MRI Applications in Spine

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Who is this for?

I assume that you know the basics of MRI physics,
but do not know much about MRI clinical applications.

Caveat:
This is mostly generic advice.
Consult vendor Apps for vendor-specific options.

Learning Objectives

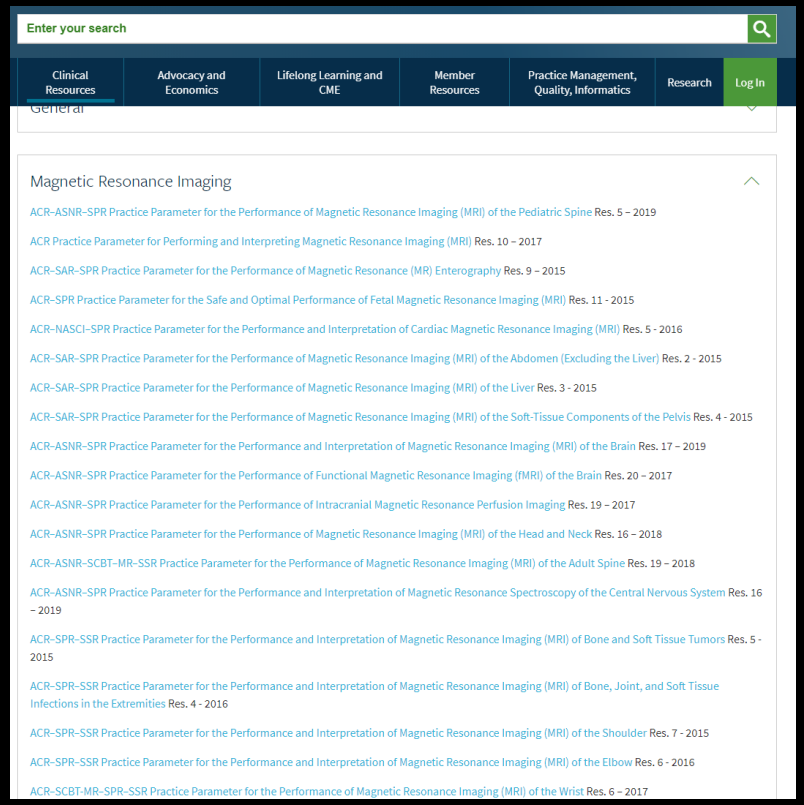
1. To be able to list and discuss basic features of several common indications for spine MRI;

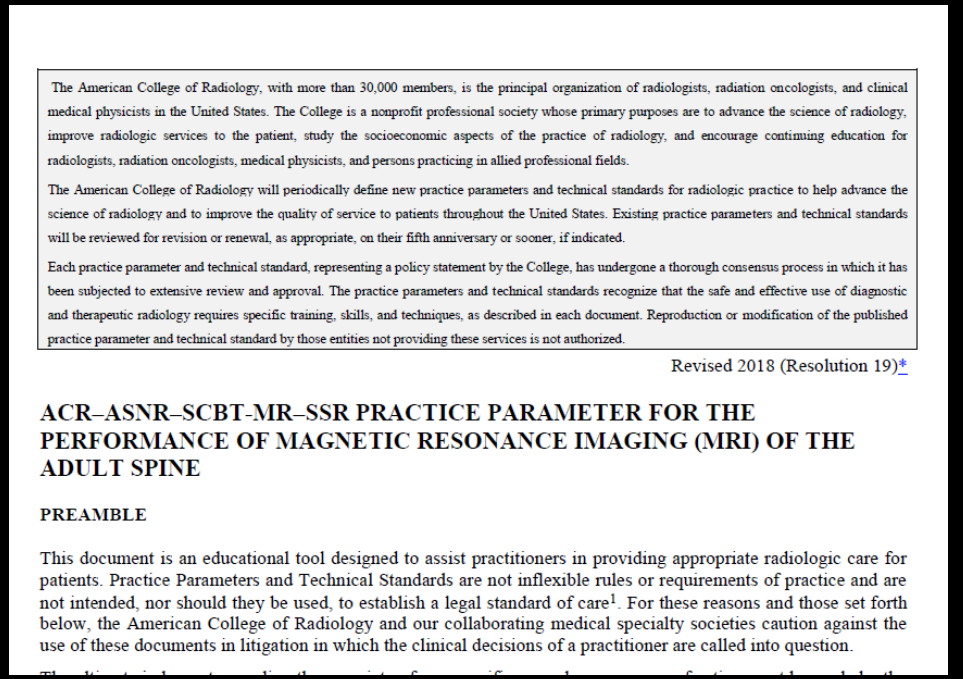
2. To be able to list and discuss the most common clinical MRI techniques used for the spine;

3. To be able to list and discuss the key image quality and MR safety issues for MRI of the spine

References

- Good place to get started with MRI clinical applications basics: https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards/Practice-Parameters-by-Modality





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Revised 2018 (Resolution 19)*

ACR–ASNR–SCBT-MR–SSR PRACTICE PARAMETER FOR THE PERFORMANCE OF MAGNETIC RESONANCE IMAGING (MRI) OF THE ADULT SPINE

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

Spine Anatomy

Typical # of vertebrae

- Cervical (C-spine): 7
- Thoracic (T-spine): 12
- Lumbar (L-spine): 5

- Spinal cord at C-spine & T-spine
- Below the conus are nerve roots, the Cauda Equina (*latin for "horse's tail"*)

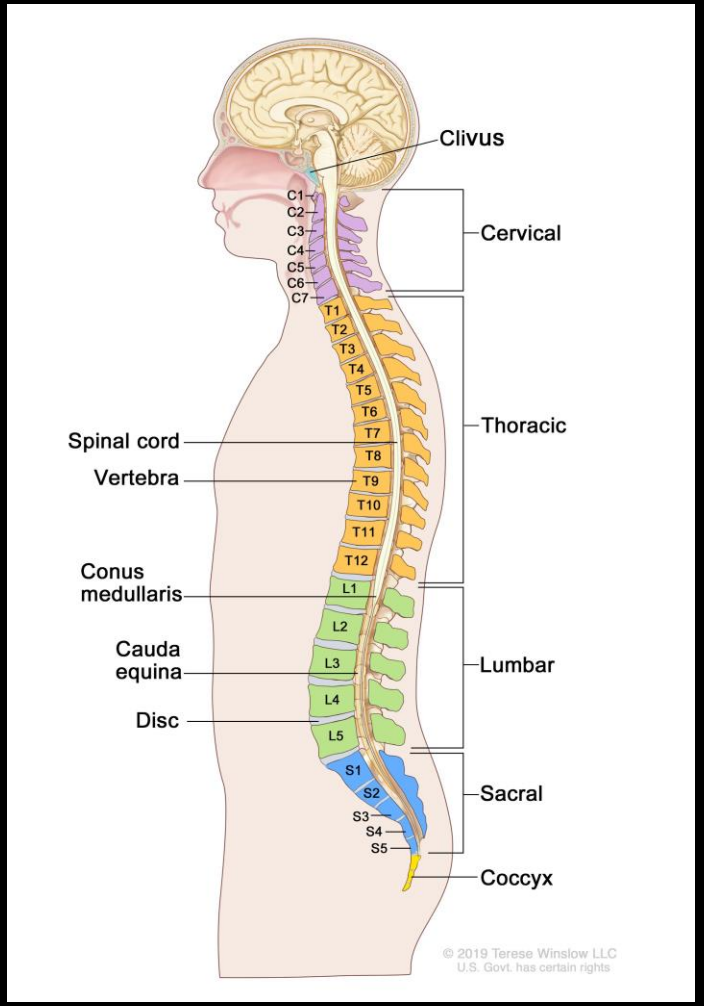


Figure courtesy cancer.gov.

Indications for Spine MRI

MRI is the only modality for evaluation of internal structure of the cord*

- Congenital spine and spinal cord malformations
- Inflammatory/autoimmune disorders (e.g. MS, lupus, muscular dystrophies)
- Infectious conditions
- Vascular disorders (vascular malformations, cord infarctions)
- Degenerative conditions (disc degeneration, disc herniation, spinal stenosis)
- Trauma
- Neoplastic abnormalities
- Miscellaneous (CSF leak, amyloid deposition)

*From ACR-ASNR-SCBT-MR-SSR Practice Parameter for the Performance of Magnetic Resonance Imaging (MRI) of the Adult Spine

Spine Coils

- CTL (older)

- Cervical

- Thoracic and Lumbar

Spine Coils Within the Bed

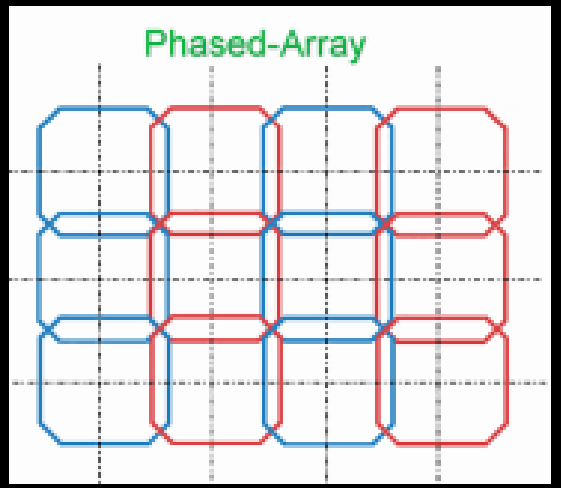
Newer spine coils for thoracic and lumbar, are embedded within the bed:

This removes need for swapping coils but may increase distance to patient (thus decreasing SNR).

Spine Coil Elements and Parallel Imaging

Note: # of coil elements in R/L and F/H direction:

- Establishes limits on parallel imaging acceleration factors (i.e. SENSE/iPAT)
- No SENSE/iPAT acceleration in A/P direction



Other Acceleration Methods

Other caveats:

- Simultaneous Multi-Slice (SMS)
  - Best used for axial stacks with a lot of slices
- Compressed Sensing
  - Vendor may have pulse sequence limitation (e.g. only 3D TSE)

Pulse Sequences for MRI

- Mainly turbo spin echo (TSE) scans
  - AKA fast spin echo
  - Relatively fast and resistant to susceptibility artifacts, BUT
  - Higher SAR (and patient heating, esp. for T1W)

MRI Sequences (at WashU)

PRE

POST

CERVICAL SPINE

- Scout (TSE)
- Sag T1 TSE
- Sag T2 TSE
- Sag T2 TSE FS – (possibly STIR)
  - for marrow replacement processes (mets), facet inflammation, cord signal abnormalities
- Ax T2 MEDIC (near metal: TSE)

CONTRAST injection - for myelopathic symtoms or Hx of malignancy

- SAG T1 TSE DIXON
- AX T1 VIBE FS

MRI Sequences (at WashU)

THORACIC and LUMBAR SPINE

PRE
- Scout (TSE)
- Sag T1 TSE
- Sag T2 TSE
- Sag T2 TSE FS – (possibly STIR)
  - for marrow replacement processes (mets), facet inflammation, cord signal abnormalities
- Ax T2 TSE

CONTRAST injection - for myelopathic symtoms or Hx of malignancy

POST
- SAG T1 TSE DIXON
- AX T1 VIBE FS

Scan Planning for Spine MRI

- Sagittal Coverage
  - Scoliosis may require more slices and increased scan duration

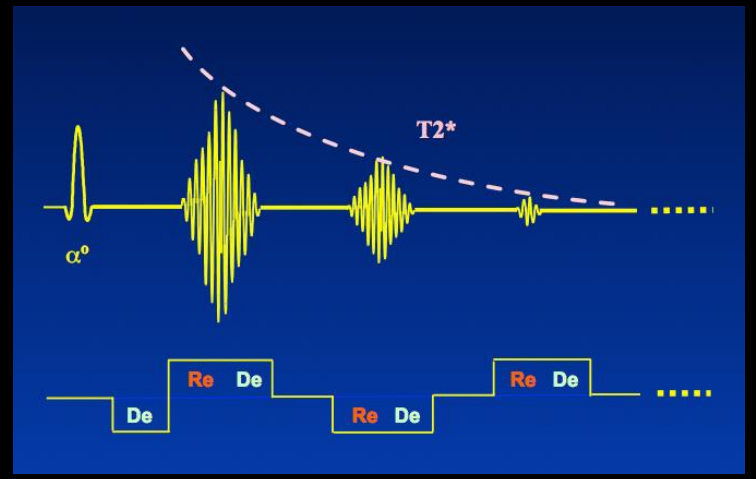
- Axial Orientation
  - Cord pathology: axials perpendicular to cord
  - Disc pathology: axials parallel to each disc

  So, multiple stacks may be needed.

- Single-Stack (e.g. tumor) vs. Multi-Stack (e.g. disc disease, curved spine)

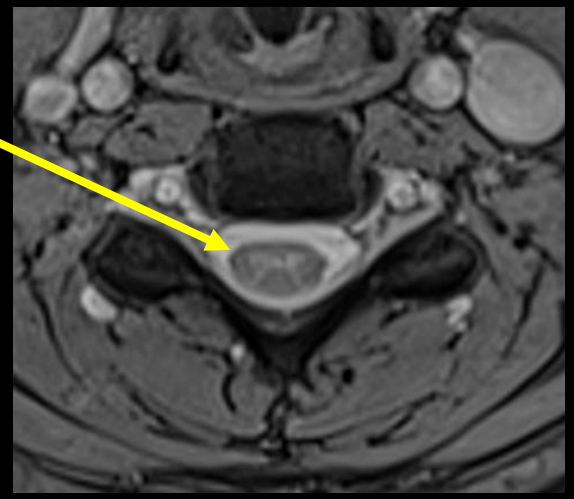
- Selective axials to save time

MERGE / MEDIC / mFFE



- Axial 2D multi-echo gradient echo
- Used for cord pathology in C-spine
- Healthy cord has “butterfly” appearance; great contrast
- Later echoes may be degraded by motion, susceptibility, or low SNR
  - Consider dropping them from the echo averaging

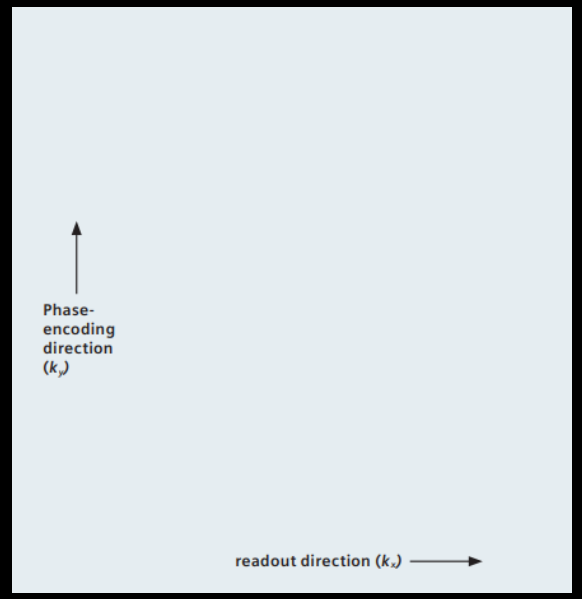
3-5 echoes are used
We use 3 at WashU.



Courtesy of Allen D. Elster, MRIquestions.com

Spine Diffusion

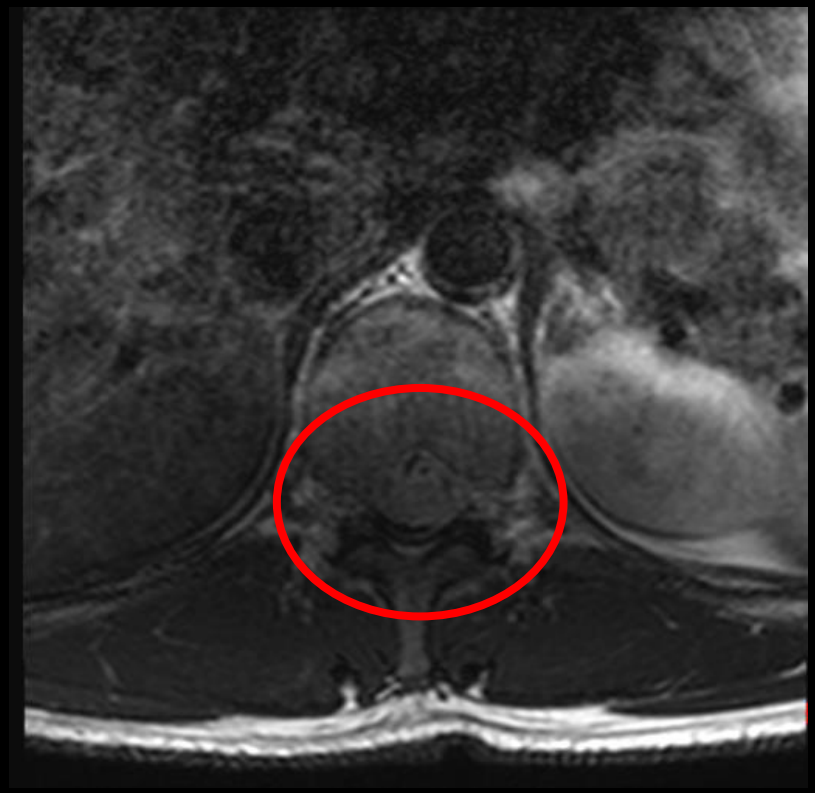
- Traditional DW-EPI will produce “sawtooth” geometric distortion
- Read-out segmented EPI (RESOLVE) can reduce this:



- For spine DTI:
  - Noguerol, et al. “Optimizing DTI Acquisition for Spinal Cord Assessment”, Radiographics 2020.

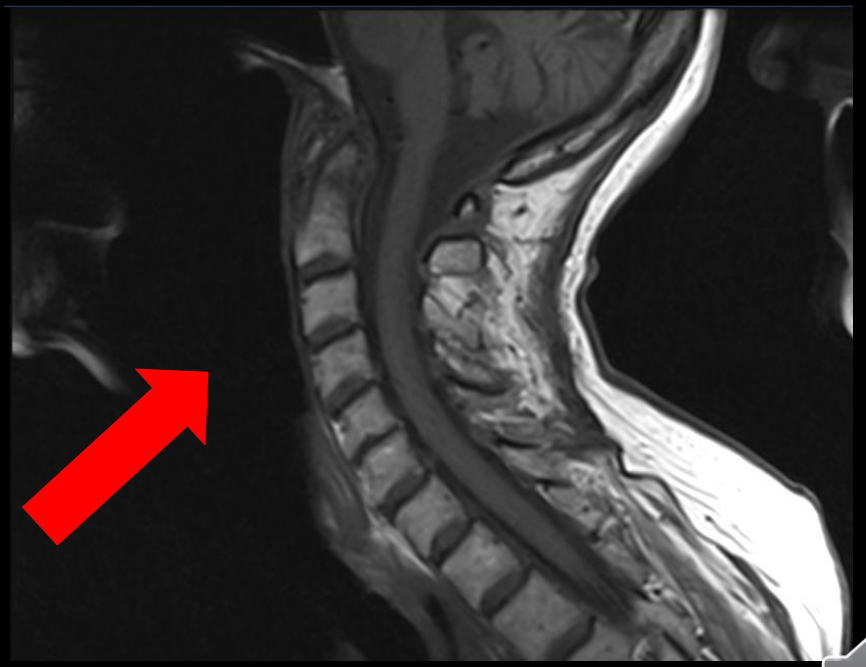
RF Shading Artifacts

- Common in torso/abdomen at 3T
- RF wavelength ~1/10 that in air
- Standing waves cause shading
- In spine: worst near T/L Junction
- Mitigation:
  - Avoid 3T
  - Use “multi-transmit RF shimming”



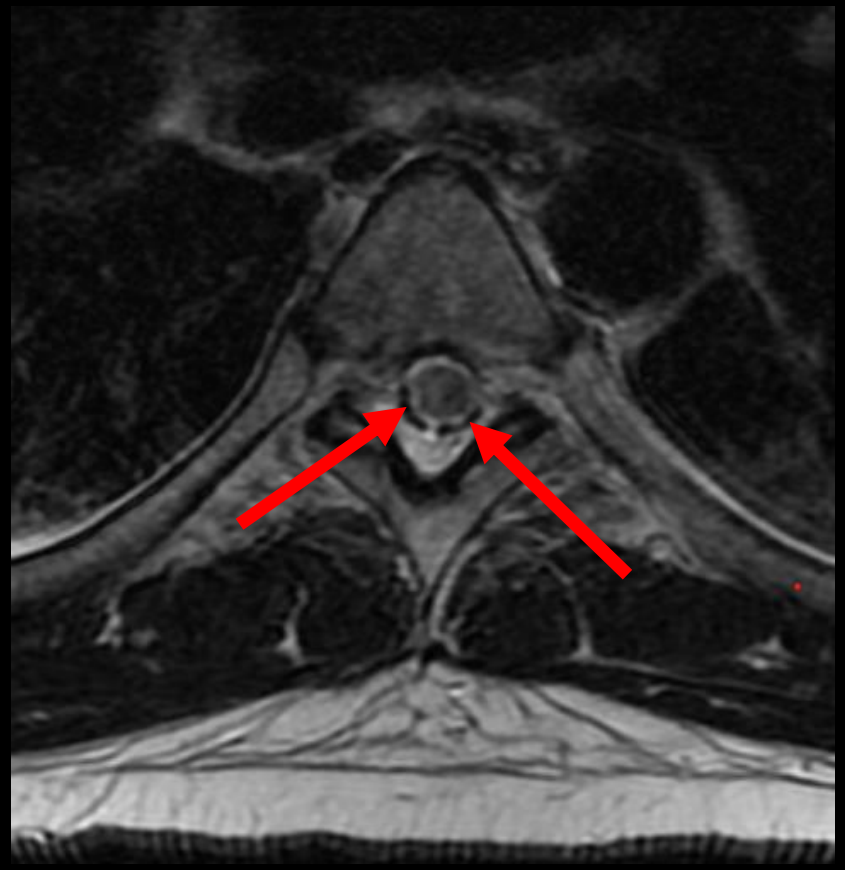
Motion Artifacts

- Motion artifacts due to cardiac motion, swallowing, respiration
- “Sat Bands”
  - Suppresses tissue signal anterior to vertebrae, BUT
  - Often not needed and adds significantly to SAR
- Consider other options
  - Motion resistant scans (e.g. Propeller)
  - Reduced echo spacing



Flow Artifacts

- CSF flow along spine
  - Younger patients have faster flow
  - T2W: flow voids
  - Use flow compensation
    - May need to specify direction (slice or readout)
  - Vendor-specific approaches
    - PSS (Pseudo-Steady State) scans reduce this
- Post-Gad
  - Consider 3D T1W (e.g. VIBE)



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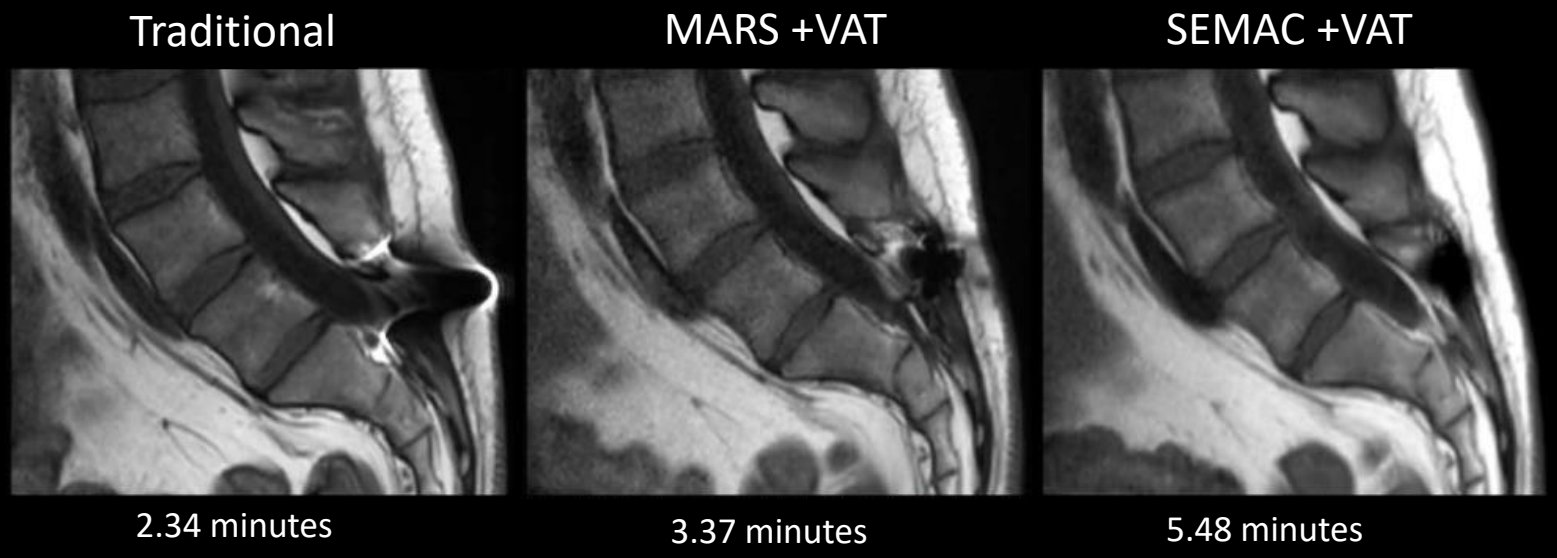
Metal Artifacts



Courtesy: Hennepin County Medical Center

Reduce metal artifacts by:

- <u>Use large bandwidth</u>
  - commonly >1000Hz/pixel
- Use strong imaging gradients
  - Some vendors lump this into a “MARS” mode
  - Otherwise try thin slices and large matrix w/ same FOV
- Use View Angle Tilting (VAT) w/ SEMAC or MAVRIC
- For Fat Sat: STIR (most robust, but only for pre-Gd) or Dixon

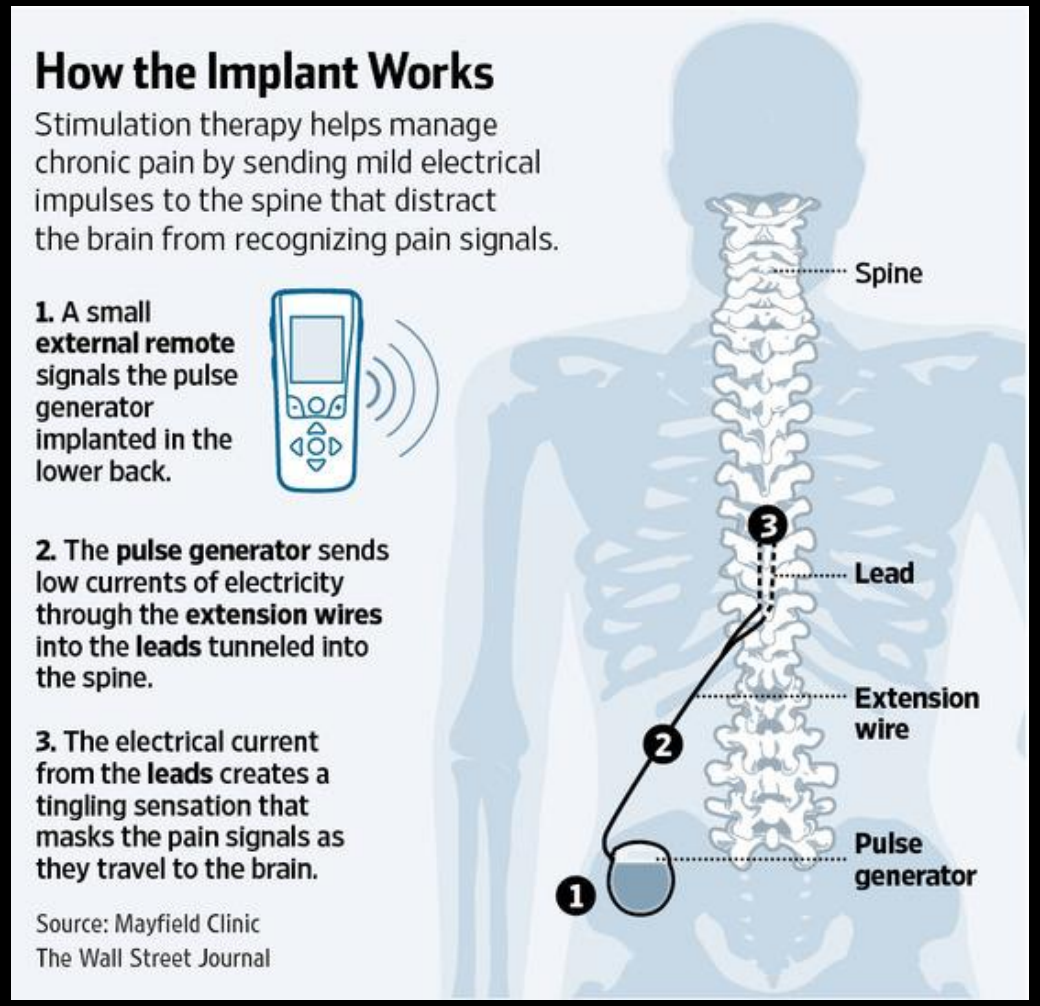
3D Turbo Spin Echo

- Good for disc pathology
- Poor cord contrast

2D T2W TSE

3D T2W TSE

Spinal Cord Stimulators



- Scan requirements vary by vendor.
- Generally:
  - Put external remote in MR Safe Mode
  - Check scanning requirements including:
    - Static Magnetic Field
    - SAR or $B1^{+}_{rms}$
- Example:
  - Abbott spinal cord stimulator w/ Penta leads:
    - 1.5T only
    - whole body SAR no more than 0.1 W/kg (!)

Low SAR Spine Protocols

- How to reduce SAR or B1+rms:
  http://mriquestions.com/uploads/3/4/5/7/34572113/mri_guidance_-_sar___b1_rms_final_12.23.15.pdf
  - Use low SAR pulses
  - Reduce flip angle for refocusing pulses
  - Get rid of sat bands
  - Increase TR (but not too much for T1W scans)
  - Increase # of concatenations (Siemens) or stacks (Philips)
- Abbott document has low SAR brain and spine (Siemens) protocols
  - Contact melissa.ham@abbott.com for a copy

Abbott Low SAR C-Spine

TABLE 3. COMPARISON OF SCAN PARAMETERS FOR CERVICAL SPINE PROTOCOLS (MALE, 72 KG/159 LB)

SCAN PARAMETERS	LOCALIZER	T2 WEIGHTED TURBO SPIN ECHO (TSE) - SAGITTAL		T2 WEIGHTED TSE WITH SHORT TAU INVERSION RECOVERY (STIR) - SAGITTAL		T2 WEIGHTED TSE - TRANSVERSE		T2 MULTI ECHO 2-D TRANSVERSE	T1 WEIGHTED TSE - SAGITTAL		T1 WEIGHTED TSE WITH DARK FLUID TECHNIQUE - SAGITTAL		3-D T2 WEIGHTED CISS - TRANSVERSE	
	STANDARD PROTOCOL, WB-SAR ≤ 0.8 W/KG & WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL & WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/ KG
B_1 RMS, µT	0.7	3.3	1.2	2.9	1.4	3.5	1.4	0.3	3.6	1.5	2.4	1.4	3.5	1.3
Slabs	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1
Slices	7,3 in two slice groups	15	15	15	15	28	28	28	15	15	15	15	NA	NA
Phase oversampling, %	50	65	65	80	80	65	70	25	80	80	80	80	50	50
Slices per Slab	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	56	56
FoV Read, mm	300	220	220	220	220	180	180	180	220	220	220	220	180	180
FoV Phase, %	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Slice thickness, mm	8.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0
TR, ms	6.0	3800.0	6500.0	3800.0	3800.0	5000.0	6500.0	553.0	550.0	600.0	1900.0	2000.0	5.1	7.6
TE, ms	2.38	84.0	83.0	32.0	32.0	82.0	80.0	24.0	9.4	11.0	9.5	11.0	2.24	3.49
Number of Averages	1	2	1	2	1	2	1	2	3	1	1	1	1	1
Concatenations	10	1	2	1	3	1	3	2	1	4	2	3	NA	NA
TI, ms	NA	NA	NA	160	160	NA	NA	NA	NA	NA	860	900	NA	NA
Flip angle, degree	20	150	120	150	150	150	150	28	150	135	150	135	63	55
Base Resolution	256	384	384	256	256	256	256	256	384	384	256	256	256	256
Phase Resolution, %	71	100	60	75	75	80	50	75	70	70	90	90	100	100
Slice resolution, %	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	100	100
PAT mode	None	GRAPPA	GRAPPA	GRAPPA	GRAPPA	None	None	GRAPPA	None	None	None	GRAPPA	None	None
Acceleration factor PE	None	2	2	2	2	None	None	2	None	None	None	2	None	None
Turbo factor	NA	18	14	9	9	13	8	NA	3	4	6	5	NA	NA
RF pulse type	Fast	Normal	Low RF Power	Fast	Low RF Power	Normal	Low RF Power	Normal	Normal	Low RF Power	Normal	Low RF Power	Normal	Low RF Power
Acquisition Time§, mm:ss	0:18	3:53	3:30	2:37	4:12	4:27	4:15	4:53	4:29	4:54	4:31	4:32	3:43	5:31

§ - Acquisition time may vary based on scan parameters and factors not listed in this table.

Note: Estimation of scanner reported SAR values requires correct patient weight and scan parameters. The SAR values may vary from patient to patient and further modifications may be needed to limit SAR.

Abbott Low SAR T-Spine

TABLE 4. COMPARISON OF SCAN PARAMETERS FOR THORACIC SPINE PROTOCOLS (MALE, 70 KG/155 LB)

SCAN PARAMETERS	LOCALIZER	T2 WEIGHTED TSE - SAGITTAL			T2 WEIGHTED TSE WITH STIR - SAGITTAL			T2 WEIGHTED TSE WITH DIXON - SAGITTAL		
	STANDARD PROTOCOL, WB-SAR ≤ 0.8 W/KG & WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG
B_1 RMS, µT	0.7	2.7	1.9	0.9	2.7	2.2	1.0	3.1	2.0	1.0
Slabs	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Slices	7,3 in two slice groups	15	15	15	15	15	7	15	15	7
Phase oversampling, %	50	100	100	45	80	80	70	90	90	45
Slice oversampling, %	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Slices per slab	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FoV Read, mm	450	340	340	340	340	340	340	340	340	340
FoV Phase, %	100	100	100	100	100	100	100	100	100	100
Slice thickness, mm	8.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TR, ms	6.0	4000.0	4000.0	4000.0	4000.0	4440.0	4200.0	4000.0	4000.0	4000.0
TE, ms	2.38	100.0	100.0	100.0	39.0	44.0	44.0	89.0	84.0	84.0
Number of Averages	1	2	1	1	2	1	1	1	1	1
Concatenations	10	1	1	5	1	1	2	1	1	2
TI, ms	NA	NA	NA	NA	160	160	160	NA	NA	NA
Flip angle, degree	20	150	150	120	150	150	120	150	150	120
Base Resolution	256	448	448	448	384	384	384	384	384	384
Phase Resolution, %	70	80	80	65	70	70	70	75	75	70
Slice Resolution, %	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PAT mode	None	GRAPPA	GRAPPA	GRAPPA	GRAPPA	GRAPPA	GRAPPA	GRAPPA	GRAPPA	GRAPPA
Acceleration factor PE	None	2	2	2	2	2	2	2	2	2
Turbo factor	NA	19	17	14	10	10	10	16	16	16
RF pulse type	Fast	Low RF Power	Low RF Power	Low RF Power	Normal	Low RF Power	Low RF Power	Normal	Low RF Power	Low RF Power
Acquire in two parts	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†
Acquisition Time§, mm:ss	0:18	2:38	1:34	5:42	3:26	2:01	3:40+	2:30	2:30	3:38+

SCAN PARAMETERS	T1 WEIGHTED TSE - SAGITTAL			T1 WEIGHTED TSE WITH DARK FLUID - SAGITTAL			T1 WEIGHTED TSE - TRANSVERSE			3-D T2 WEIGHTED CISS - TRANSVERSE		T2 MULTI ECHO 2-D TRANSVERSE
	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	STANDARD PROTOCOL, WB-SAR ≤ 0.8 W/KG & WB-SAR ≤ 0.1 W/KG
B_1 RMS, µT	3.4	2.4	1.1	2.6	2.3	1.1	3.5	2.5	1.1	3.8	2.0	0.4
Slabs	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	NA
Slices	15	15	7	15	15	7	25	25	12	NA	NA	25
Phase oversampling, %	80	80	60	80	80	70	50	50	50	50	50	10
Slice oversampling, %	NA	NA	NA	NA	NA	NA	NA	NA	NA	28.6	28.6	NA
Slices per slab	NA	NA	NA	NA	NA	NA	NA	NA	NA	56	56	NA
FoV Read, mm	340	340	340	340	340	340	190	190	190	190	190	190
FoV Phase, %	100	100	100	100	100	100	100	100	100	100	100	100
Slice thickness, mm	4.0	4.0	4.0	4.0	4.0	4.0	3.5	3.5	3.5	2.0	2.0	3.5
TR, ms	650.0	650.0	720.0	1900.0	1900.0	1900.0	550.0	550.0	550.0	5.4	7.54	400.0
TE, ms	10.0	10.0	10.0	9.8	11.0	11.0	9.5	9.5	9.5	2.21	3.46	17.0
Number of Averages	1	1	1	2	2	1	2	1	1	1	1	2
Concatenations	1	2	5	2	2	5	2	4	9	NA	NA	2
TI, ms	NA	NA	NA	860	860	860	NA	NA	NA	NA	NA	NA
Flip angle, degree	150	150	120	150	150	120	150	150	120	70	70	30
Base Resolution	384	384	384	384	384	384	256	256	256	256	256	256
Phase Resolution, %	75	75	65	75	75	68	75	75	75	100	100	70
Slice Resolution, %	NA	NA	NA	NA	NA	NA	NA	NA	NA	100	100	NA
PAT mode	None	None	GRAPPA	GRAPPA	GRAPPA	GRAPPA	None	None	GRAPPA	None	None	None
Acceleration factor PE	None	None	2	2	2	2	None	None	2	None	None	None
Turbo factor	9	3	4	8	8	8	3	3	3	NA	NA	NA
RF pulse type	Low RF Power	Low RF Power	Low RF Power	Normal	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Normal	Low RF Power	Normal
Acquire in two parts	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†	Not needed	Not needed	Not needed
Acquisition Time§, mm:ss	3:47	3:48	3:16+	4:16	4:16	4:56+	3:34	3:35	4:24+	3:30	5:28	5:18

§ - Acquisition time may vary based on scan parameters and factors not listed in this table.

† - For reducing WB-SAR or B_1 RMS in the case of RF intensive protocols, splitting the protocol in two parts may be needed (i.e., an MRI protocol with 15 slices can be split into two acquisitions of 7 and 8 slices each). Please note that the listed parameters are for 7 slices. Similar acquisition will be needed for the second part of the protocol.

Note: Estimation of scanner reported SAR values requires correct patient weight and scan parameters. The SAR values may vary from patient to patient and further modifications may be needed to limit SAR values.

Abbott Low SAR L-Spine

TABLE 5. COMPARISON OF SCAN PARAMETERS FOR LUMBAR SPINE PROTOCOLS (MALE, 81 KG/179 LB)

SCAN PARAMETERS	LOCALIZER	T2 WEIGHTED TSE - SAGITTAL			T2 WEIGHTED TSE WITH STIR - SAGITTAL			T2 WEIGHTED TSE - TRANSVERSE			T2 WEIGHTED TSE MULTISHOT MULTI ANGLE (MSMA) - TRANSVERSE			T1 WEIGHTED TSE - SAGITTAL			T1 WEIGHTED TSE - TRANSVERSE		
	STANDARD PROTOCOL, WB-SAR ≤ 0.8 W/KG & WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG	STANDARD PROTOCOL	WB-SAR ≤ 0.8 W/KG	WB-SAR ≤ 0.1 W/KG
B_{1+}RMS, μT	0.7	2.8	2.0	0.9	2.9	2.4	1.0	3.5	2.0	0.9	2.9	2.0	1.0	3.0	2.2	0.9	3.0	2.5	1.1
Slices	7,3 in two slice groups	15	15	15	15	15	8	20	20	10	6,6,6 in three slice groups	6,6,6 in three slice groups	3,3,3 in three slice groups	15	15	8	20	20	10
Phase oversampling, %	50	80	80	50	80	80	80	40	40	40	20	20	20	80	80	60	30	30	30
FoV Read, mm	450	260	260	260	260	260	260	220	220	220	200	200	200	260	260	260	220	220	220
FoV Phase, %	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Slice thickness, mm	8.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TR, ms	6.0	3500.0	3500.0	4000.0	3500.0	3500.0	3600.0	4000.0	4000.0	4000.0	4000.0	4000.0	4000.0	550.0	550.0	600.0	550.0	550.0	600.0
TE, ms	2.38	91.0	91.0	91.0	41.0	43.0	43.0	89.0	89.0	89.0	92.0	92.0	92.0	9.6	9.6	9.6	10.0	10.0	10.0
Number of Averages	1	2	1	1	2	2	1	2	1	1	3	2	1	3	2	1	2	1	1
Concatenations	10	1	2	4	1	1	3	1	2	4	1	2	4	1	2	4	2	3	8
TI, ms	NA	NA	NA	NA	170	170	170	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Flip angle, degree	20	150	150	120	150	150	120	150	150	120	150	150	120	150	150	120	150	120	120
Base Resolution	256	384	384	384	256	256	256	384	384	384	320	320	320	320	320	320	256	256	256
Phase Resolution, %	70	70	70	50	80	80	80	75	75	75	80	80	80	70	70	70	85	85	85
PAT mode	None	None	None	GRAPPA	GRAPPA	GRAPPA	GRAPPA	None	None	GRAPPA	None	None	GRAPPA	None	None	None	None	None	GRAPPA
Acceleration factor PE	None	None	None	2	2	2	2	None	None	2	None	None	2	None	None	None	None	None	2
Turbo factor	NA	17	17	9	9	9	9	15	15	15	17	17	17	3	3	3	3	3	3
RF pulse type	Fast	Low RF Power	Low RF Power	Low RF Power	Fast	Low RF Power	Low RF Power	Normal	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power	Low RF Power
Acquire in two parts	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†	Not needed	Not needed	Yes†
Acquisition Time§, mm:ss	0:18	3:28	3:32	5:06	2:32	2:32	4:10+	3:42	3:46	4:18+	3:54	5:14	2:58+	3:45	5:00	4:52+	3:32	2:40	4:11+

§ - Acquisition time may vary based on scan parameters and factors not listed in this table.

† - For reducing WB-SAR in the case of RF intensive protocols, splitting the protocol in two parts may be needed (i.e., an MRI protocol with 16 slices can be split into two acquisitions of 8 slices each). Please note that the listed parameters are for 7 slices. Similar acquisition will be needed for the second part of the protocol.

Note: Estimation of scanner reported SAR values requires correct patient weight and scan parameters. The SAR values may vary from patient to patient and further modifications may be needed to reduce SAR.

Acknowledgements

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Joyce Spilker, RT
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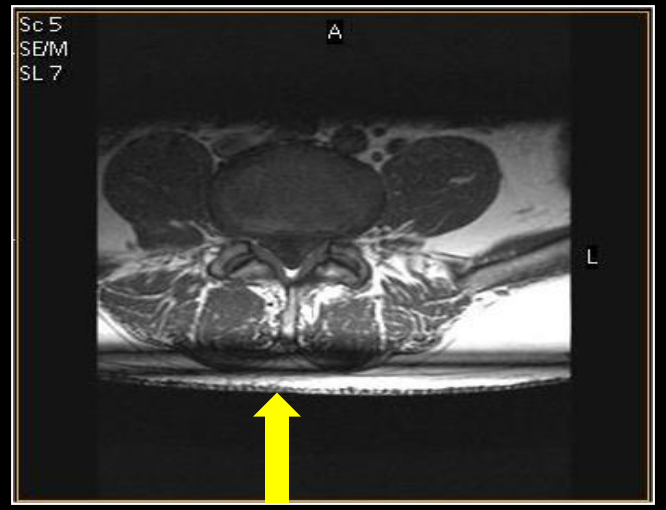
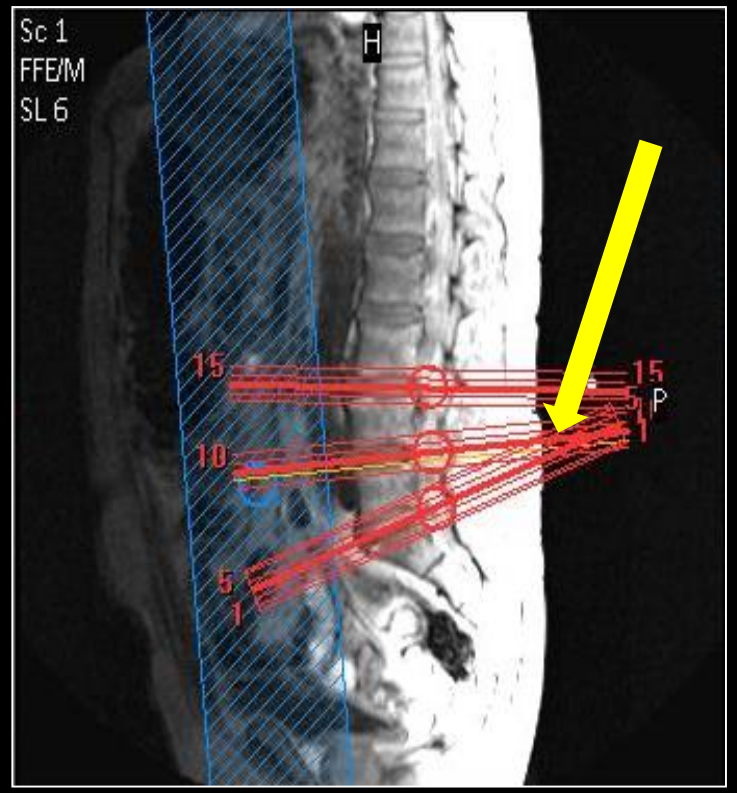
Thank You!

Multiple Stack Artifact

Cause: Slice overlap from different stacks





How to avoid: Scanning each stack sequentially rather than interleaved