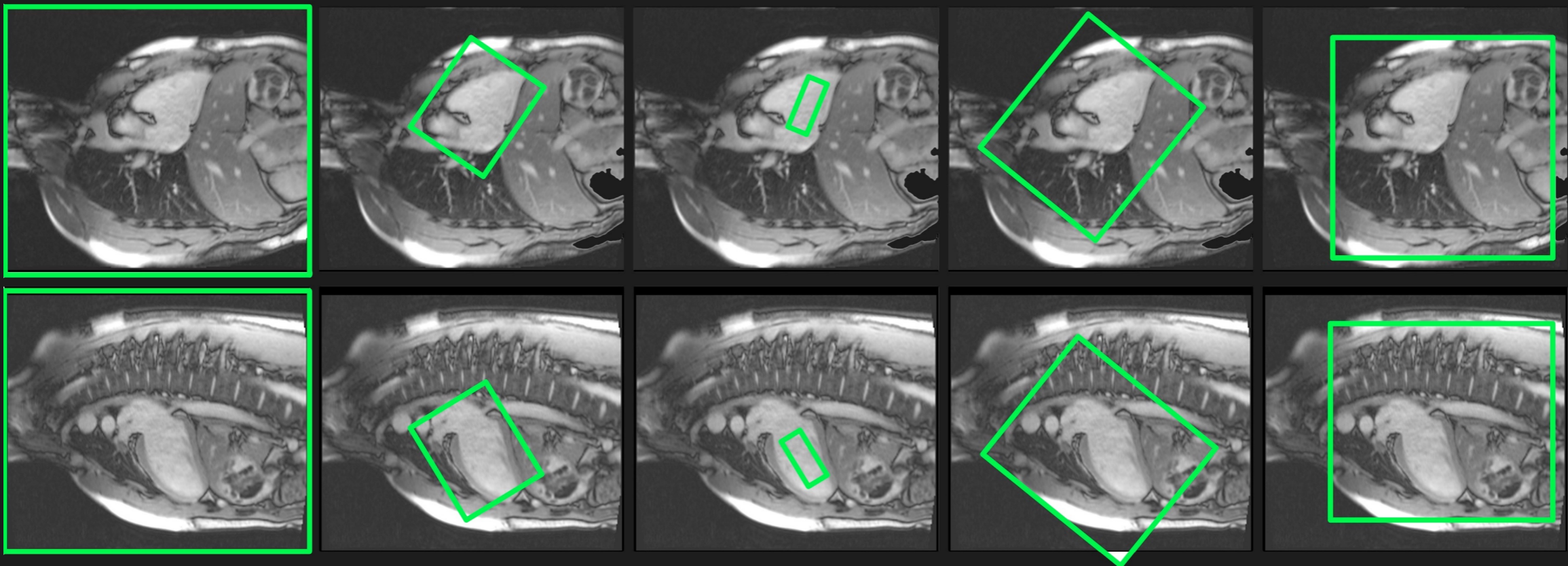


Dark band b-SSFP artefact

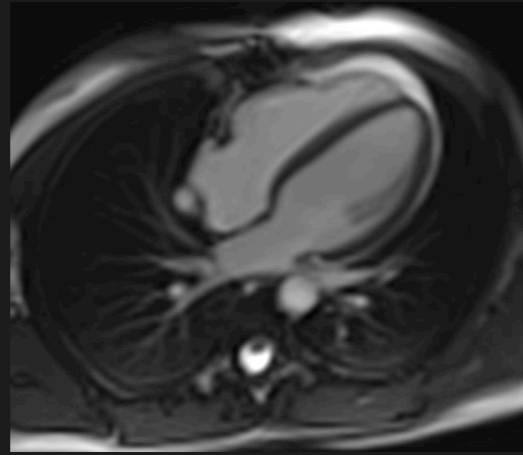
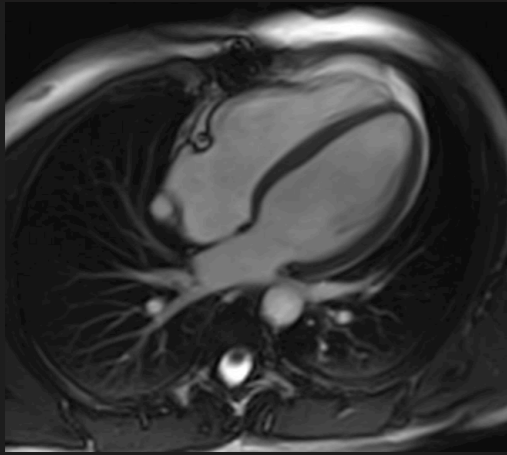
Sensitive to off resonance

Magnetic field inhomogeneity

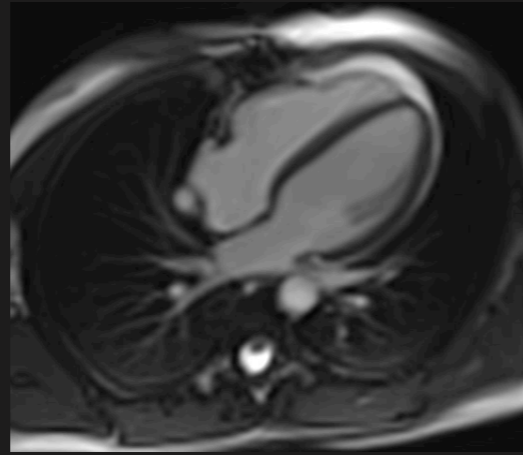
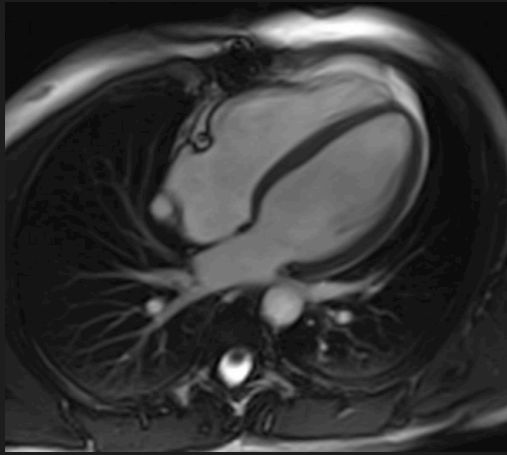
Time is a factor = TR

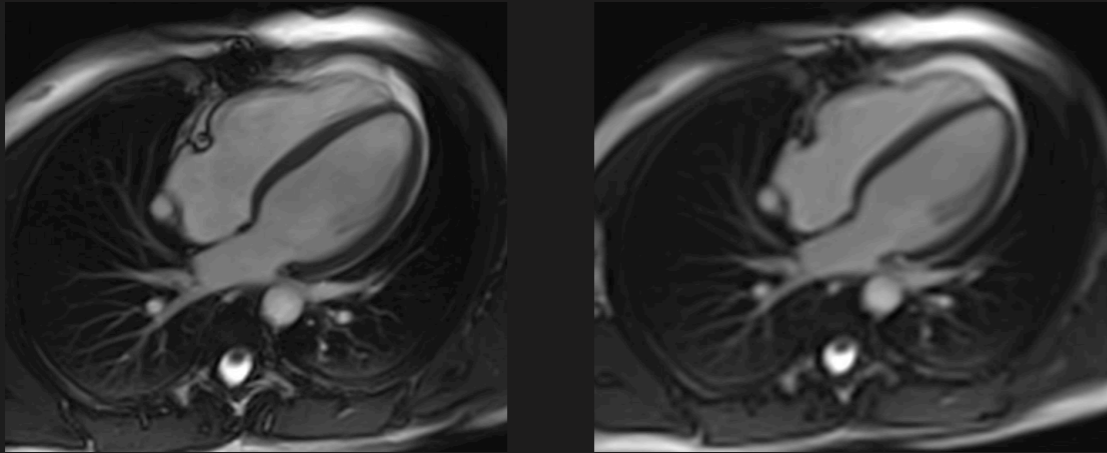


Sharp edges - spatial resolution

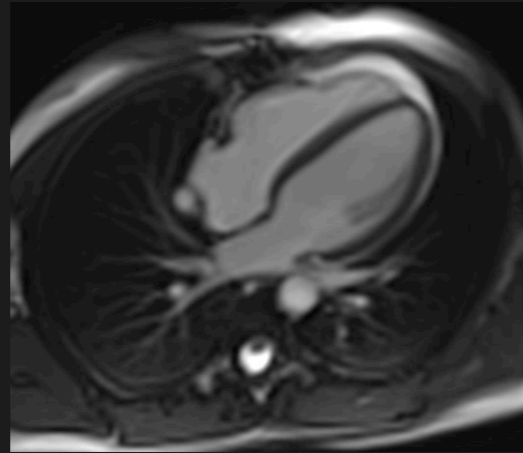
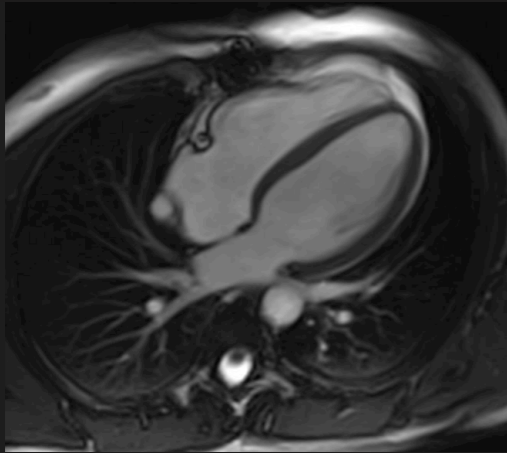


Sharp edges - spatial resolution

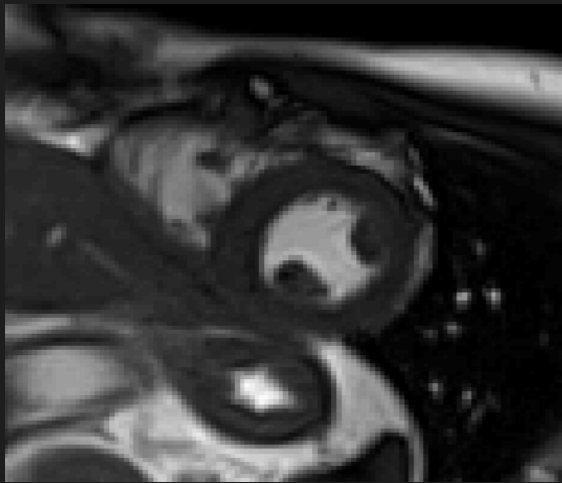


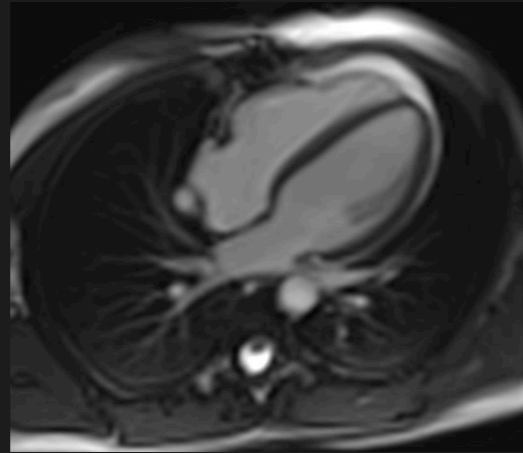
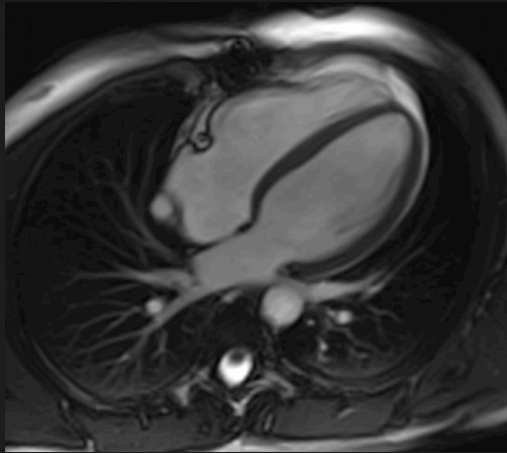


Does it effect volumes

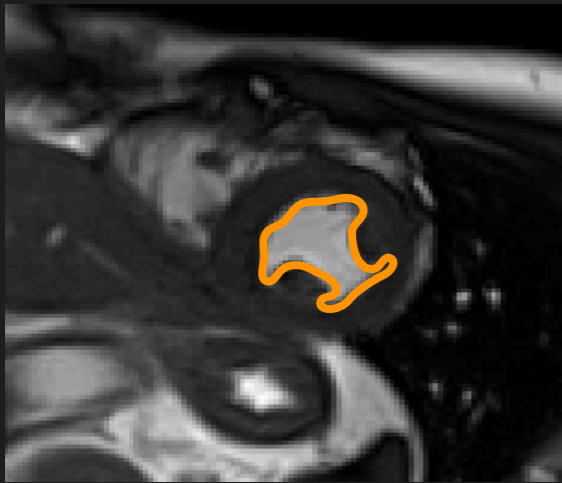


Does it effect volumes

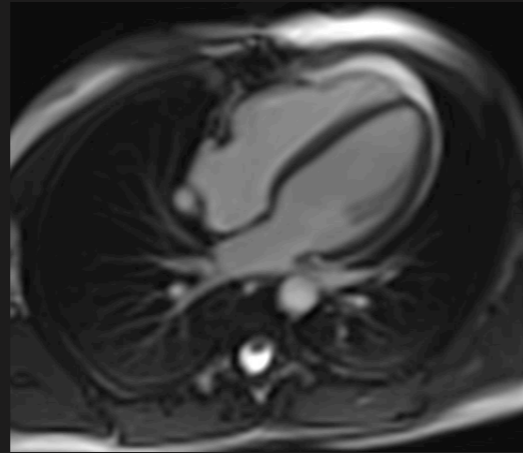
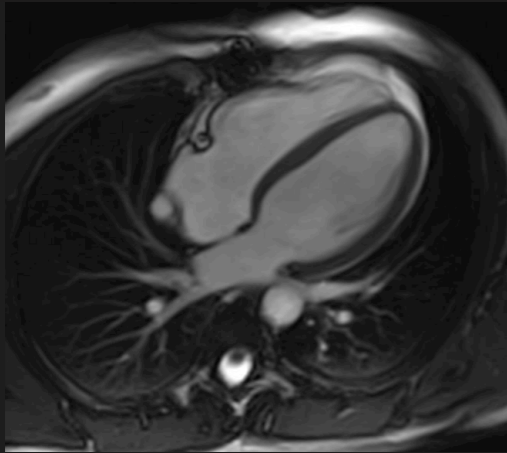




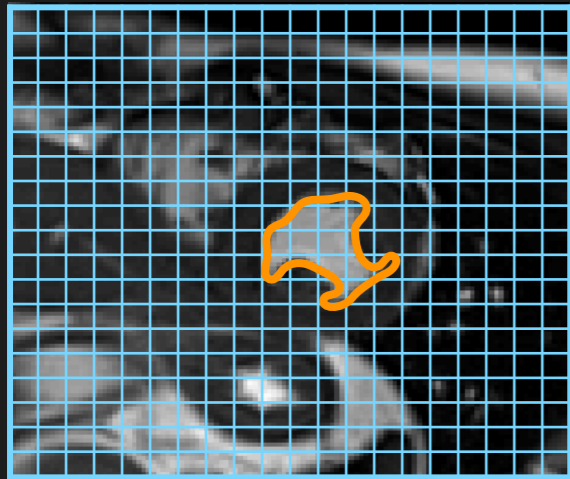
Does it effect volumes



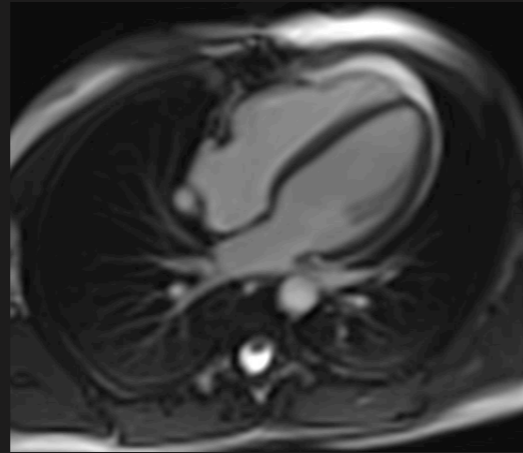
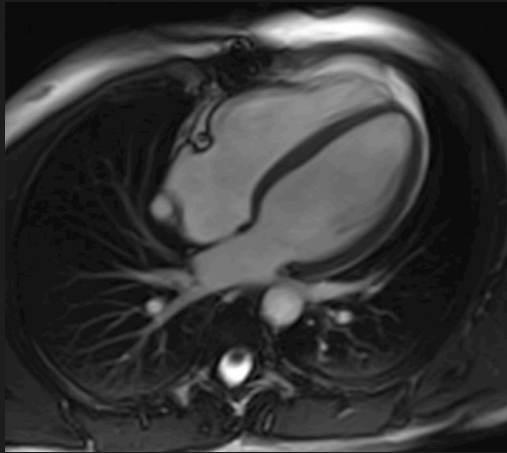
Sharp edges - spatial resolution



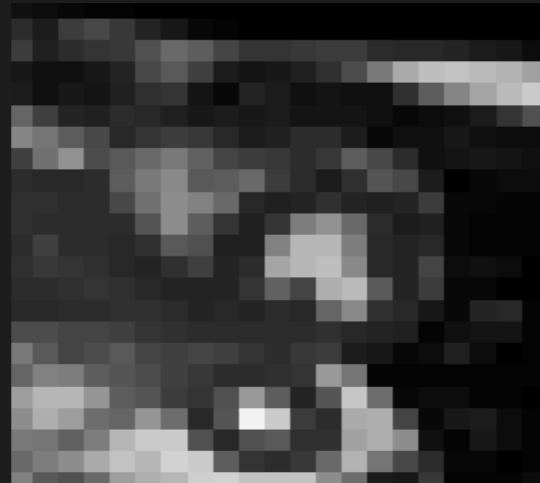
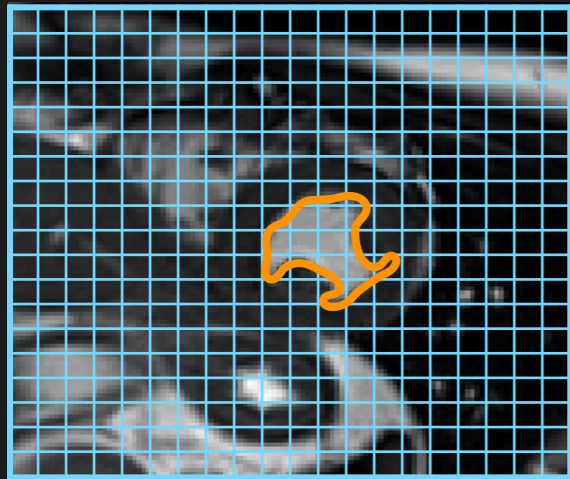
Does it effect volumes

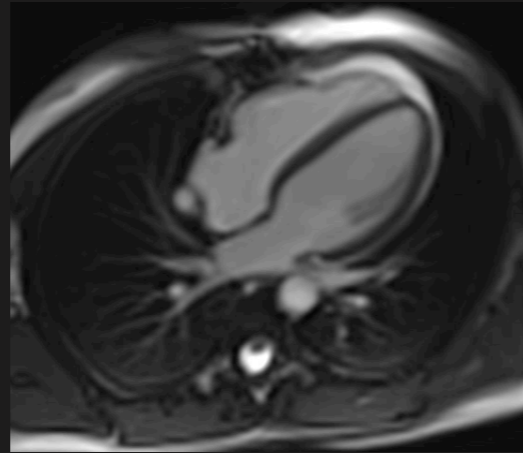
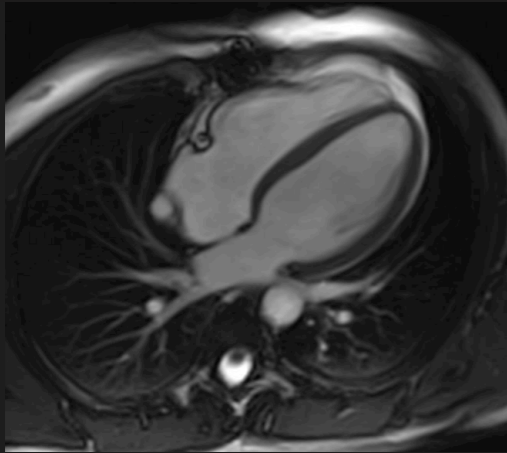


Sharp edges - spatial resolution

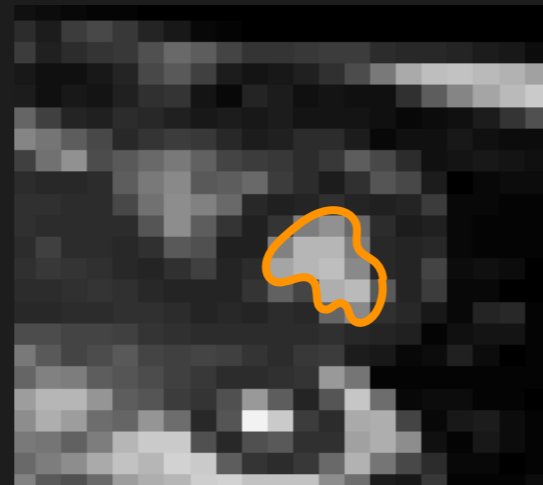
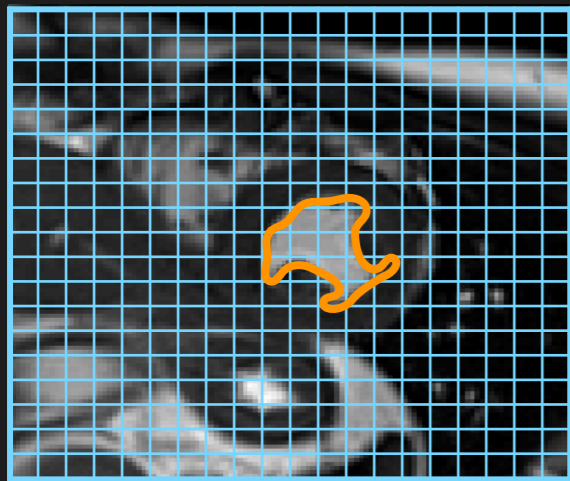


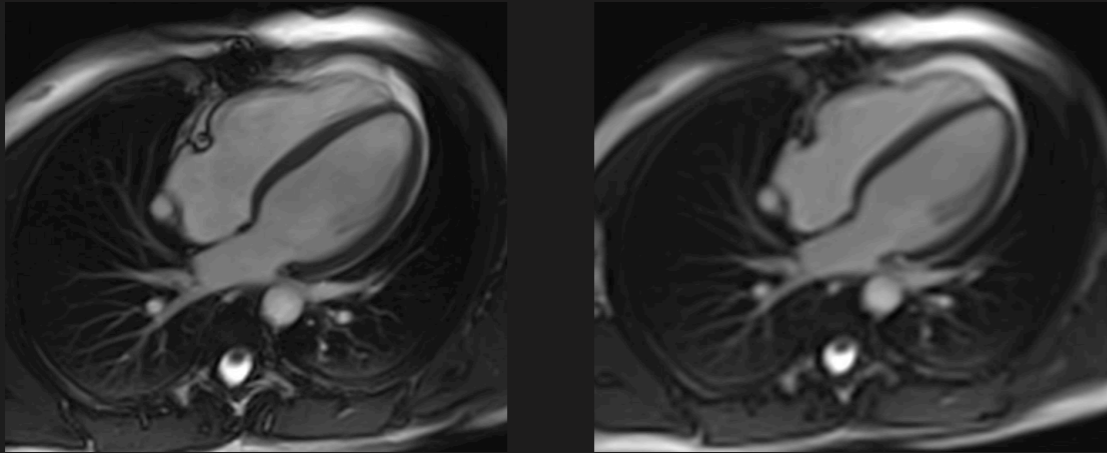
Does it effect volumes



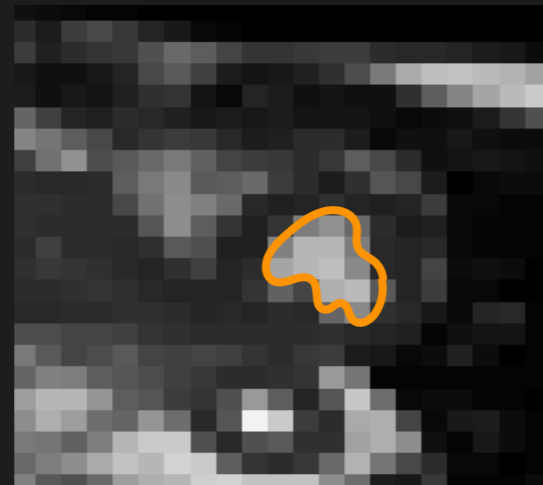
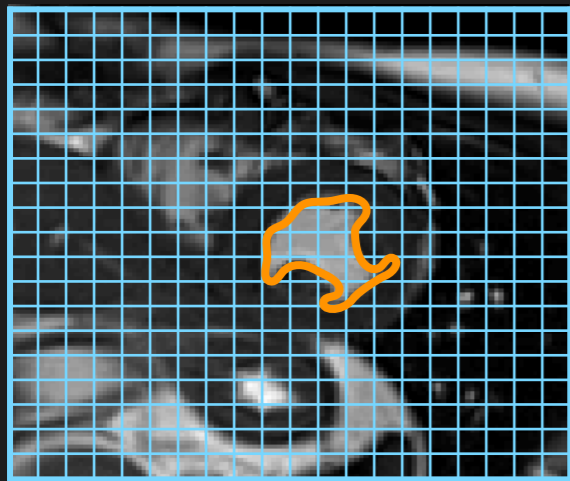


Does it effect volumes

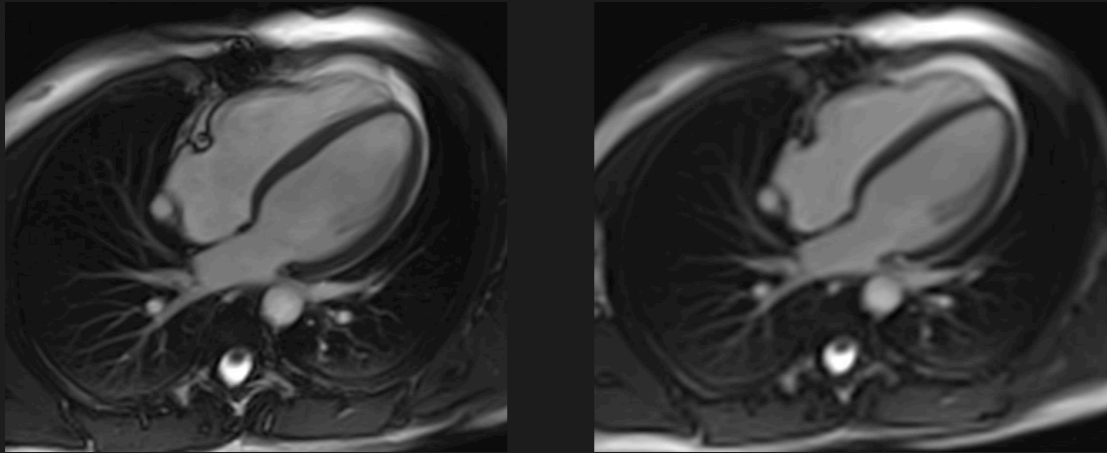




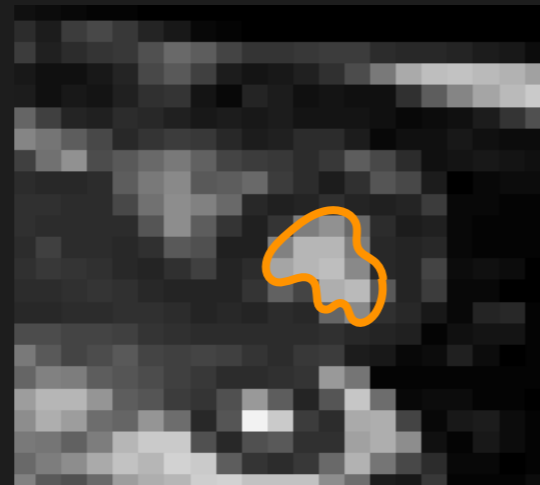
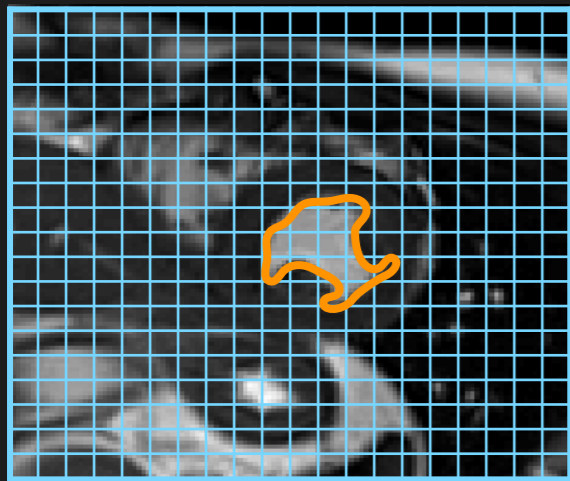
Does it effect volumes



Error - segmentation



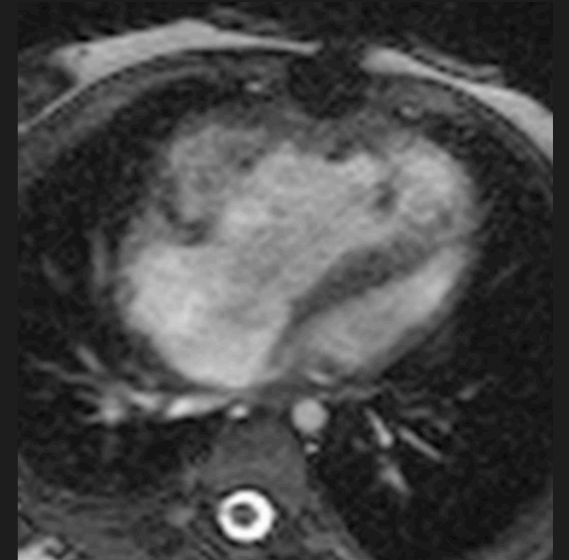
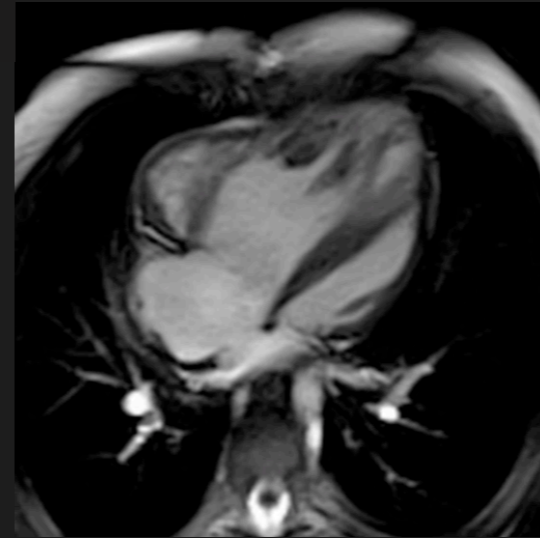
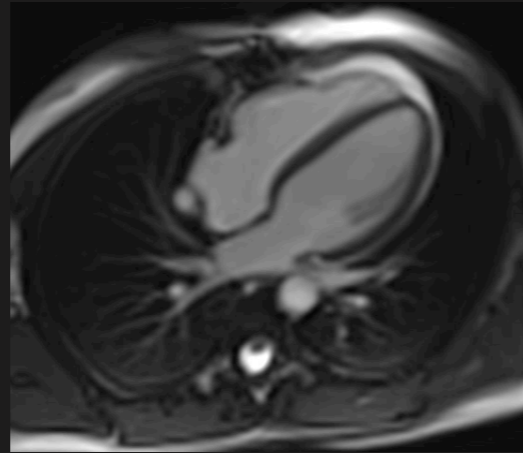
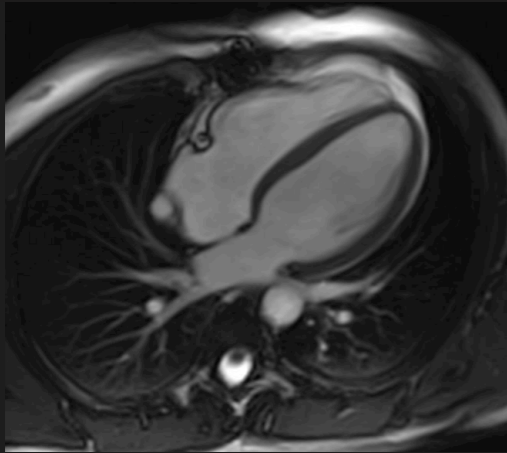
Does it effect volumes



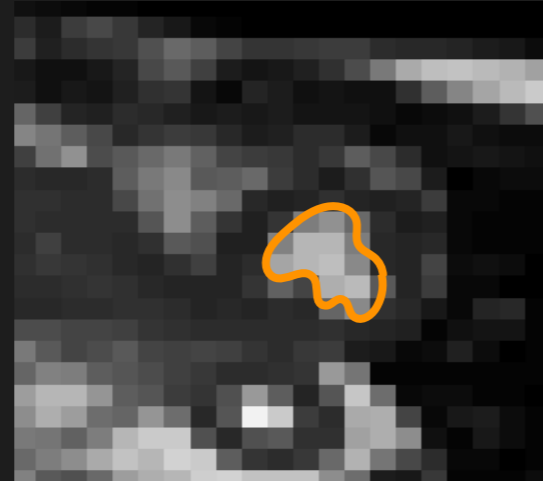
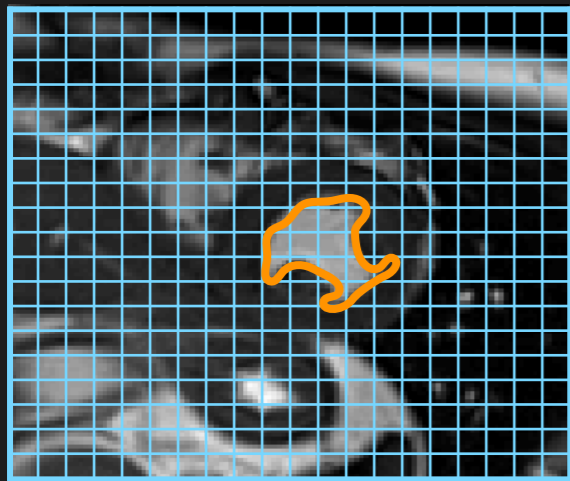
Error - segmentation

Proportional to pixel size

Sharp edges - spatial resolution



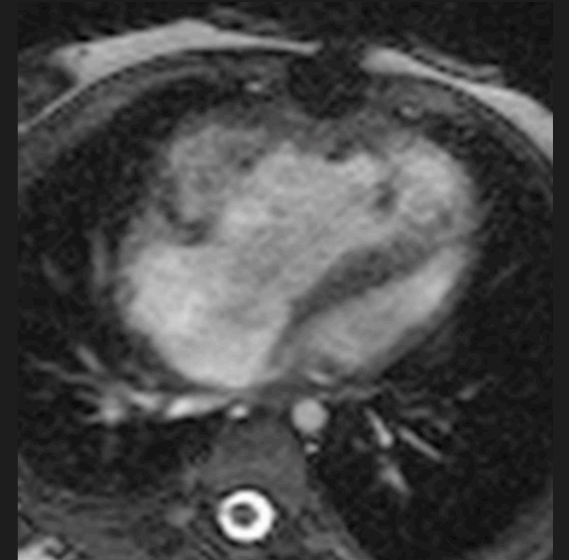
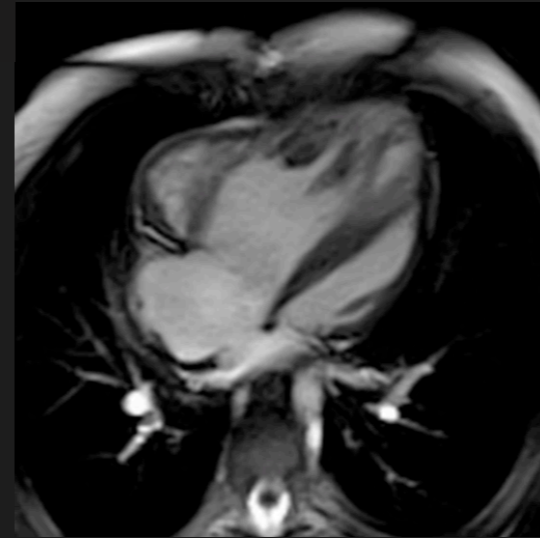
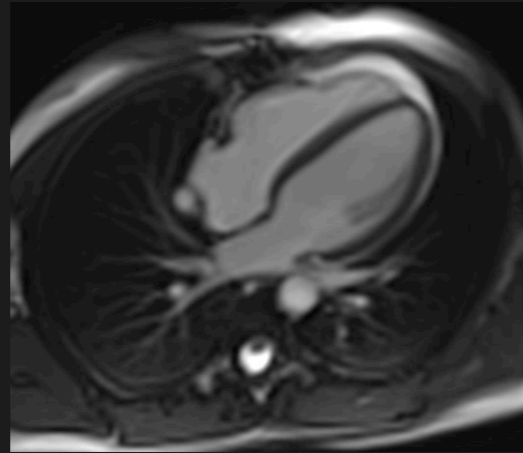
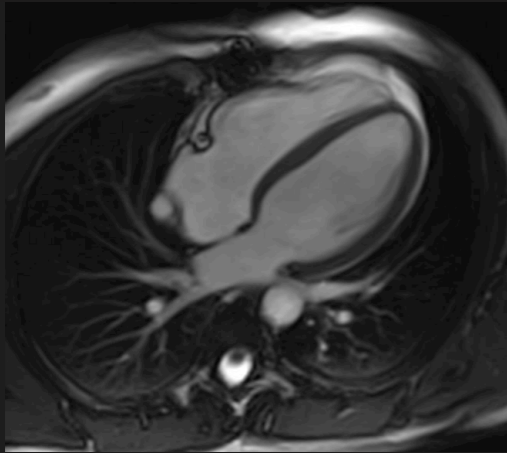
Does it effect volumes



Error - segmentation

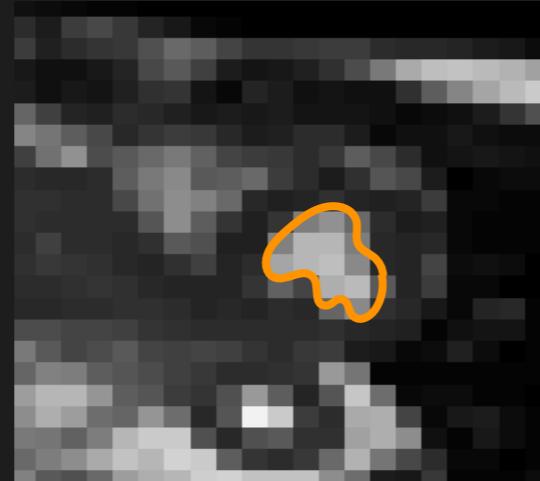
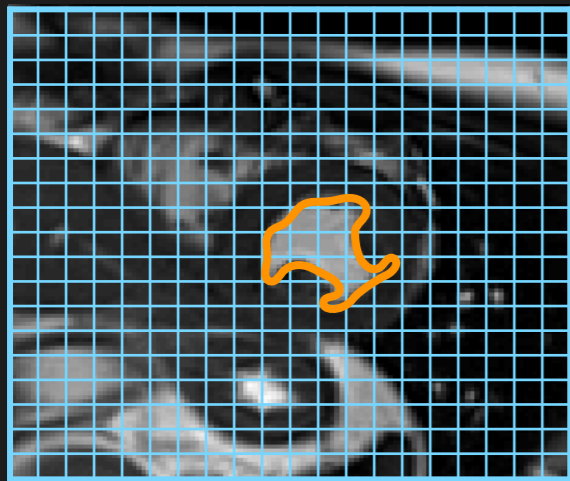
Proportional to pixel size

Sharp edges - spatial resolution



Does it effect volumes

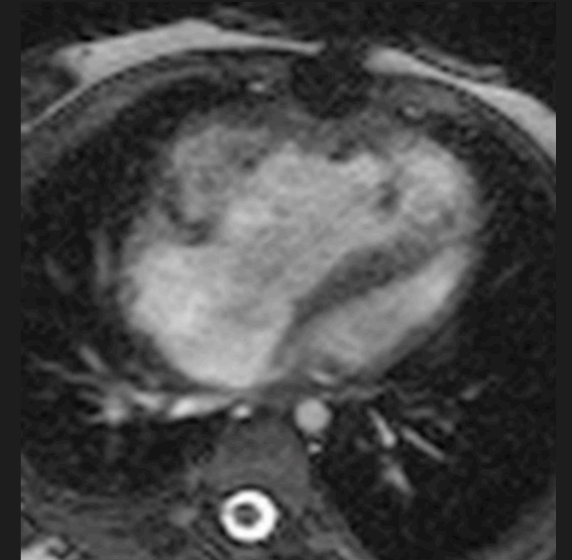
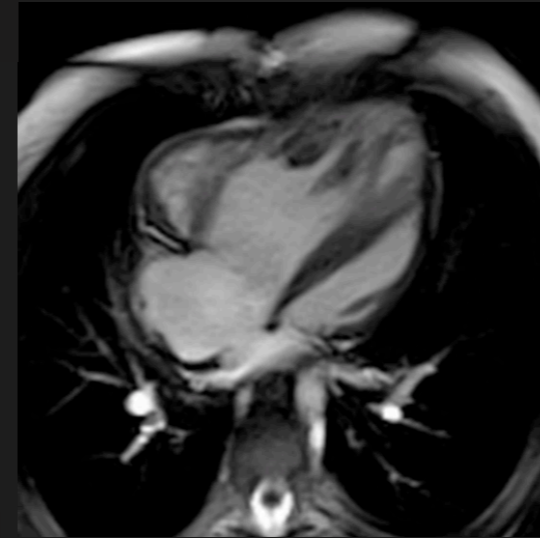
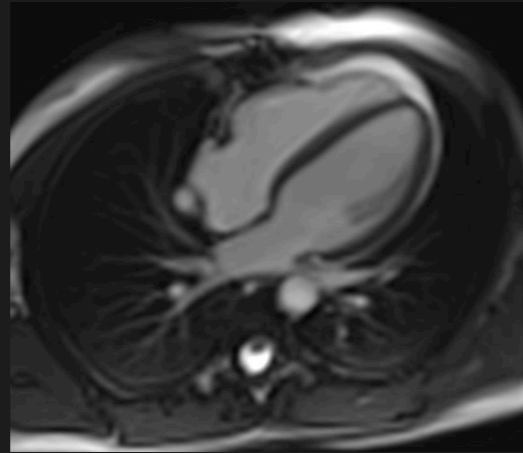
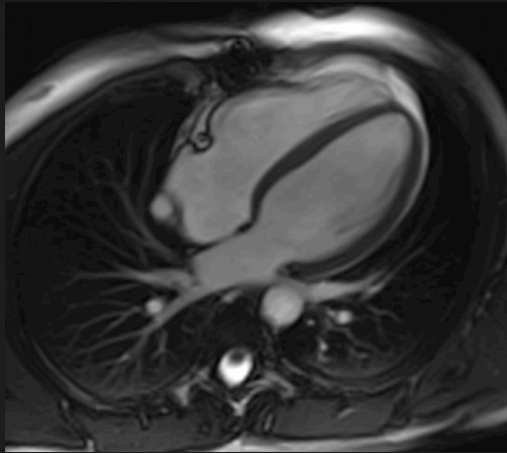
Low Res



Error - segmentation

Proportional to pixel size

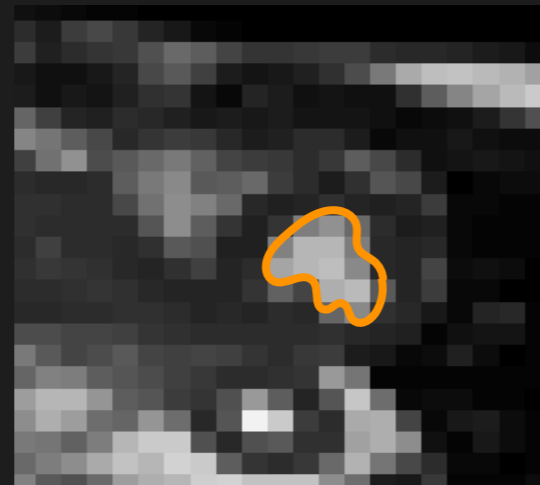
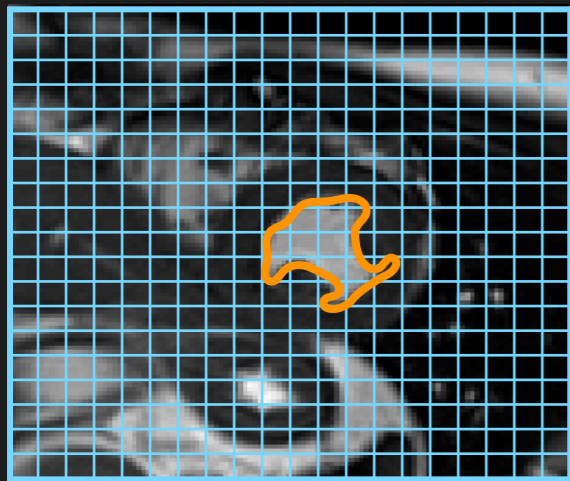
Sharp edges - spatial resolution



Does it effect volumes

Low Res

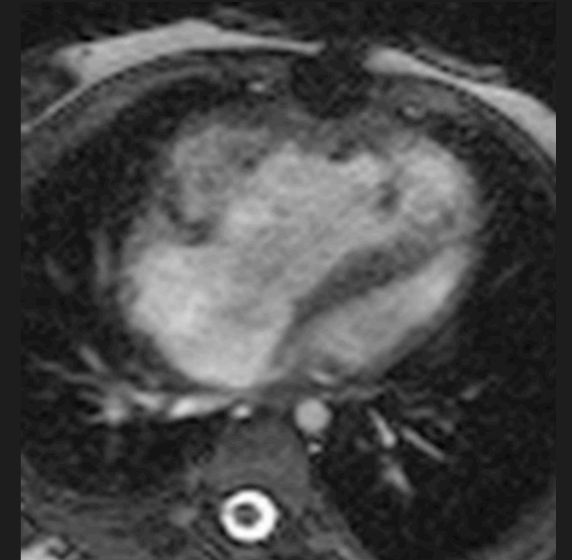
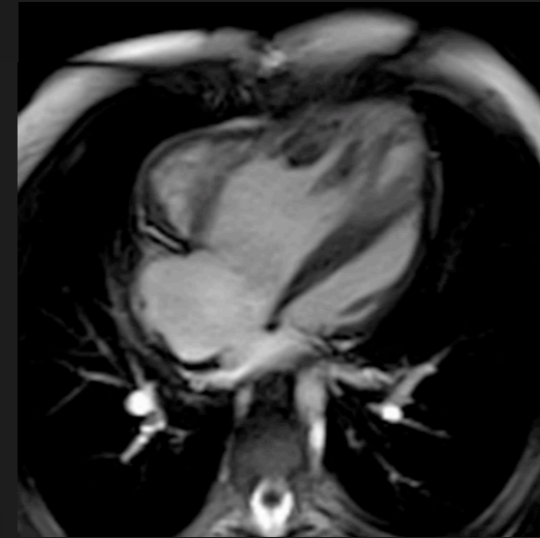
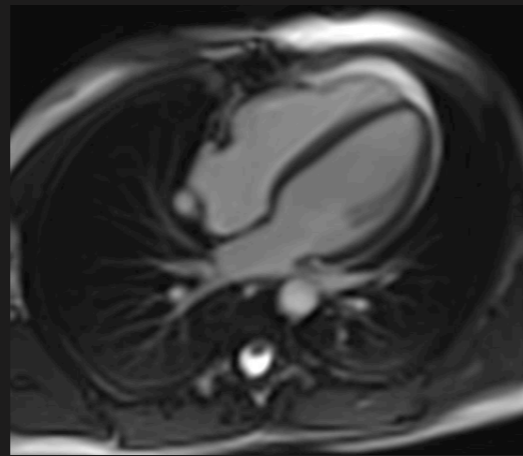
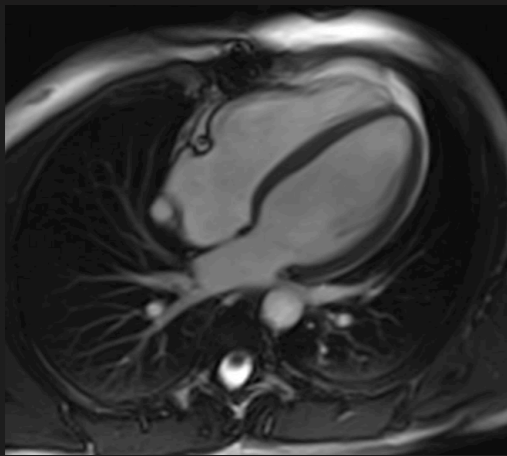
High Res



Error - segmentation

Proportional to pixel size

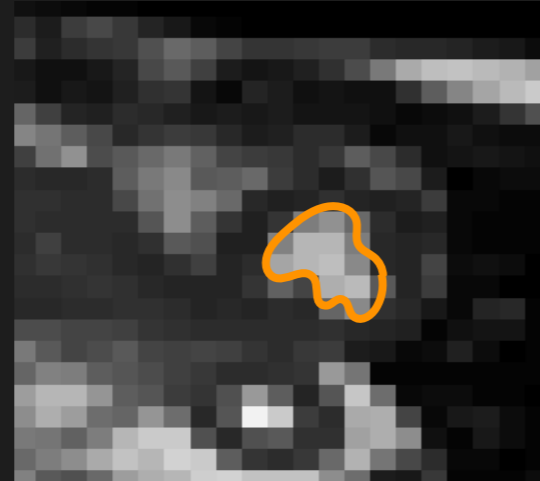
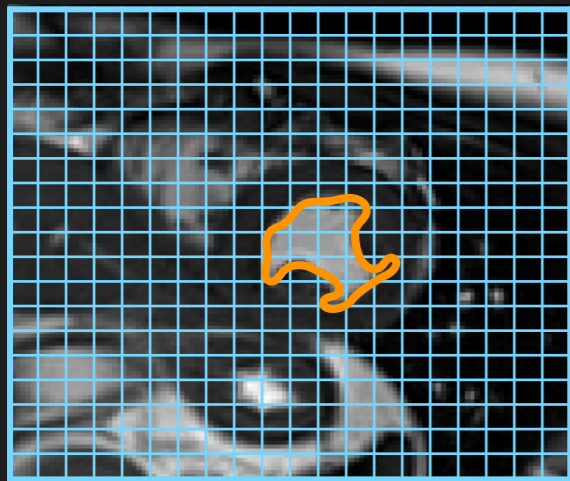
Sharp edges - spatial resolution



Does it effect volumes

Low Res

High Res

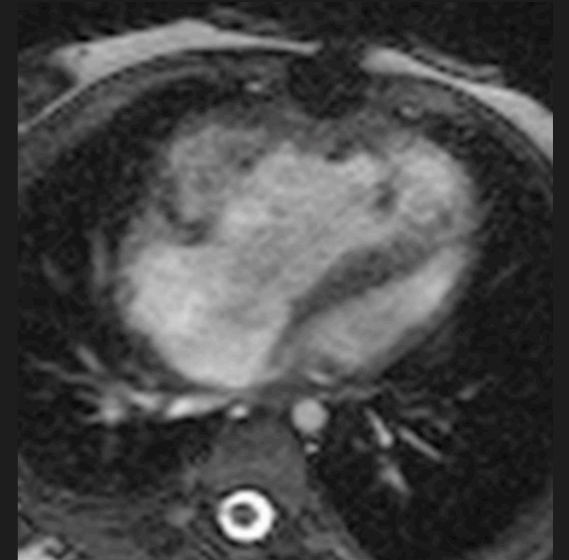
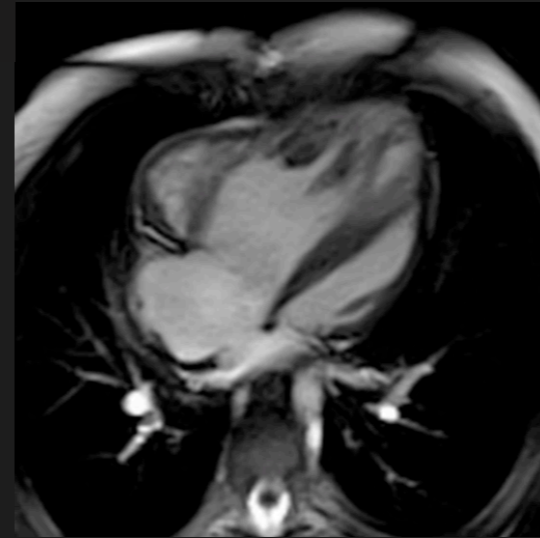
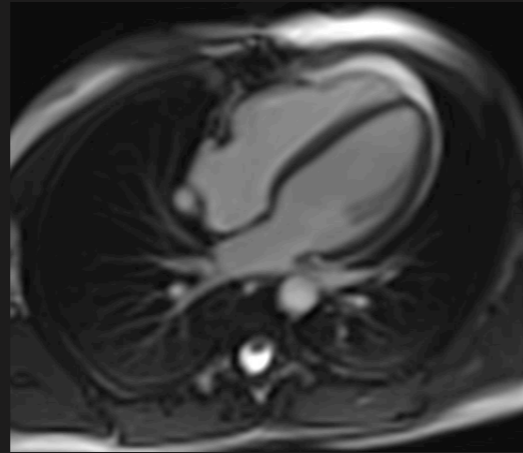
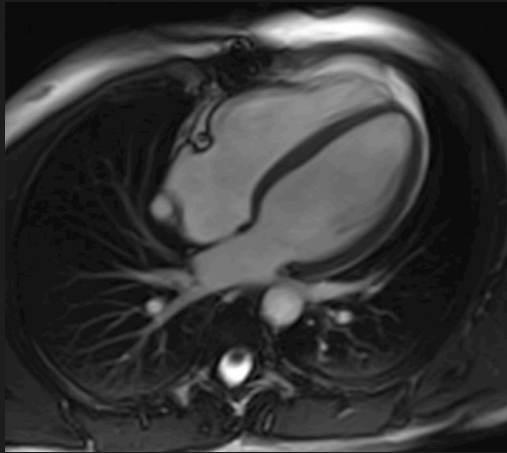


Low SNR

Error - segmentation

Proportional to pixel size

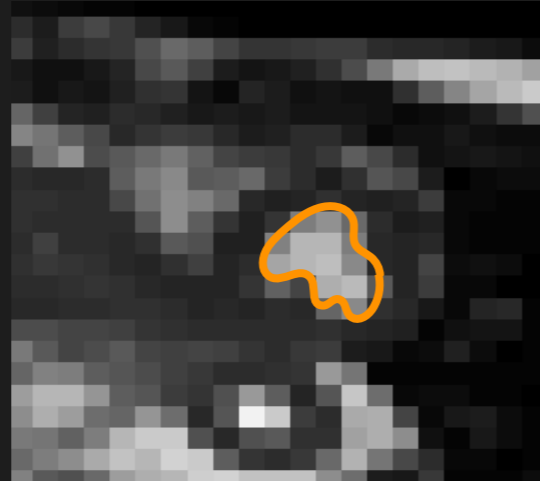
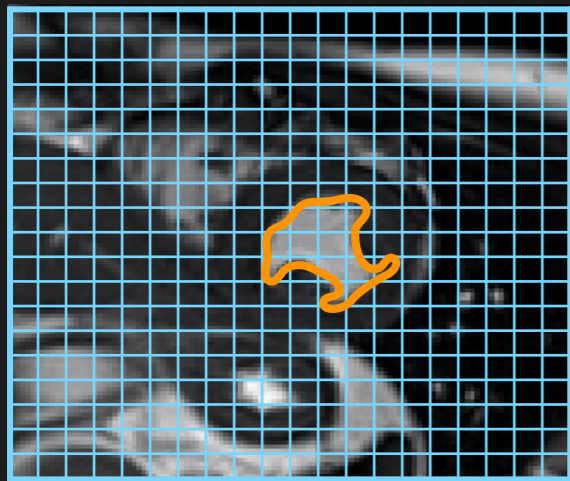
Sharp edges - spatial resolution



Does it effect volumes

Low Res

High Res



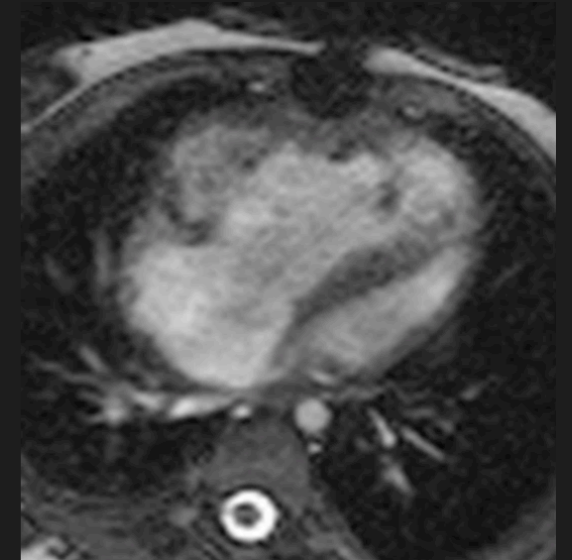
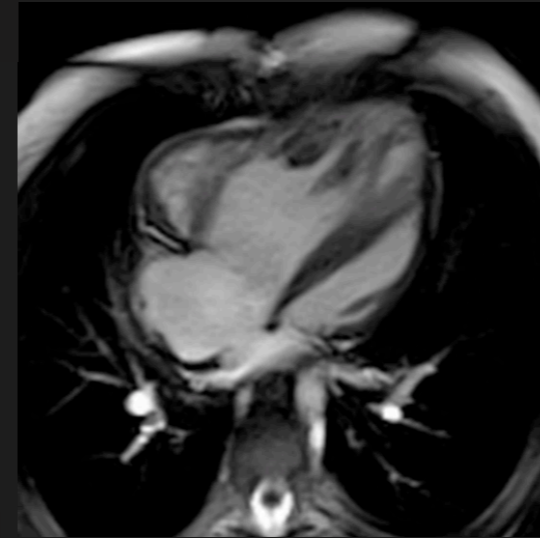
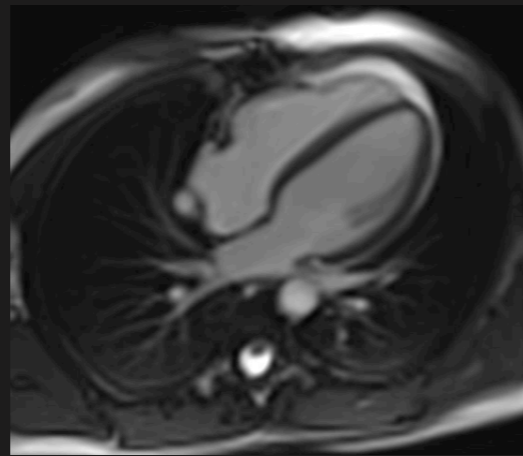
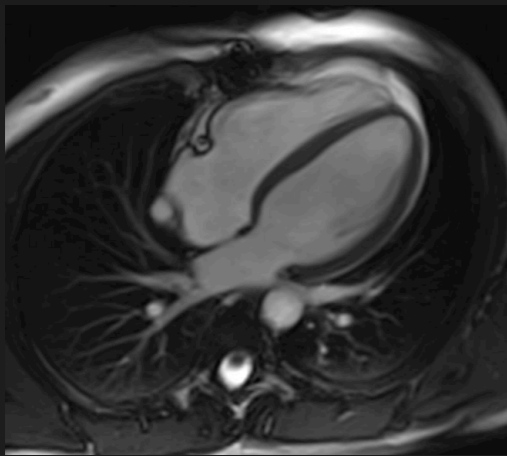
Low SNR

Long TR's - dark band

Error - segmentation

Proportional to pixel size

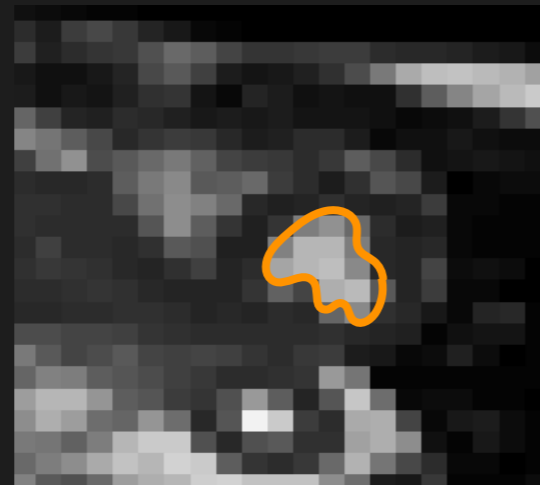
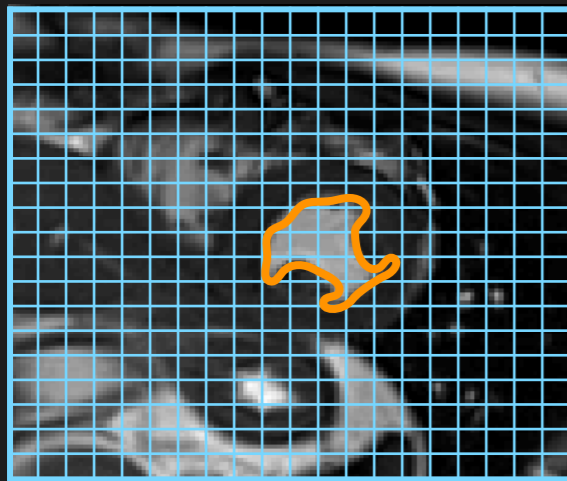
Sharp edges - spatial resolution



Does it effect volumes

Low Res

High Res



Error - segmentation

Proportional to pixel size

Low SNR

Long TR's - dark band

1.2 - 2.0mm

Non Cartesian and parallel imaging



Non Cartesian and parallel imaging



Non Cartesian and parallel imaging



RF + readout time

Non Cartesian and parallel imaging



RF + readout time



Reduced excitations

Non Cartesian and parallel imaging



RF + readout time



Reduced excitations



Efficient readout

Non Cartesian and parallel imaging



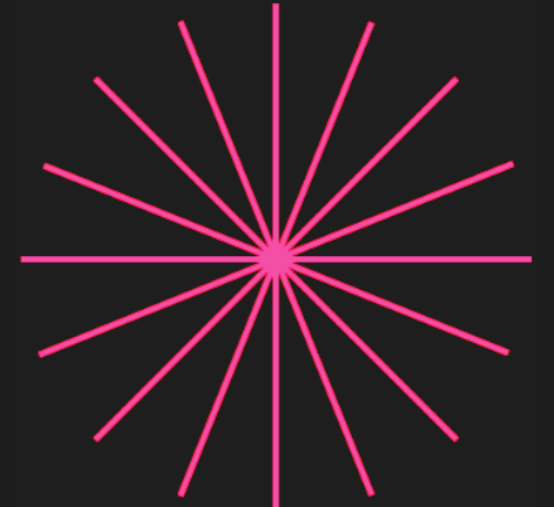
RF + readout time



Reduced excitations



Efficient readout



Less artefact

Non Cartesian and parallel imaging



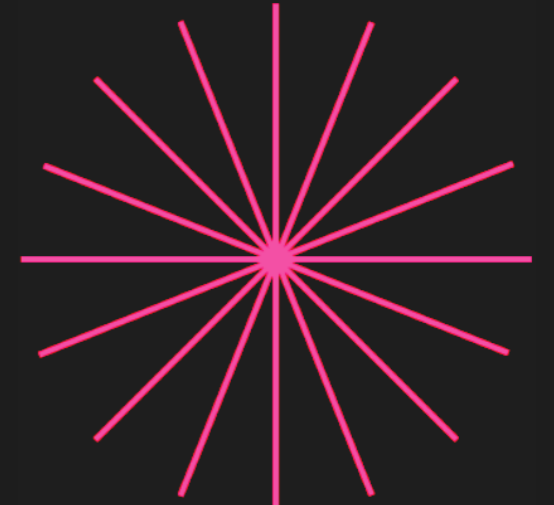
RF + readout time



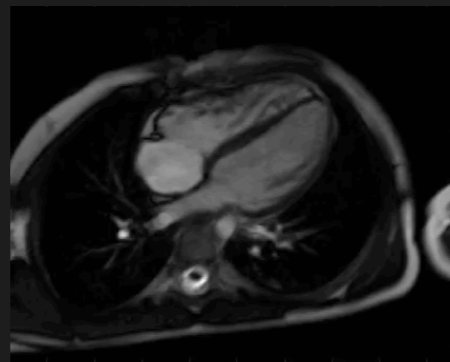
Reduced excitations



Efficient readout



Less artefact



Non Cartesian and parallel imaging



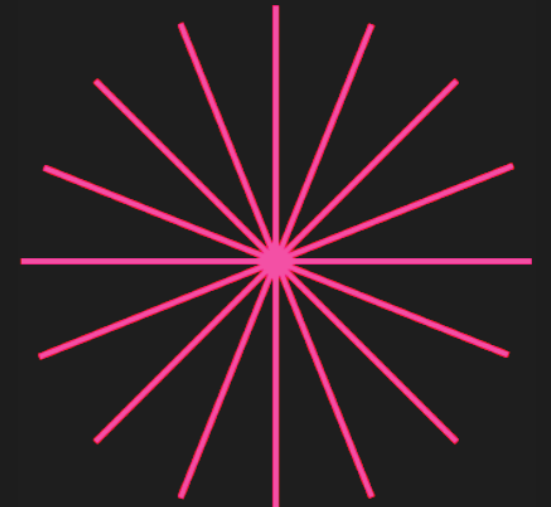
RF + readout time



Reduced excitations



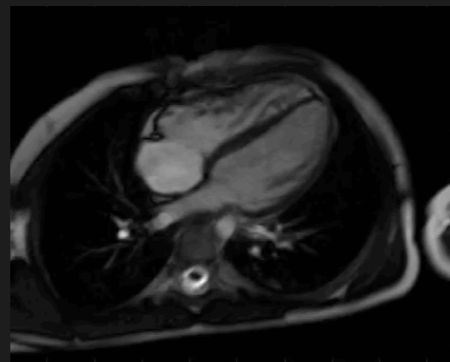
Efficient readout



Less artefact



2x Undersampling



Non Cartesian and parallel imaging



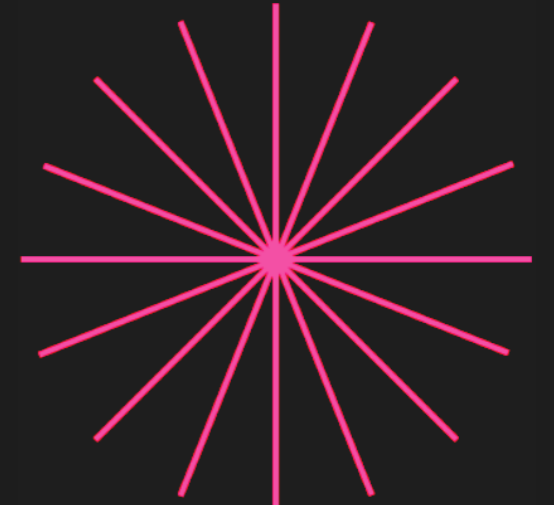
RF + readout time



Reduced excitations



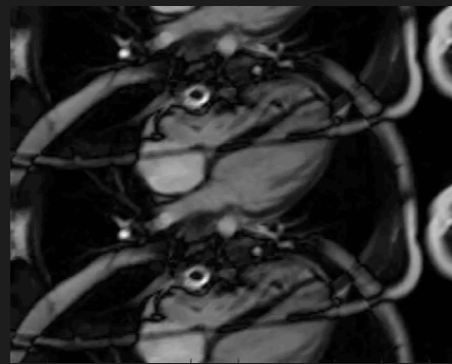
Efficient readout



Less artefact



2x Undersampling



Non Cartesian and parallel imaging



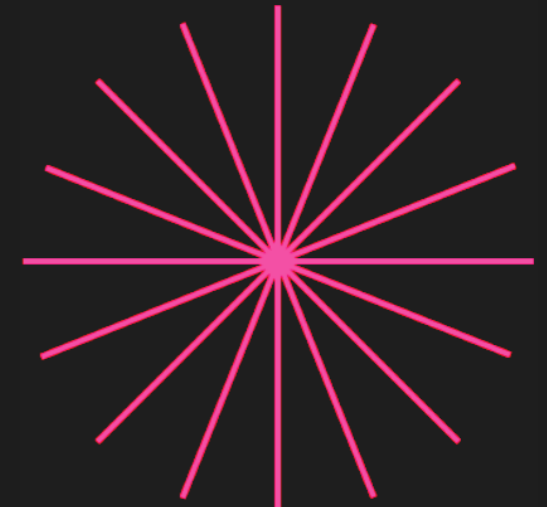
RF + readout time



Reduced excitations



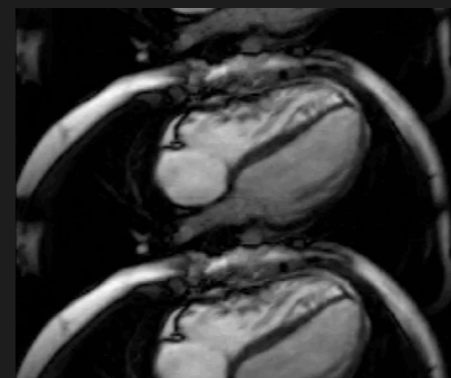
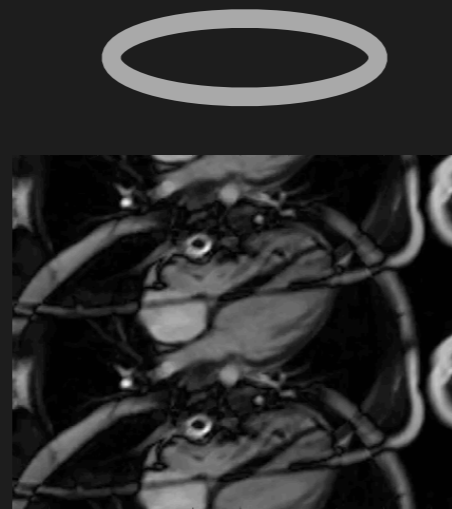
Efficient readout



Less artefact



2x Undersampling



Non Cartesian and parallel imaging



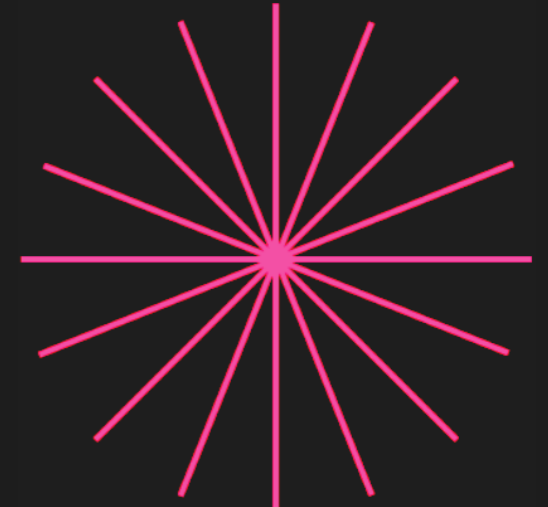
RF + readout time



Reduced excitations



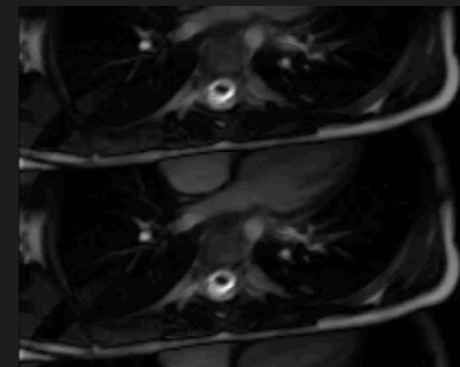
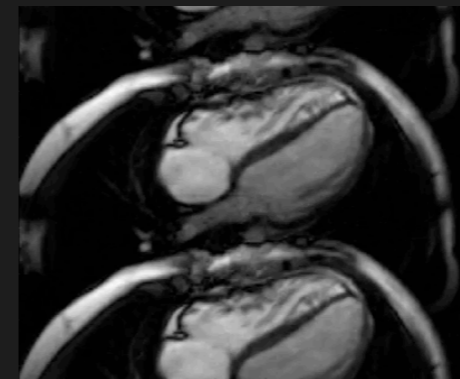
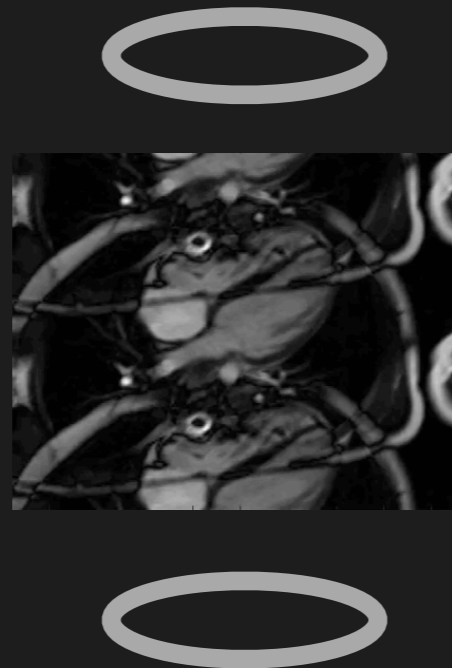
Efficient readout



Less artefact



2x Undersampling



Non Cartesian and parallel imaging



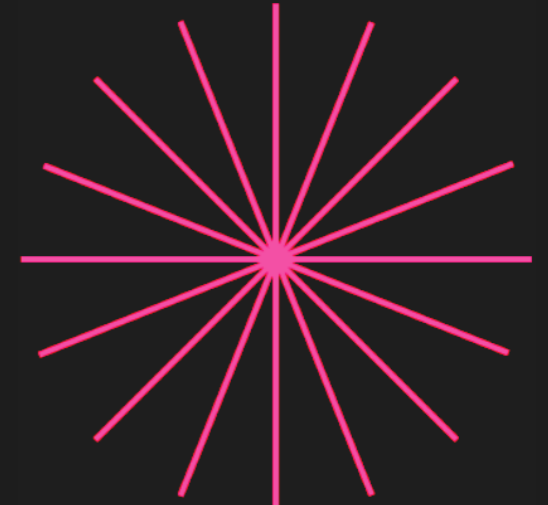
RF + readout time



Reduced excitations



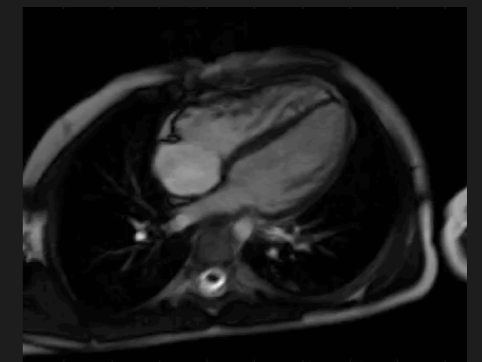
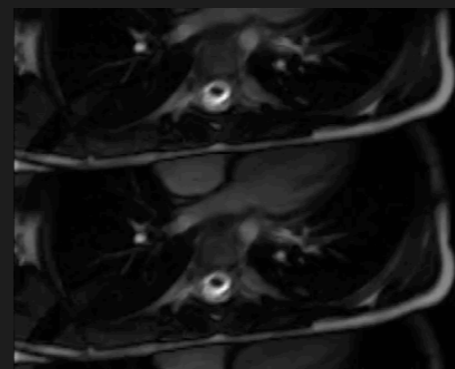
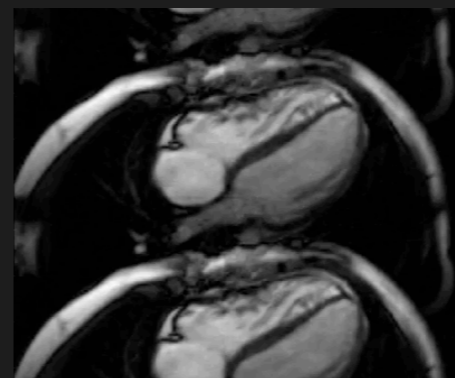
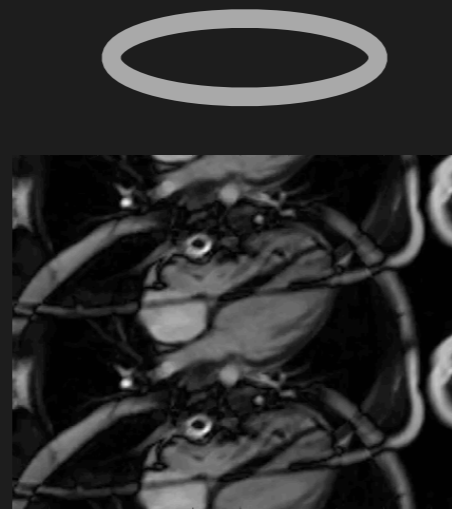
Efficient readout



Less artefact



2x Undersampling



SENSE/GRAPPA

MRI physics

Takes time

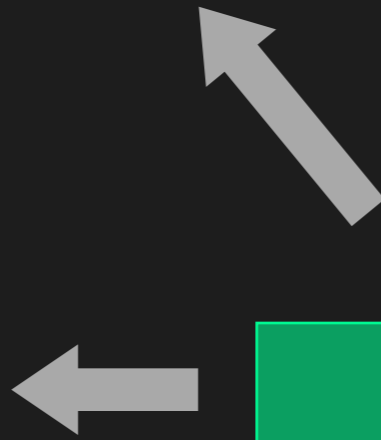


MRI physics

Ask someone

Takes time

MRI physics



Ask someone

Create a model

Takes time

MRI physics



