Qualitative Comparison of Conventional and Oblique MRI for Detection of Herniated Spinal Discs

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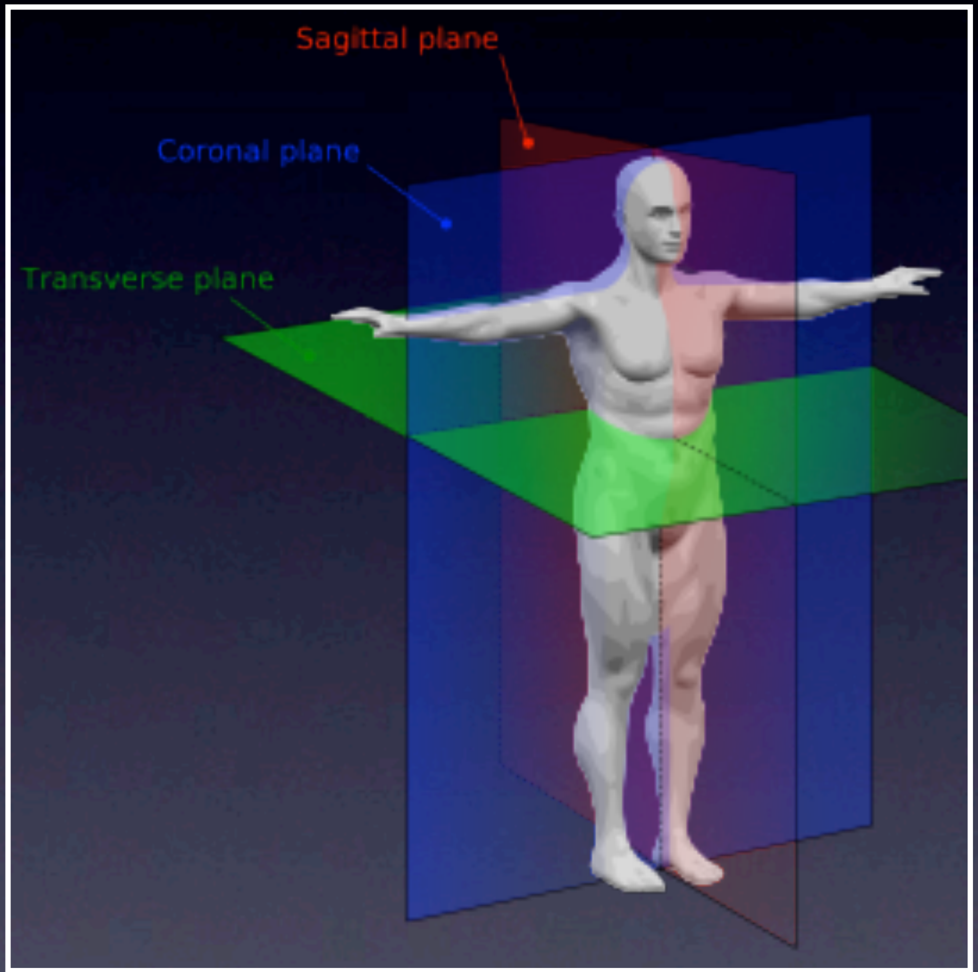
Final Project Presentation
ENGN 2500: Medical Image Analysis
May 16, 2011

Outline

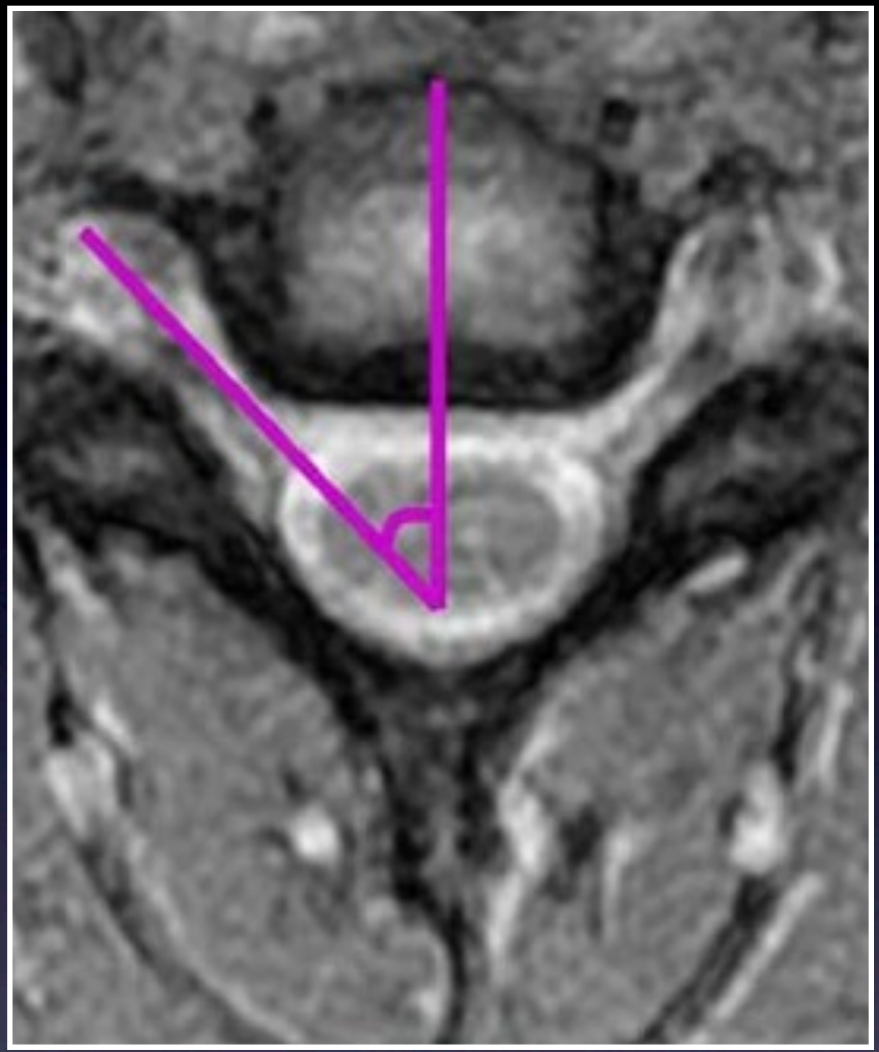
- Review of the problem presented in the paper: “A comparison of angled sagittal MRI and conventional MRI in the diagnosis of herniated disc and stenosis in the cervical foramen” (Authors: Shim JH, Park CK, Lee JH, et. al)
- Approach to solve this problem
    - Data Acquisition
    - Analysis Methods
- Results
- Discussion/Conclusions

Review of Problem

- Difficult to identify herniated discs and spinal stenosis using conventional (2D) MRI techniques
- These conventional methods result in patients condition being misdiagnosed.



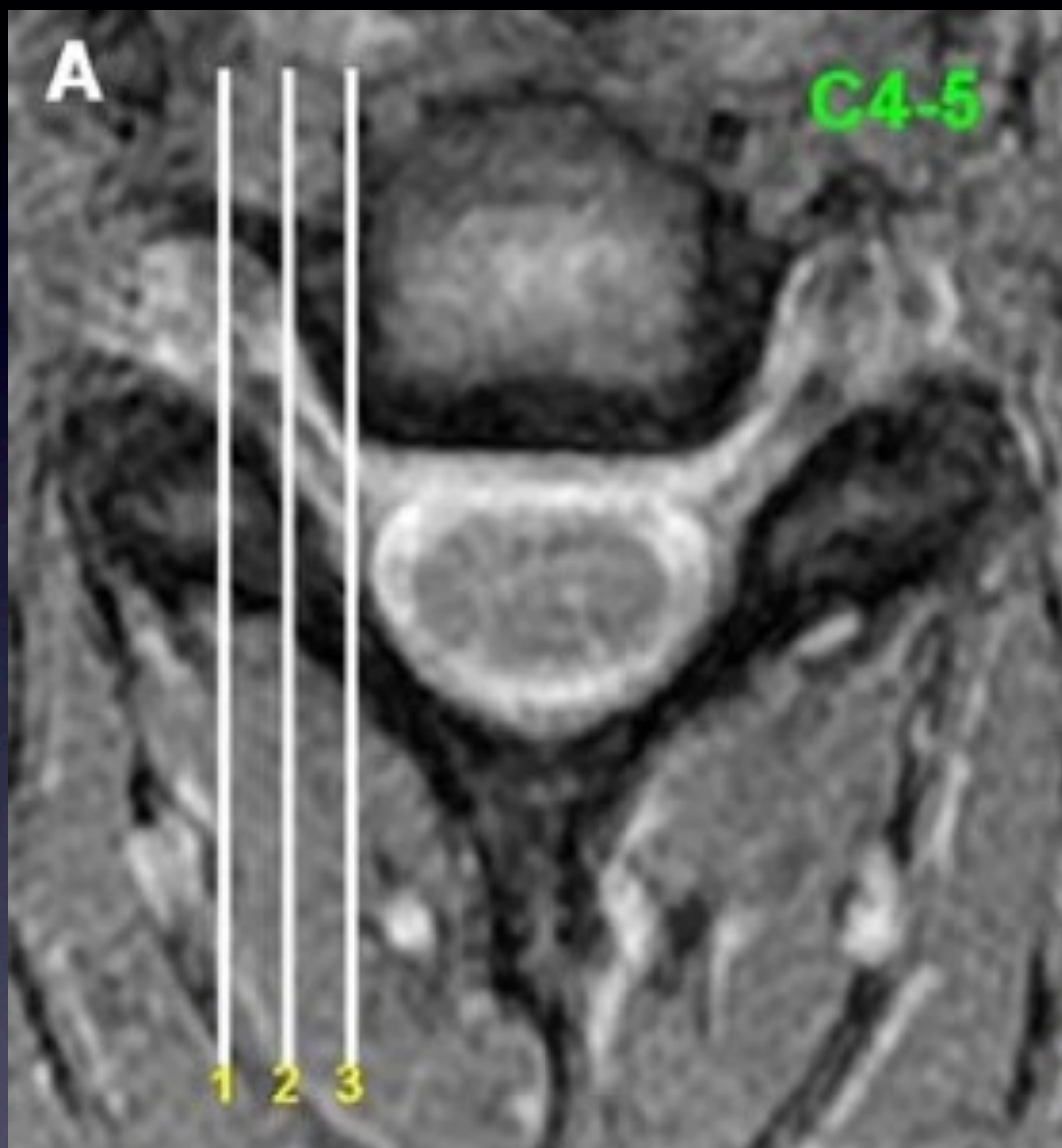
"Conventional MRI": Images acquired along one of three anatomical planes



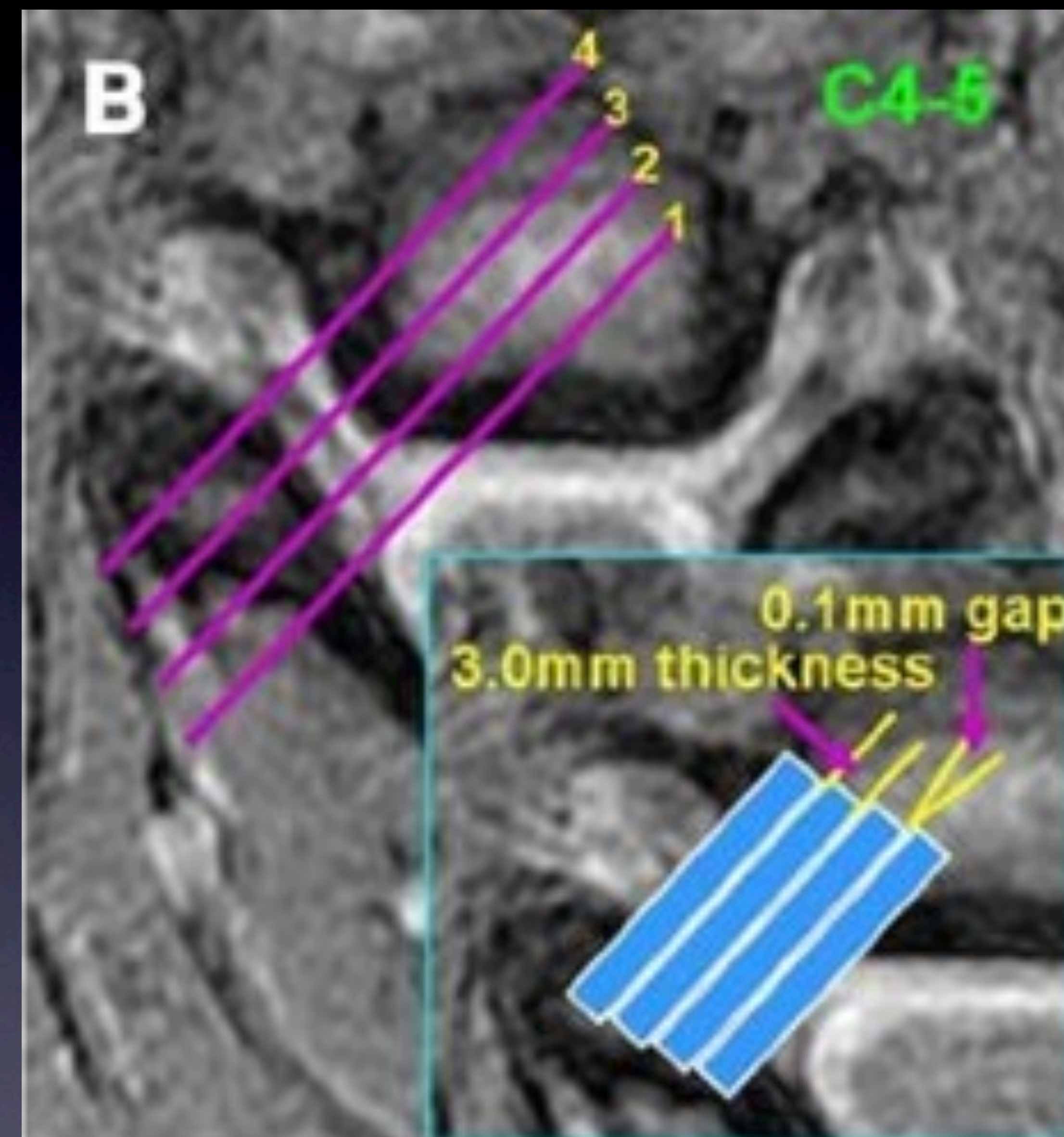
Axial, T2-weighted Image: Cervical Foramen is directed at 45 degrees with respect to coronal plane.

3D reconstructive CT Image shows that the cervical foramina are directed downward around 10-15 degrees with respect to axial plane

Orientation of Images



Conventional MRI: Sagittal Protocol



Oblique MRI: Sagittal Protocol

Timeline

- Week 1 (4/11-4/16)
  - Work on developing MR imaging protocols and sequences
  - Recruit volunteers (~4-5 volunteers)
- Week 2 (4/17-4/23)
  - Continue developing imaging sequences and begin data acquisition at the MRI facility
  - Assisted by Dr. Deoni
- Week 3&4 (4/24-5/7)
  - Continue developing and testing sequence
  - 4/27/2011: Acquisition of first subject
  - Mid Project Presentation: Describe the imaging protocols, present data that had been acquired from previous week, describe what still needs to be done.
  - 5/2/2011: Finish data collection (4 other participants)
- Week 5&6 (5/8-5/16)
  - 5/9/2011: Meeting with Dr. Marco Dirks (orthopedic surgeon), to analyze images and get his evaluation
  - Continue analysis of MRI protocols. Determine which technique is best for detection of cervical foramina. Base these conclusions on the SNR and CNR measurements as well as the advice from Doctors and ROIs.
  - 5/11/2011: Meeting with Dr. Lucy Mathews (neurologist) to analyze images and get her evaluation.
  - 5/16/2011: Final Project Presentation

Pulse Sequences (Imaging Protocol)

The following imaging sequences were developed on the MR scanner (used in Shim, Lee, Park, et al):

- Fast Spin Echo Sequence:
  - Sagittal T_1 weighted images:
    - TR: 500ms
      TE: 10ms
      Matrix Size: 320x224
      Echo Train Length: 3
      FOV: 240mm
      NEX: 4
  - Sagittal T_2 weighted images:
    - TR: 3500ms
      TE: 110ms
      Matrix Size: 320x224
      Echo Train Length: 30
      FOV: 240mm
      NEX: 4
  - Axial T_2 weighted images:
    - TR: 4000ms
      TE: 110ms
      Matrix Size: 320x224
      Echo Train Length: 18
      FOV: 160mm
      NEX: 4

Slice Thickness: 3.0mm
Spacing: 0.5mm

Pulse Sequence (Continued)

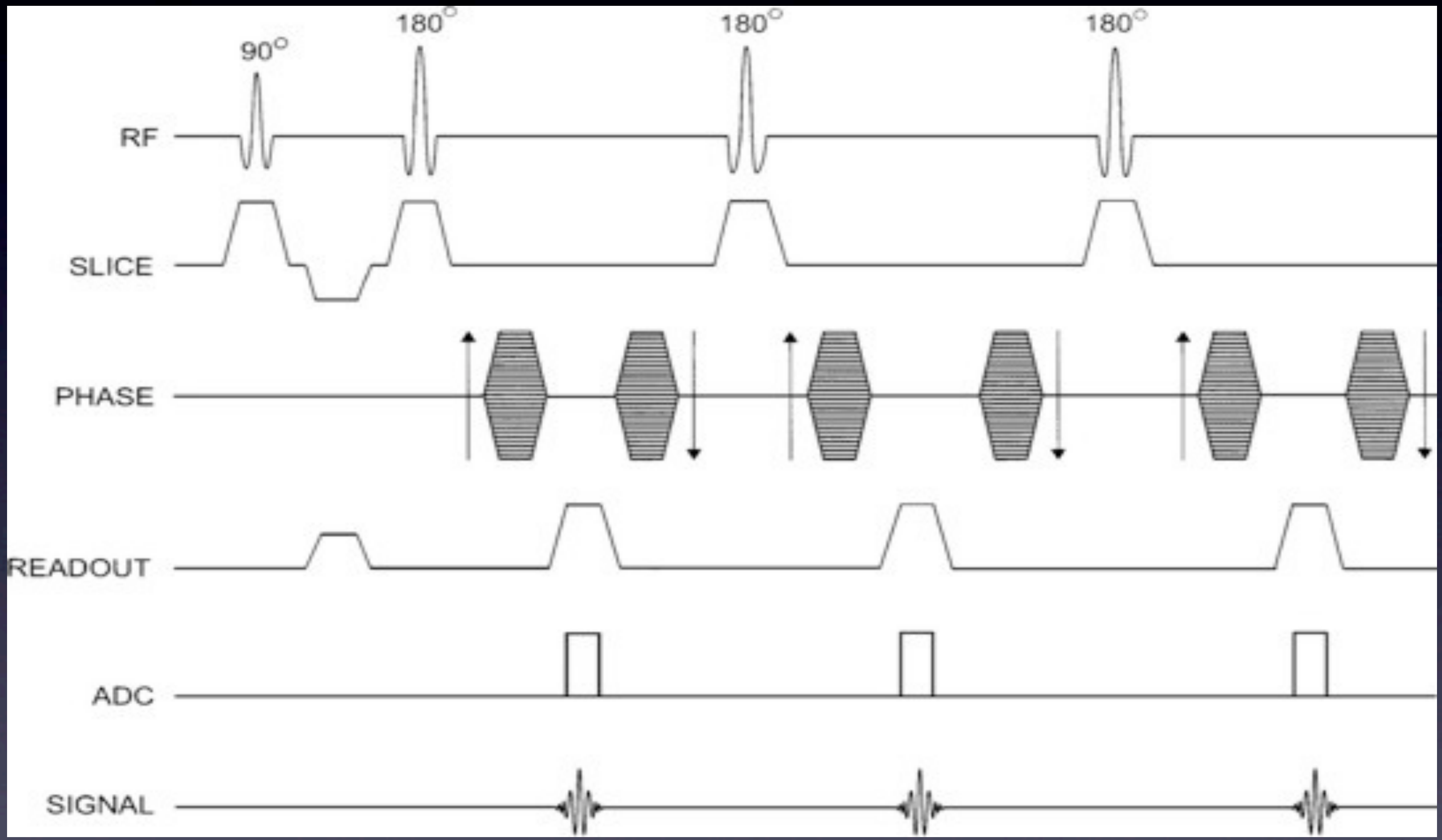


Image Taken From: http://bitc.bme.emory.edu/seq_dia.html

Spin Echo Signal Equation:

$$I(x,y) = K\rho(x,y)[1 - e^{\frac{-\mathrm{TR}}{T_1}}]e^{\frac{-\mathrm{TE}}{T_2}}$$

Pulse Sequences (Continued)

- In addition to the Fast Spin Echo Sequences, 3-dimensional (3D) volumetric data was also acquired
- However, to acquire a full volume requires a fast imaging technique such as a gradient echo sequence.
- To acquire the 3D volumetric data we used a spoiled gradient sequence (SPGR) as well as a Steady State Free Precession (SSFP) pulse sequence.
- This data was acquired for two purposes. First, with a 3D volume, one is able to view a slice in any particular direction, hence not limiting the researcher or clinician to one viewing direction.
- The second reason why this data was desired was to quantitatively fit the data to a model to determine T_1 and T_2 for the full volume. This step is for future work and was not the focus of this project, but will be described.

SPGR Images

SSFP Images

Pulse Sequences (Continued)

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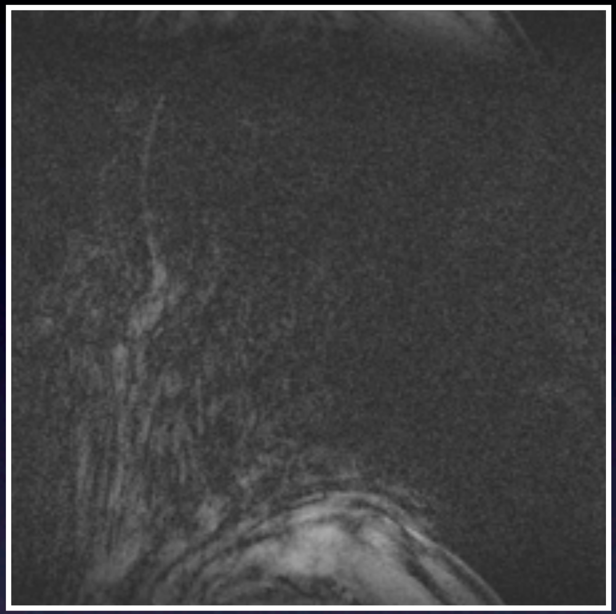
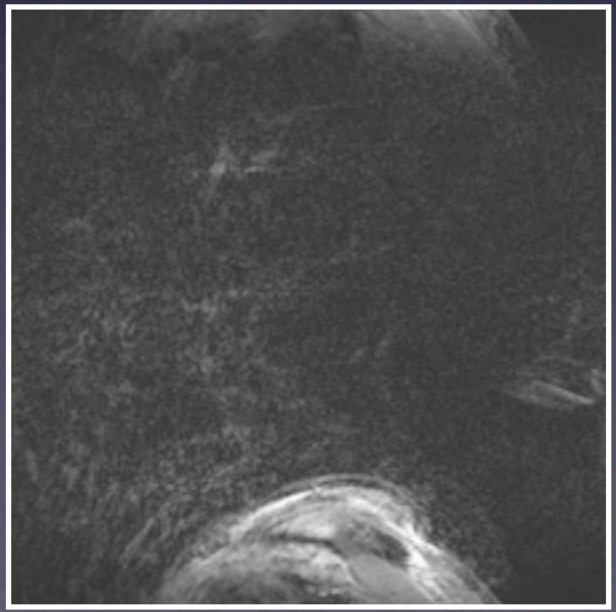


SPGR Images



SSFP Images

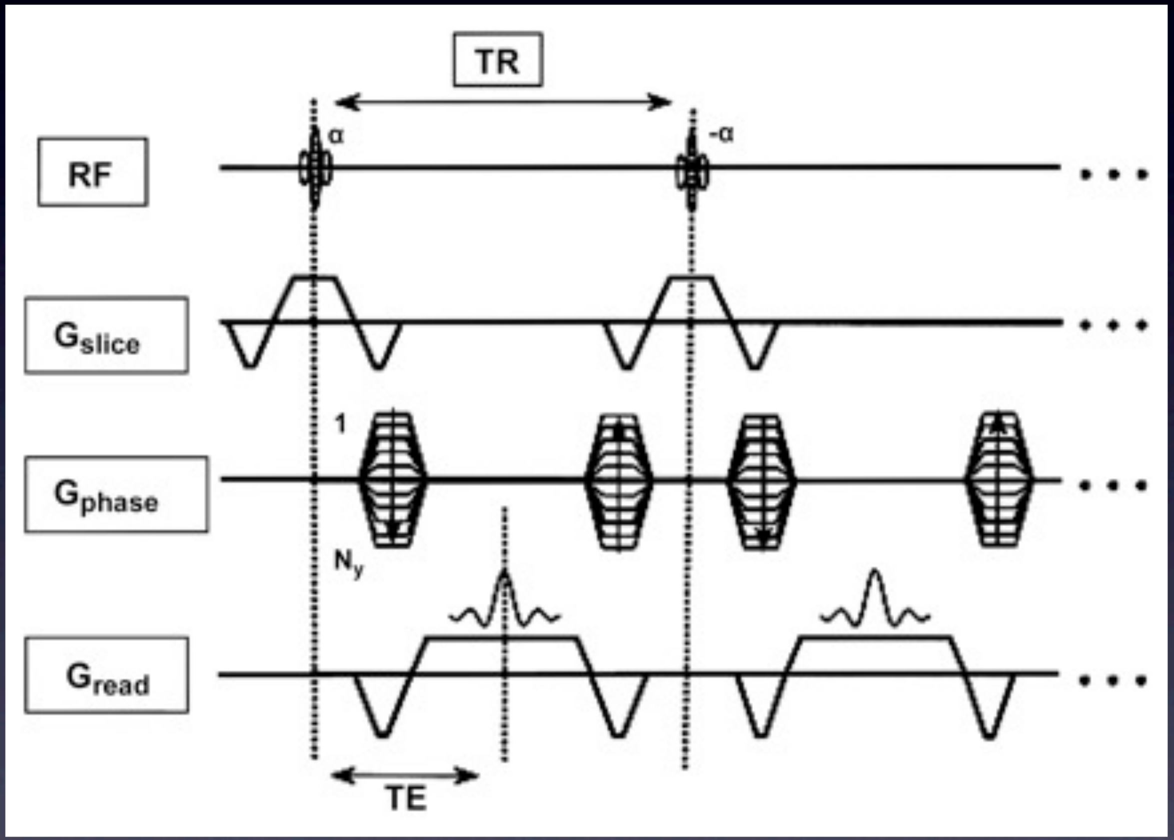
Pulse Sequences (Continued)

SPGR Signal Equation:

$$S_{SPGR} = \frac{M_0(1 - e^{\frac{-\mathrm{TR}}{T_1}})\sin\alpha}{1 - e^{\frac{-\mathrm{TR}}{T_1}}\cos\alpha}$$

SSFP Signal Equation:

$$S_{SSFP} = \frac{M_0(1 - e^{\frac{-\mathrm{TR}}{T_1}})\sin\alpha}{1 - e^{\frac{-\mathrm{TR}}{T_1}} e^{\frac{-\mathrm{TR}}{T_2}} - e^{\frac{-\mathrm{TR}}{T_1}}\cos\alpha}$$



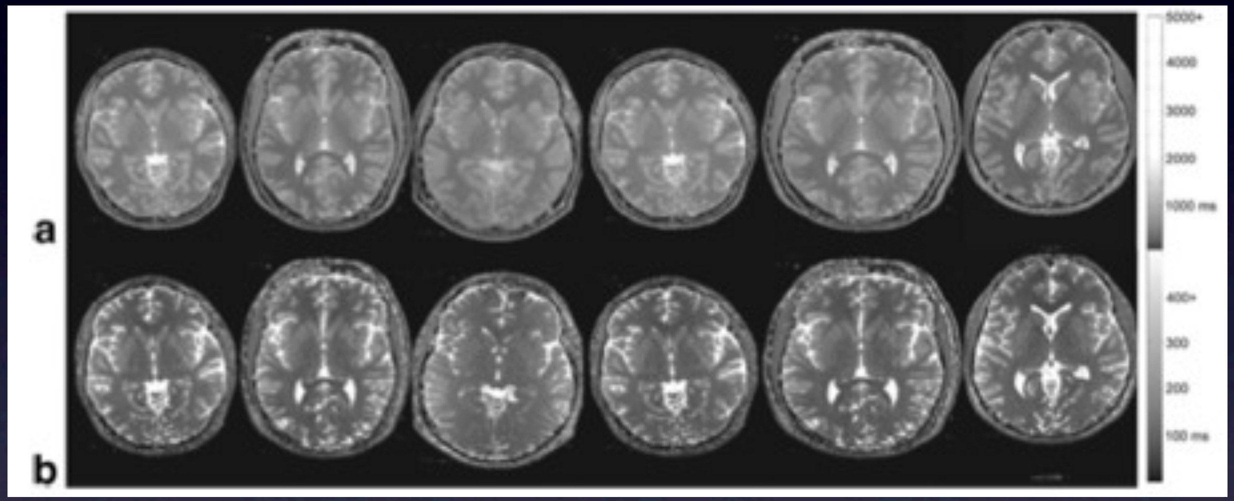
General SSFP Pulse Squence Diagram

Image From: http://radiology.rsna.org/content/241/2/338.full

α represents the flip angle of the magnetization, M

Quantitative Imaging and "Synthetic Imaging"

- Quantitative imaging, in contrast to qualitative imaging, provides a way to map T_1 and T_2 of a volume.
- This mapping provides the optimal tissue contrast as well as allowing for synthetic image generation.
- Synthetic images are images that are artificially generated from known T_1, T_2 and other timing parameters generally used in MR pulse sequences (TR, TE, flip angle, etc...)
- Thus, by knowing actual T_1 and T_2 values, one can generate any T_1, T_2 or proton density image. This is because we can model these images with their respective signal equations.
- To generate these T_1 and T_2 maps, multiple volumes are acquired and fit to a multi-variate model. These methods have been long been known to be slow. Recently, some newer methods have been developed to map T_1 and T_2.



Examples of T_1 and T_2 maps [Deoni, et al.]

Recruitment

- 5 adults were recruited
    - Age range: 35-54
    - 2-3 of them have had either back pain or other back problems in the past
    - Scans were scheduled at Brown University's MRI Research Facility at times that were convenient for the participants (evening hours).
- Participants were able to comfortably relax in the scanner, either watch a movie, listen to music or sleep

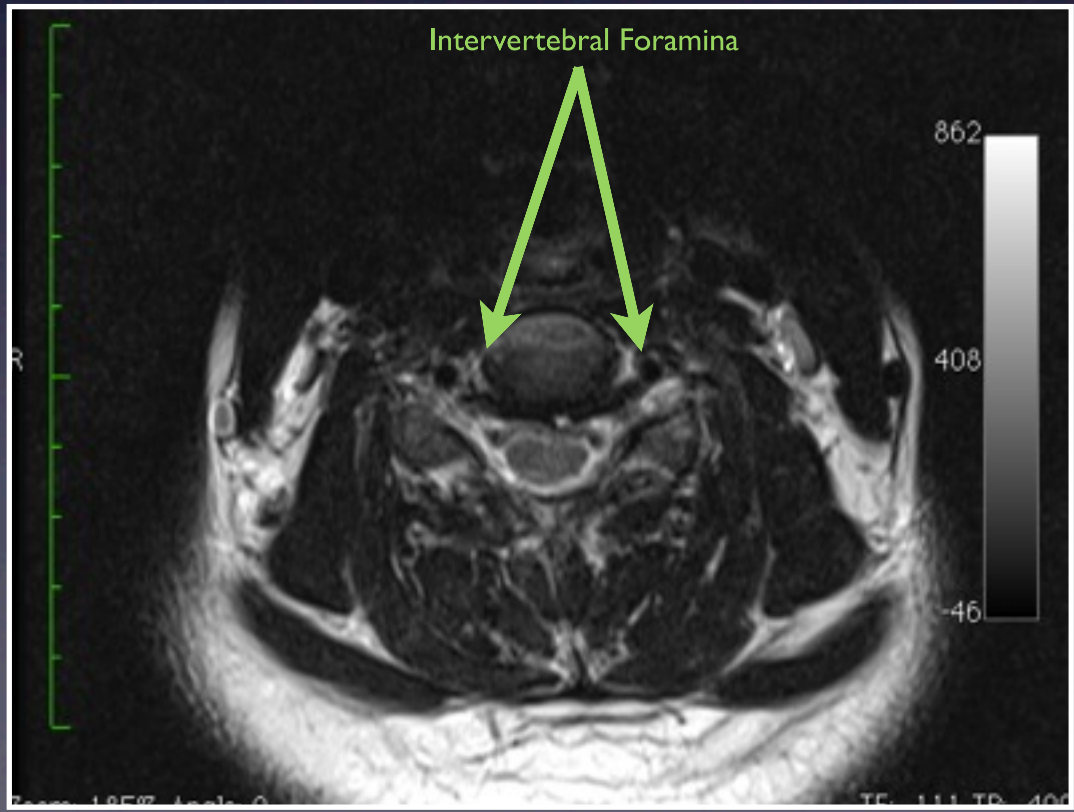
Data Acquisition

- Data acquisition with these particular sequences take a very long time. Unable to acquire a full volume of data because of this. Instead, slices were acquired that covered the desired region of interest (cervical spine).
- Scanning took place in evening hours and was dependent upon schedules of participants
- Volumetric datasets was also collected to compare the efficiency as well as diagnostic ability.
- Scan Time for protocol: ~ 30 min.

Results

- 5 Sets of Data from 5 participants was collected
    - T_1 Weighted Sagittal
    - T_2 Weighted Axial
    - T_2 Weighted Sagittal
    - T_2 Weighted Sagittal (Oblique)
    - Volumetric Acquisition (SPGR and SSFP acquisitions)
- OsiriX and FSL were used to analyze images
- Contours of ROIs were provided by Dr. Marco Dirks and Dr. Lucy Mathews. Further evaluations with Dr. Glenn Tung will be planned for future work on this project. Timing was an issue for not being able to schedule this.

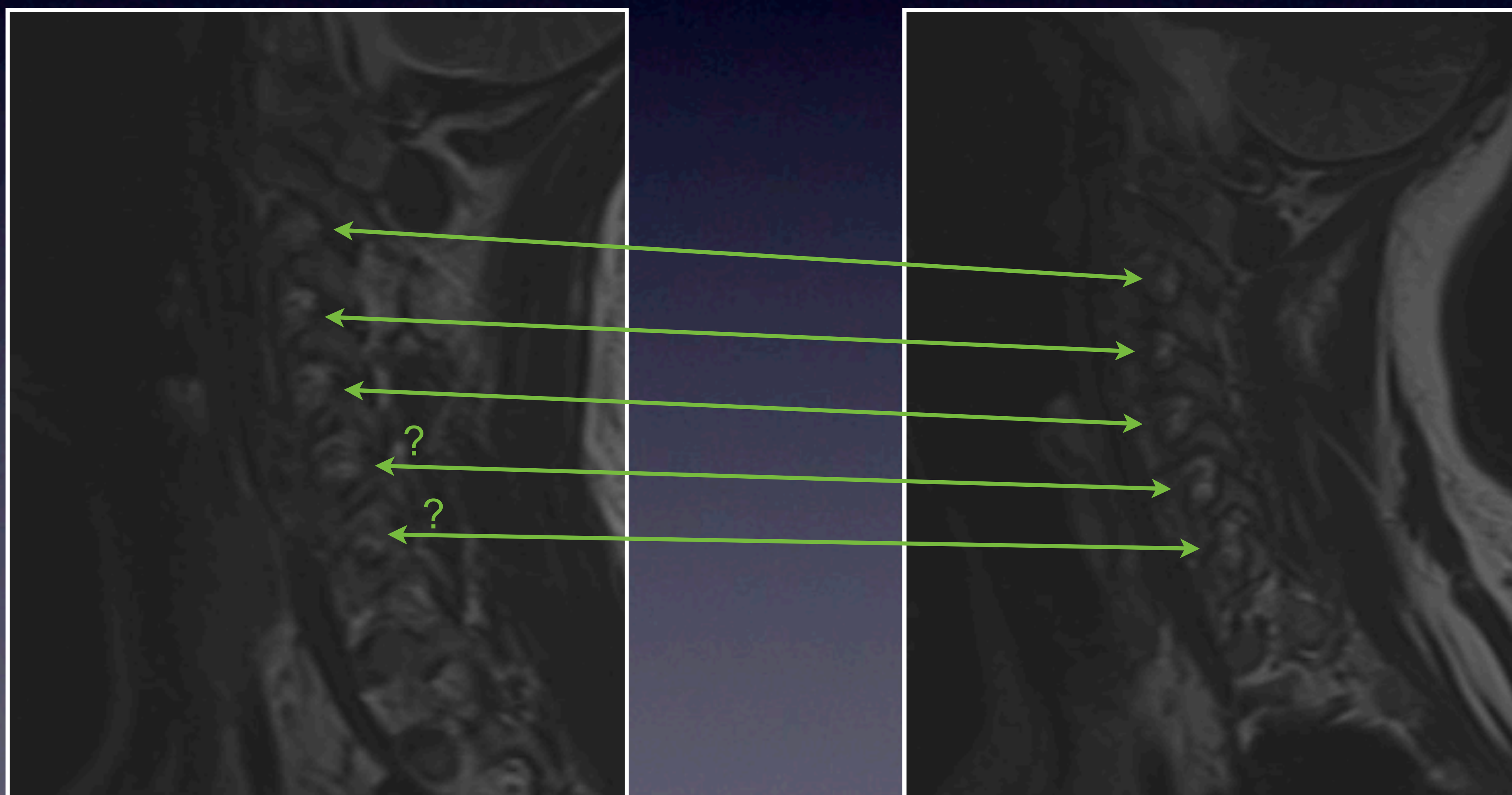
T_1 Weighted Sagittal



T_2 Weighted Axial

Image Comparisons

- As done in the paper, the T_2 Weighted Sagittal Acquisitions were used to compare which technique (conventional or oblique) could be used to better detect the inter-vertebrae formina.
- Both medical professionals viewed and provided contours of the neural foramina when possible.



Conventional T_2 Weighted Sagittal

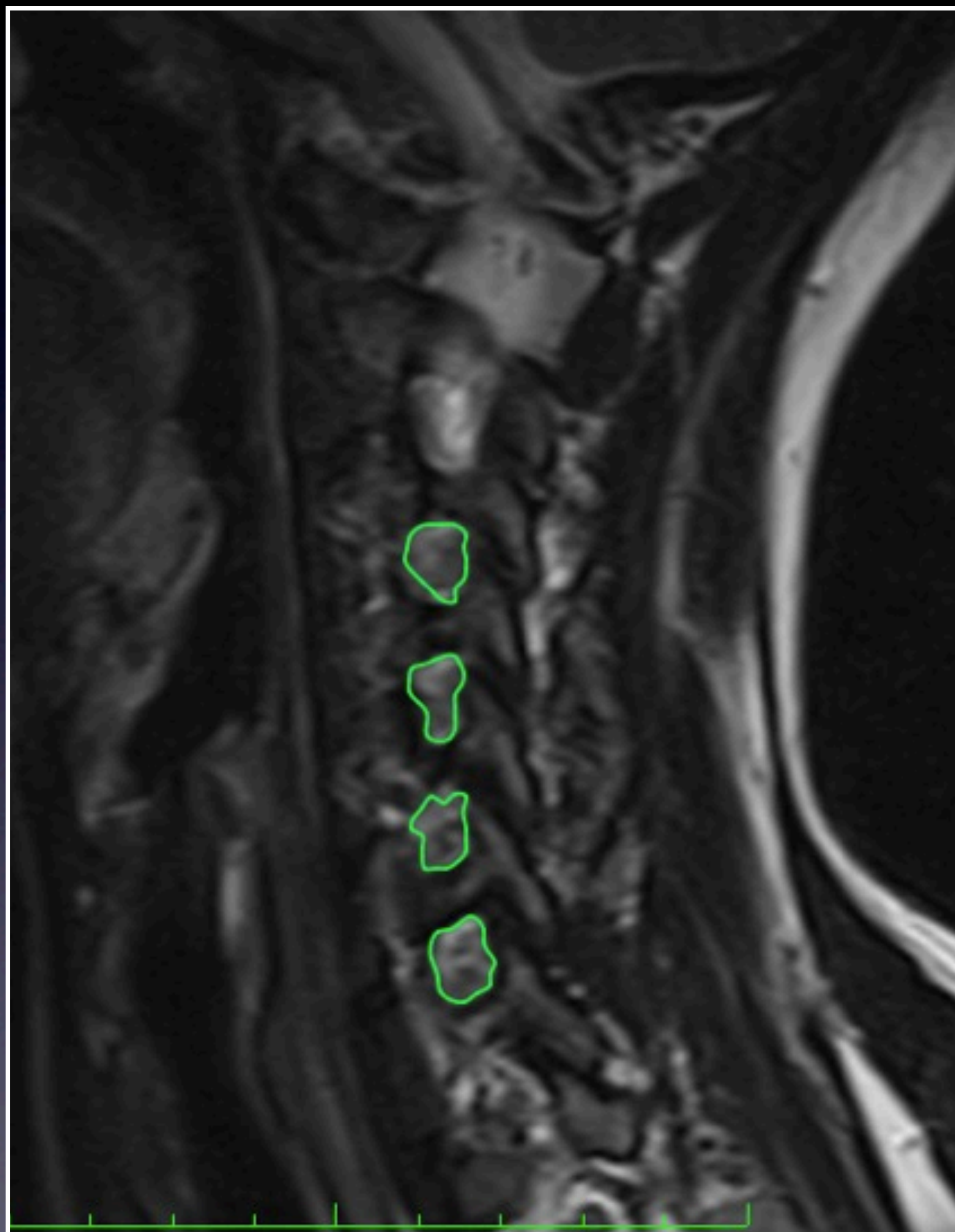
Oblique T_2 Weighted Sagittal

Participant 3: Side by Side Comparison #1

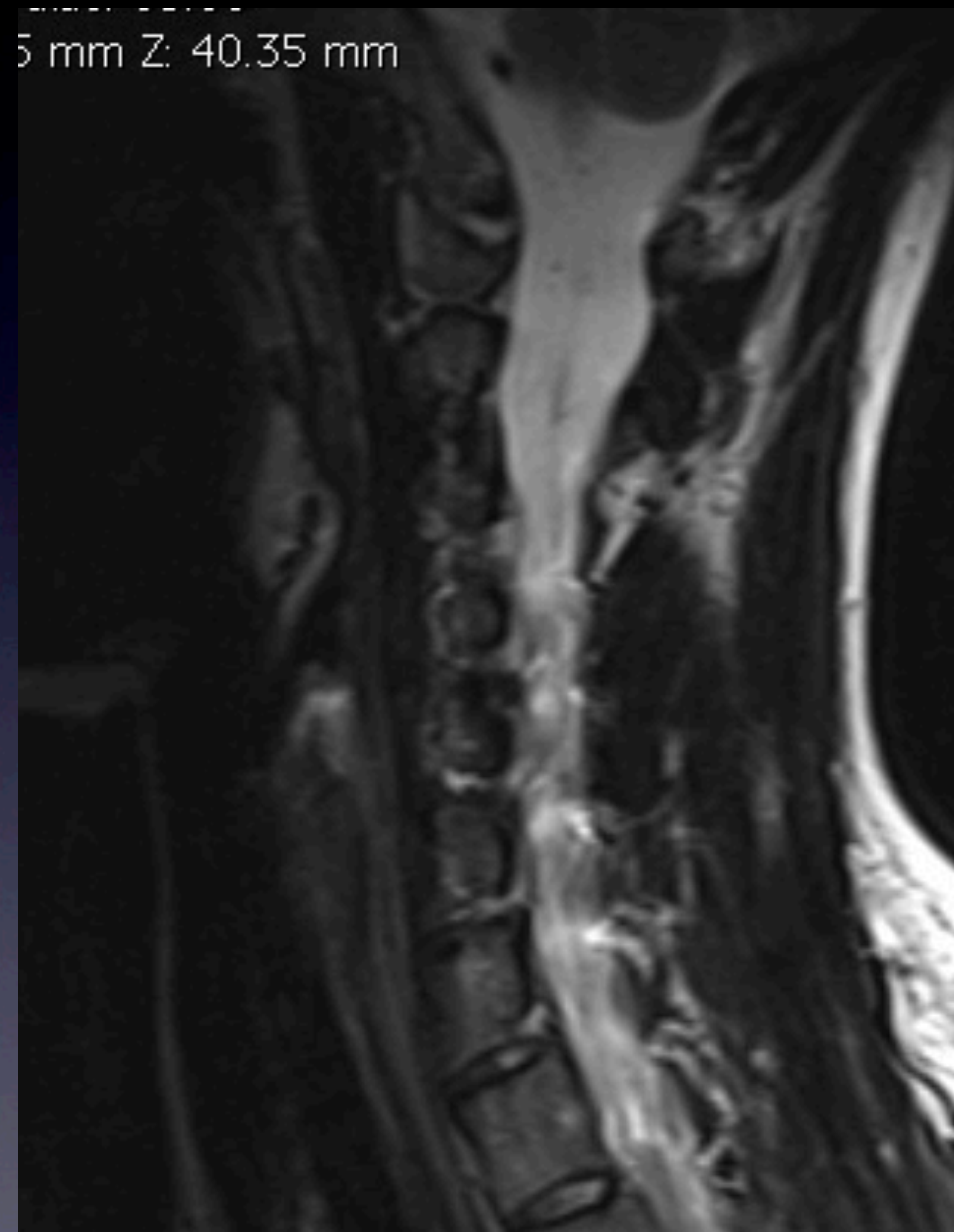
Oblique T_2 Weighted Sagittal

Conventional T_2 Weighted Sagittal

Participant 3: Side by Side Comparison #2

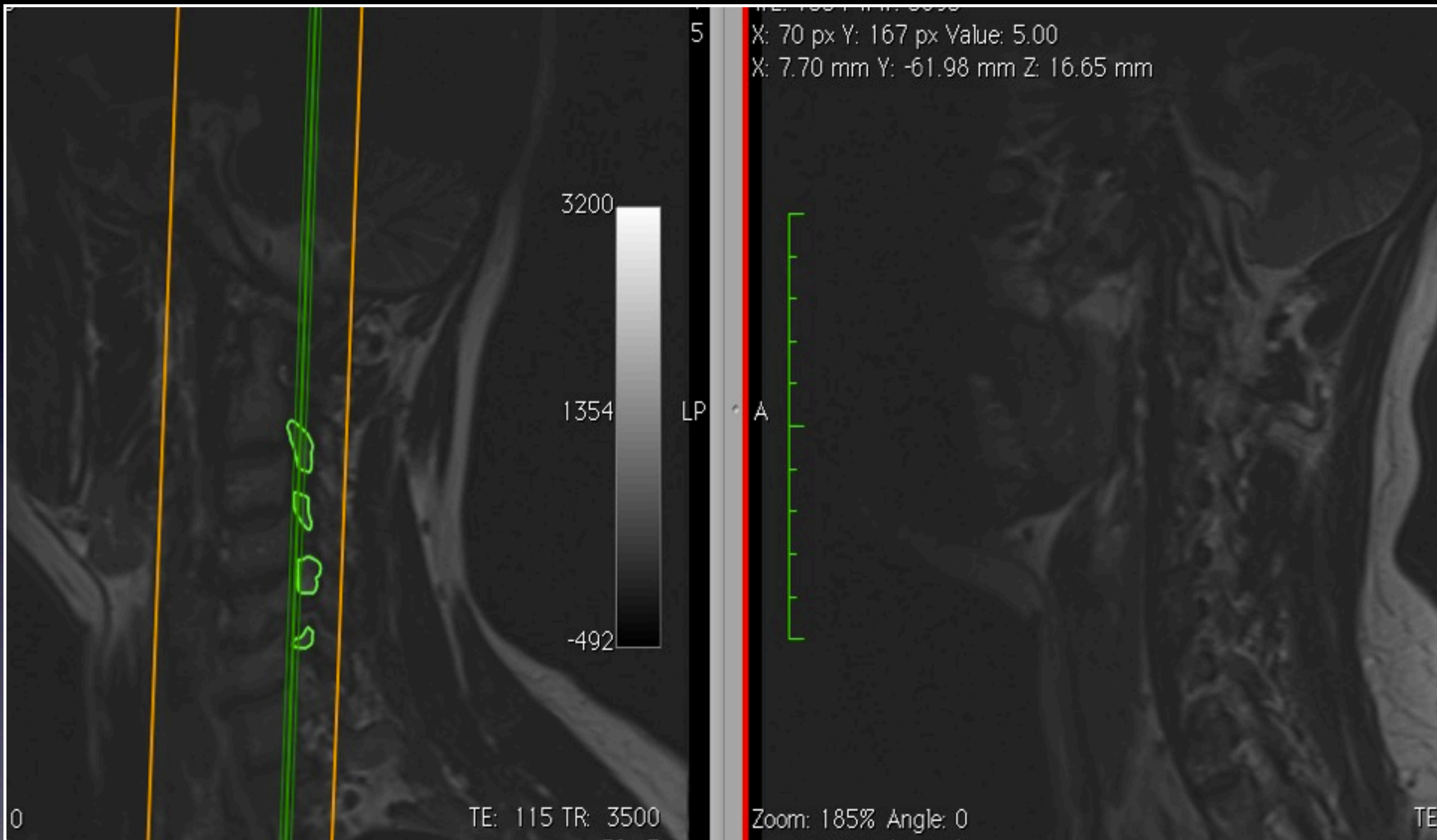


Oblique T_2 Weighted Sagittal



Conventional T_2 Weighted Sagittal

Participant 4: Side by Side Comparison #1



Oblique T_2 Weighted Sagittal

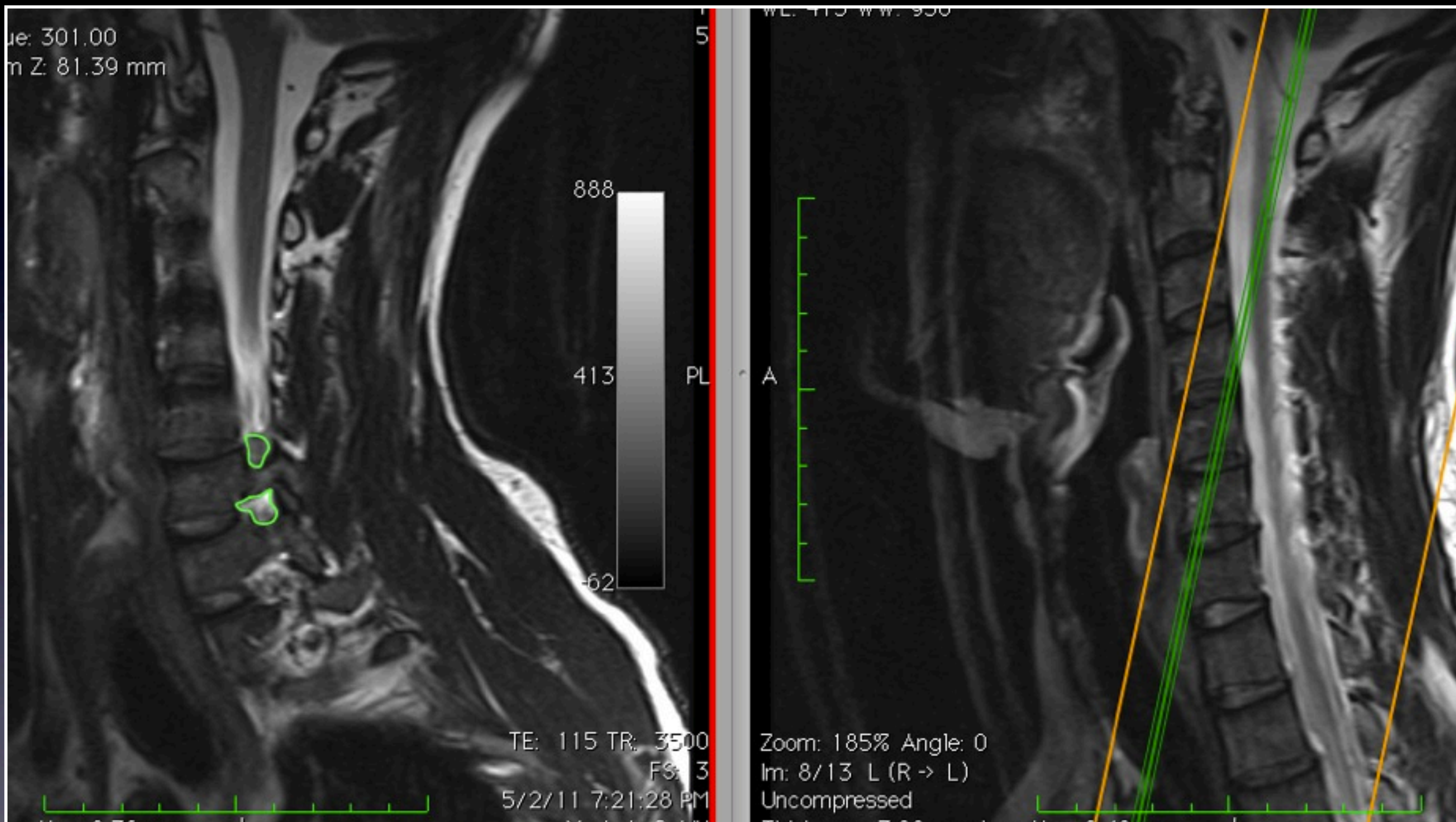
Conventional T_2 Weighted Sagittal

Participant 4: Side by Side Comparison #2

Oblique T_2 Weighted Sagittal

Conventional T_2 Weighted Sagittal

Participant 5: Side by Side Comparison #1

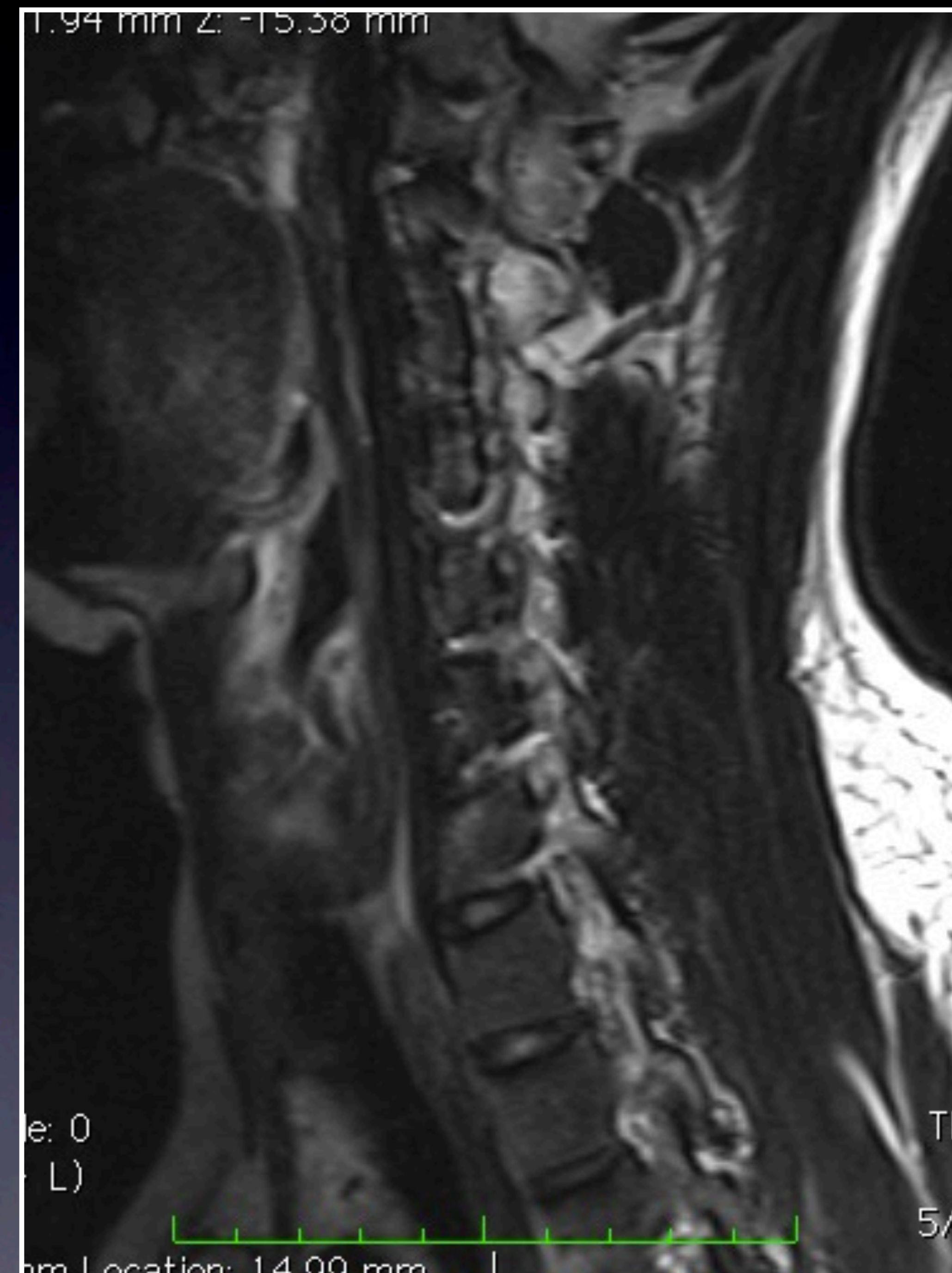


Oblique T_2 Weighted Sagittal

Conventional T_2 Weighted Sagittal

Participant 5: Side by Side Comparison #2

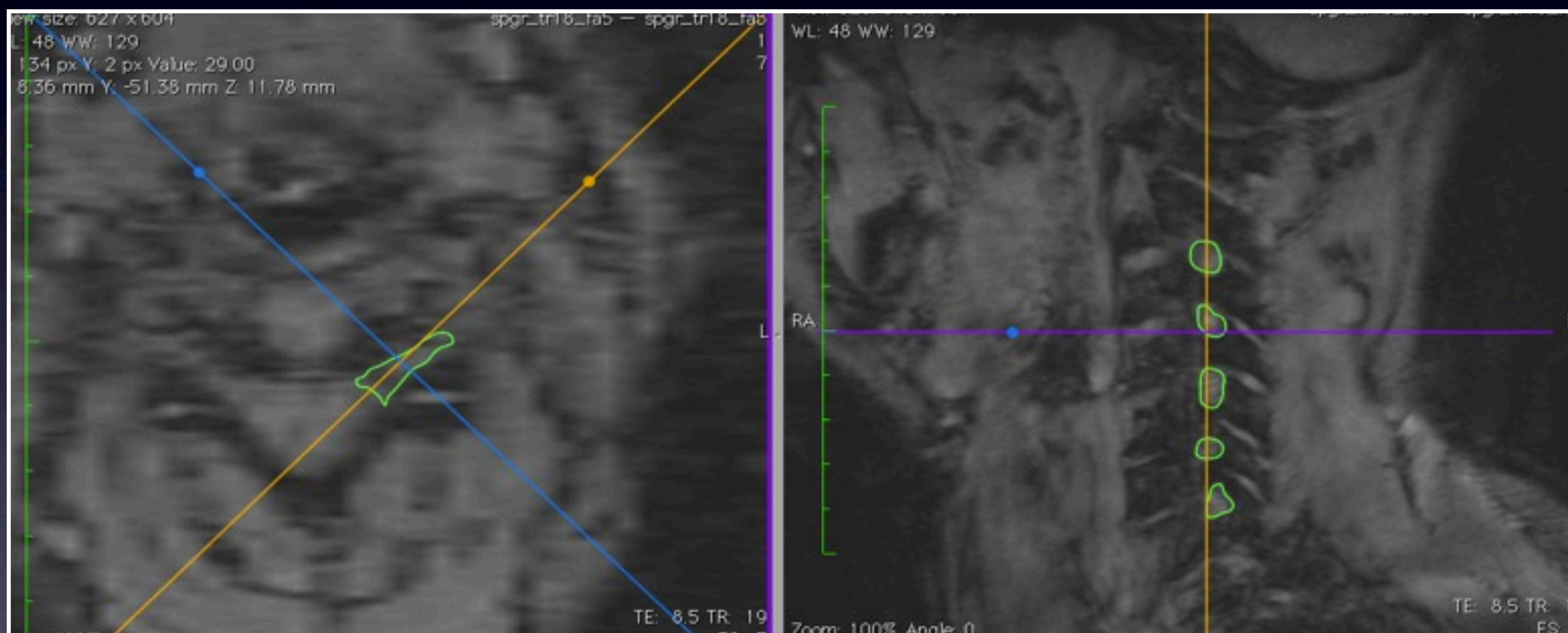
Oblique T_2 Weighted Sagittal



Conventional T_2 Weighted Sagittal

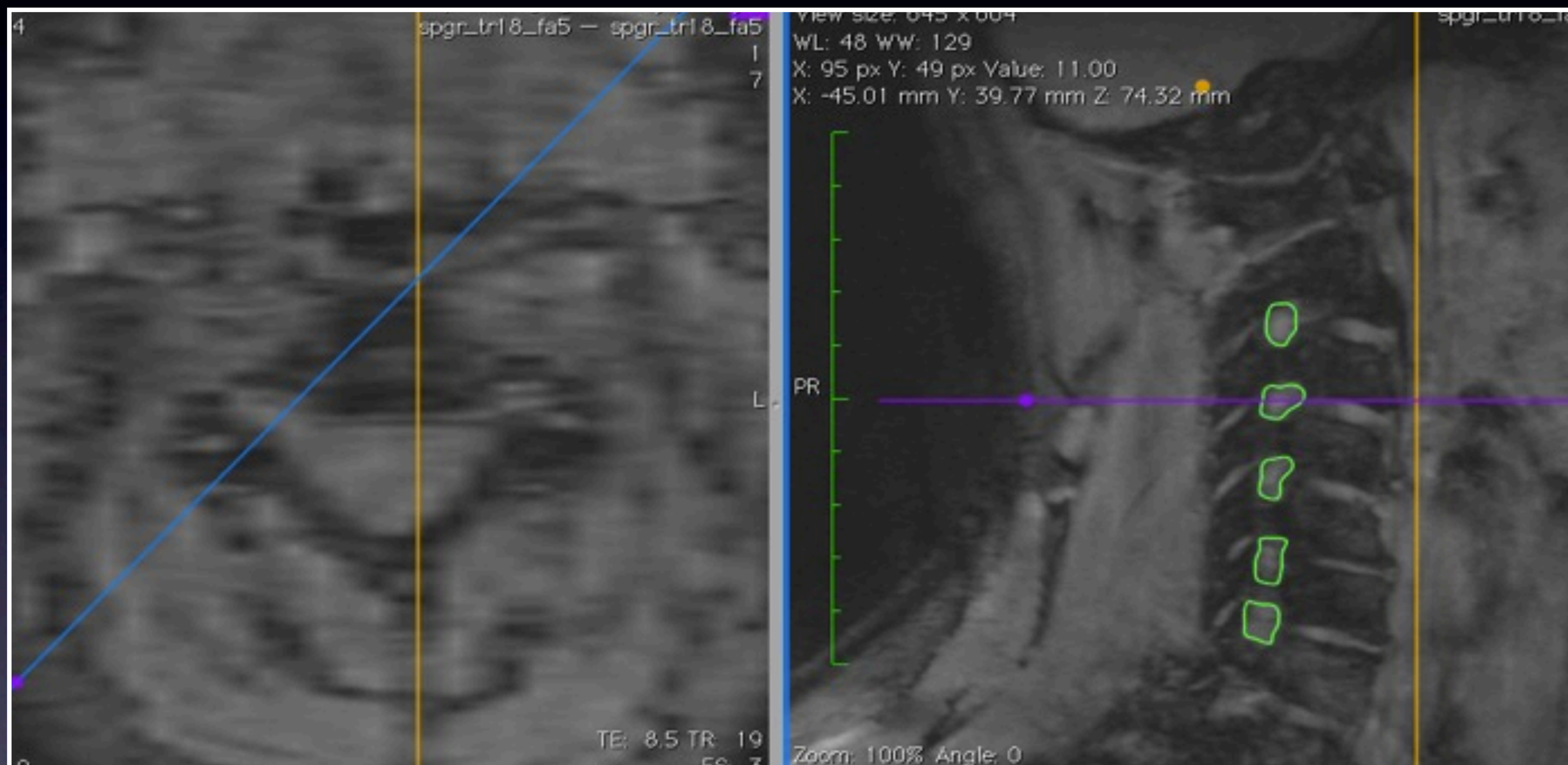
Comparison with Volumetric Data

- With a volume of data, we can “slice” any direction we desire



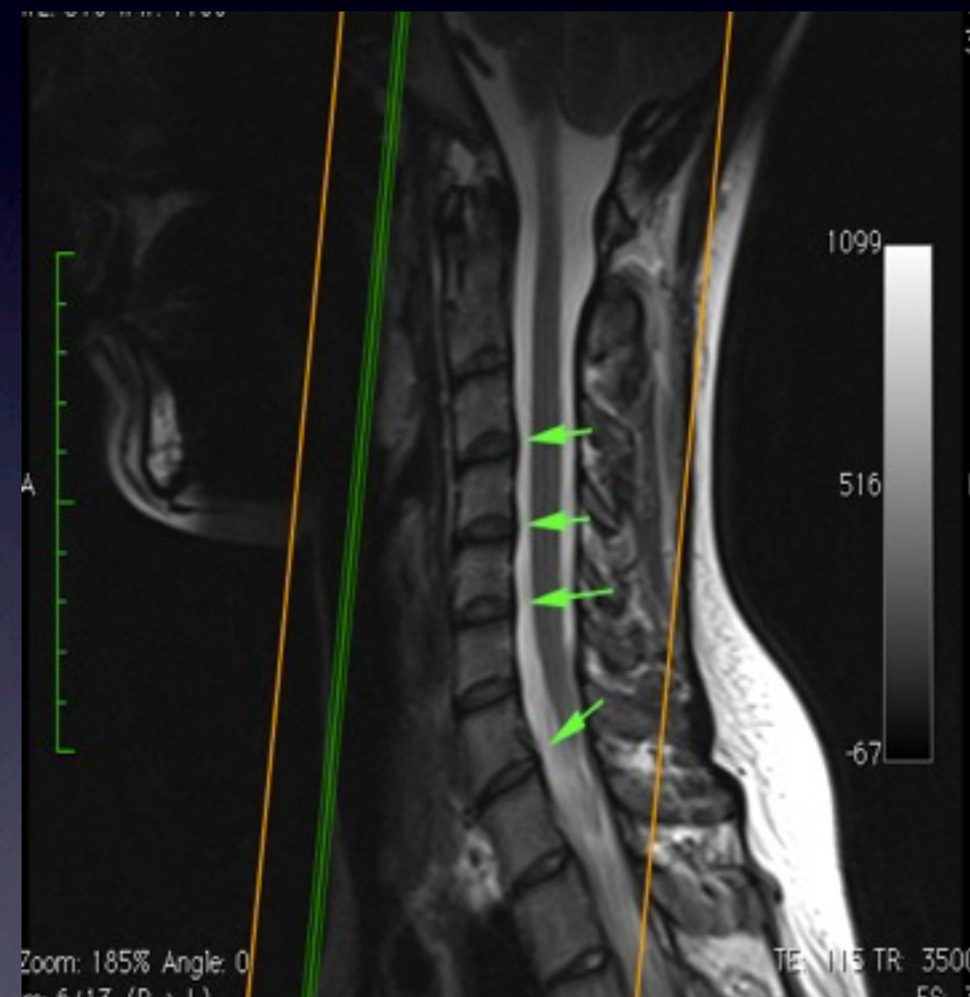
- Shown above are two slices acquired from the 3D SPGR sequence. The left image is an axial view of the foramen. The blue and yellow lines indicate the position of the other slices (yellow refers to a coronal view, not shown here). The blue line indicates a sagittal slice oriented perpendicular to the neural foramen and is shown in the right image. As with the Fast Spin Echo images, the neural foramen can also be seen with the 3D images. The purple axis indicates the position of the axial slice on the left.
- Using a DICOM viewer (OsiriX for this project) a researcher or clinician is able to slice through the 3D data at any orientation desired, unlike the 2D fast spin echo images.

Comparison with Volumetric Data



- Unlike the 2D fast spin echo images, one is only able to visualize either the left or the right side of the foramen, not both. Therefore, if it is necessary to view both sides, two sets of data will need to be acquired due to the slice acquisition.
- With a volumetric dataset, one can orient the viewing slices (indicated in blue and yellow, with the yellow slice not shown) any direction and therefore has the ability to see the opposite side of the foramen (compared with the previous slide). The purple axis on the right image indicates the position of the left axial slice.

Additional Images (Interesting Findings)



- During the study, disc bulging was also noticed on the conventional MRI slices. These bulges may be related to the back problems some of the participants have complained about.
- These bulges are indicated by the arrows in the slices

Discussion

- Both doctors agreed that detection of the neural foramen in the oblique sagittal T_2 weighted images was much better (and possible) than in the conventional T_2 weighted sagittal images. Statistically, 75% foramina was detected in the cervical spine, with the with a 98% improvement of detection when compared with the conventional techniques

- The acquisition of the two types of images is almost identical (only difference was the FOV and ETL parameters). However, the doctors also agreed that the oblique sagittal images took some time getting used to. This may be a reason why these types of images are not generally used in practice.

- Although the oblique images made it easier to detect neural foramen, one doctor thought that conventional images provided better images for looking at the vertebrae, discs and spinal cord.

- The doctors commented that the partial volume effects were greater in the oblique sagittal images due to the orientation of the slices (this also could be a result of the smaller FOV for the oblique sagittal images, causing the SNR to decrease)

- They also thought that being able to slice through a volume at any direction could be more helpful than just having a stack of 2D images. However, the quality (SNR, partial volume effects) of the images would would need to be improved for better use for diagnosis.

Conclusions

- Acquiring sagittal slices at an oblique angle (perpendicular to the direction of the foramen) can be used for better detection of the neural foramina

- This better visualization can be helpful with the diagnosis of foramina narrowing (stenosis)

- Although oblique images can be used for better detection of the foramina, they are more difficult to look at the entire spinal region and therefore may be a reason why they are not generally used in practice

- Volumetric data may provide an alternative technique for visualizing not only oblique slices, but any desired direction and therefore can provide further useful information in disease diagnosis.

Future Work

- Have additional doctors (Dr. Glenn Tung) evaluate the data to get more opinions, and further develop the statistics in comparing these techniques

- Quantitatively determine T_1 and T_2 maps from the SPGR and SSFP datasets using Dr. Deoni's mapping technique. This can in turn be used to "create" synthetic images and may provide an alternative method to visualizing and diagnosing diseases.

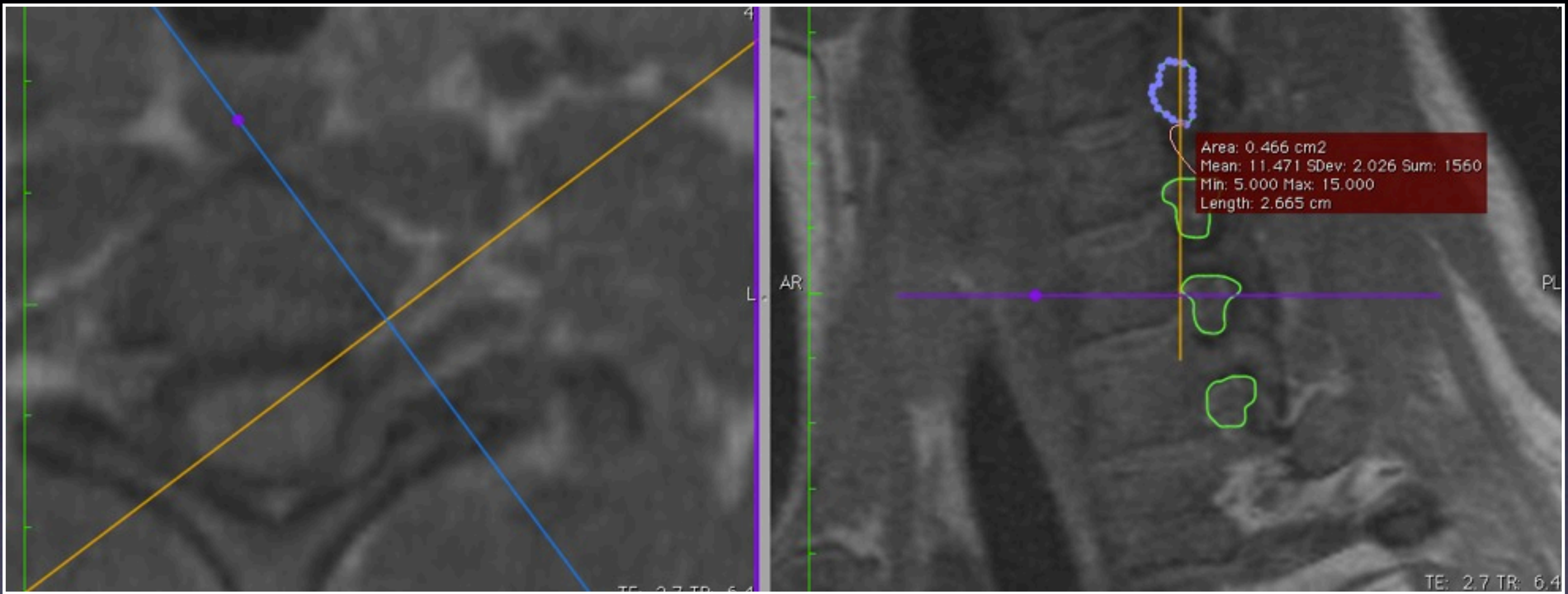
- I plan to continue to work on this project to explore these two points in order to compare the 3D volumetric data with the 2D imaging data.

References

- Shim JH, Park CK, Lee JH et al (2009) A comparison of angled sagittal MRI and conventional MRI in the diagnosis of herniated disc and stenosis in the cervical foramen. Eur Spine J 18:1009– 1116
- Bischoff RJ, Rodriguez RP, Gupta K, Righi A, Dalton JE, Whitecloud TS (1993) A comparison of computed tomography-myelography, magnetic resonance imaging, and myelography in the diagnosis of herniated nucleus pulposus and spinal stenosis. J Spinal Disord 6:289–295. doi:10.1097/00002517-199306040- 00002
- Humphreys SC, An HS, Erk JC, Coppes M, Lim TH, Estkowski L (1998) Oblique MRI as a useful adjunct in evaluation of cervical foraminal impingement. J Spinal Disord 11:295–299. doi: 10.1097/00002517-199808000-00005
- Edelman RR, Stark DD, Saini S, Ferrucci JT Jr, Dinsmore RE, Ladd W et al (1986) Oblique planes of section in MR imaging. Radiology 159:807–810
- Deoni SC, Peters TM, Rutt BK. High-resolution T1 and T2 mapping of the brain in a clinically acceptable time with DESPOT1 and DESPOT2. *Magn Reson Med* 2005; **53**: 237–241.
- OsiriX DICOM Viewer/Imaging Software: Open Source (MAC ONLY) available at http://www.osirix-viewer.com/index.html
- FMRIB Software Library (FSL): Library of tools to analyze MRI images. Available at http://www.fmrib.ox.ac.uk/fsl/

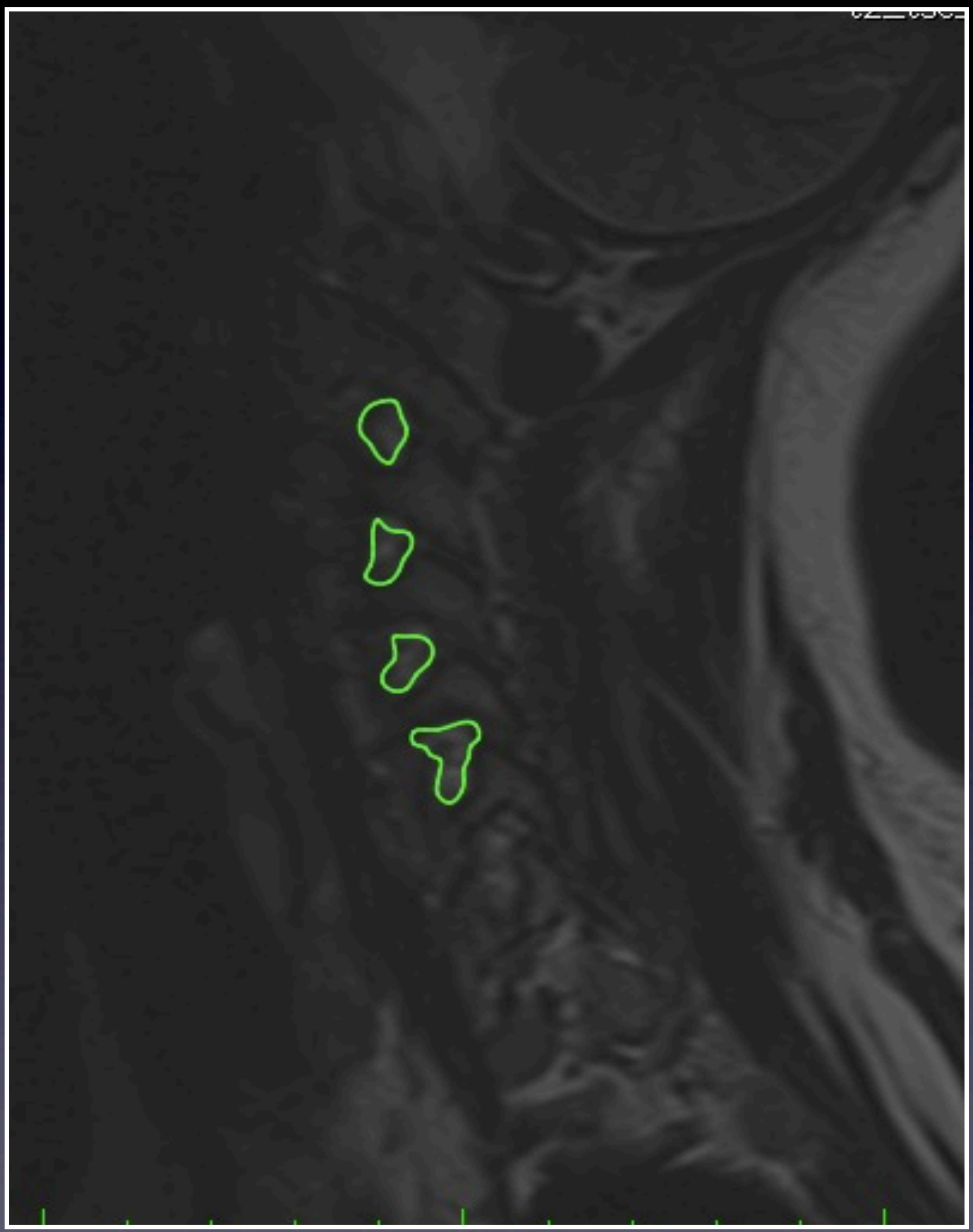
Thank You!

Appendix of Images

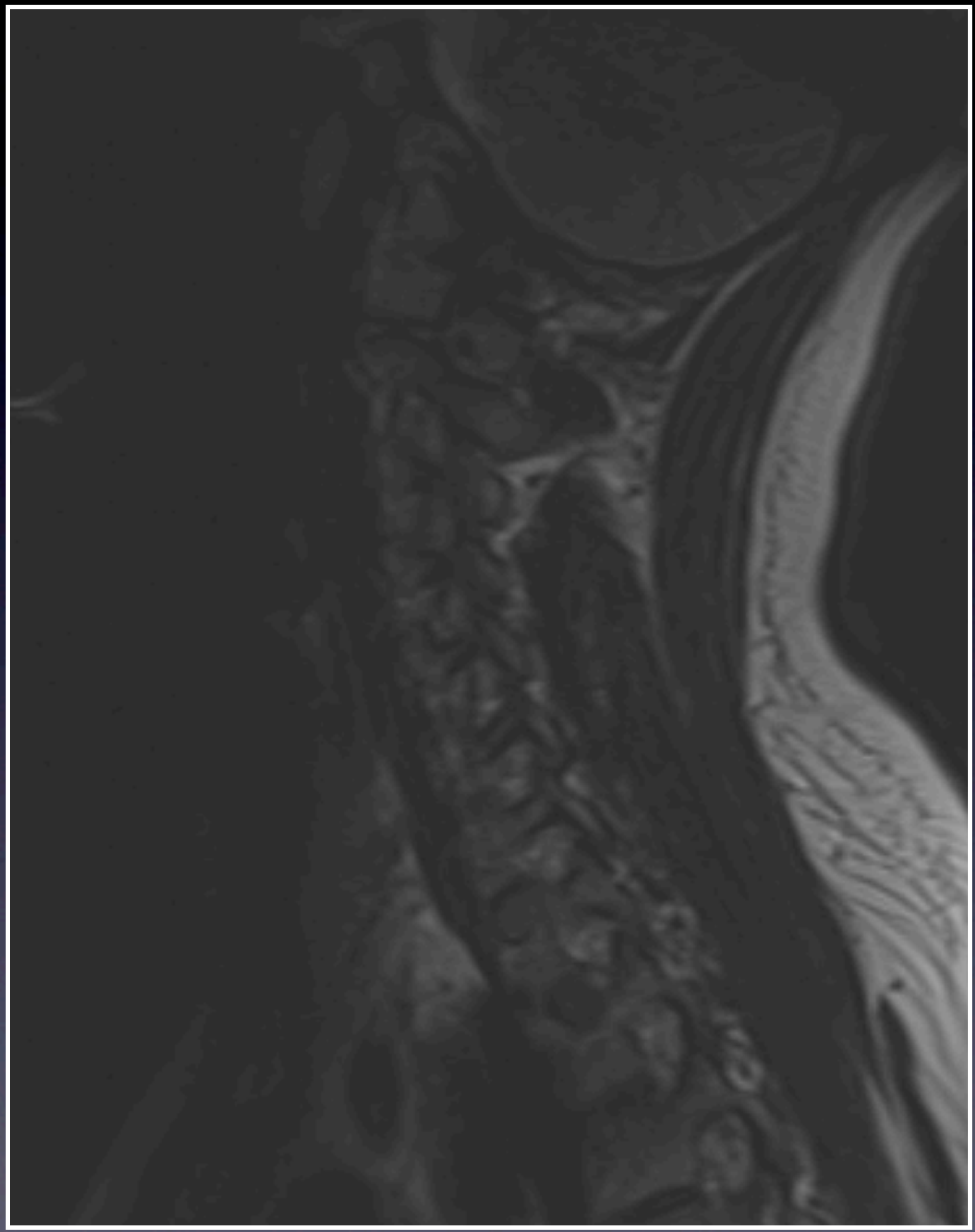


Participant 1: ROI of foramina from oblique sagittal image

Participant 2: Side by Side Comparison #2

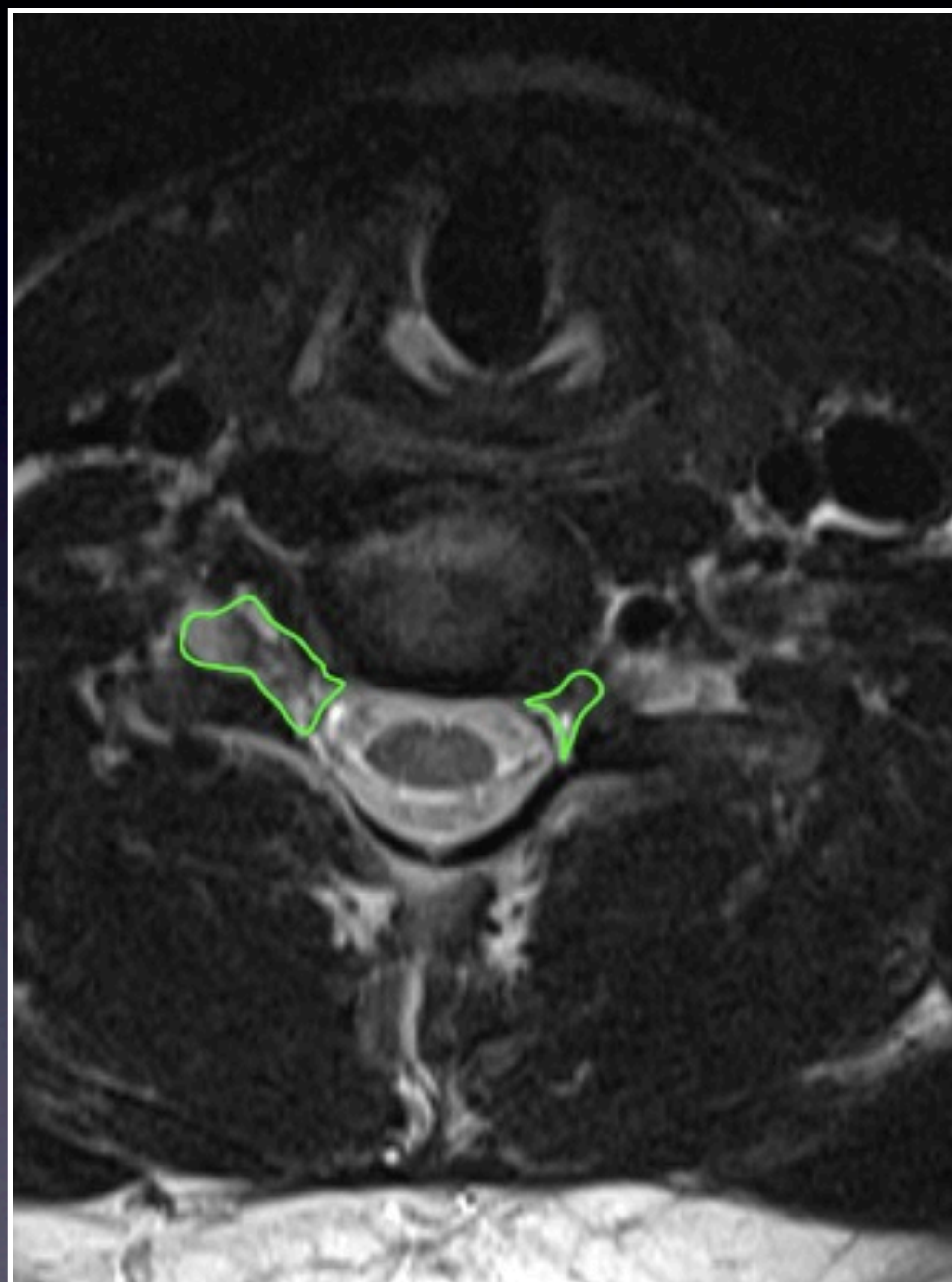


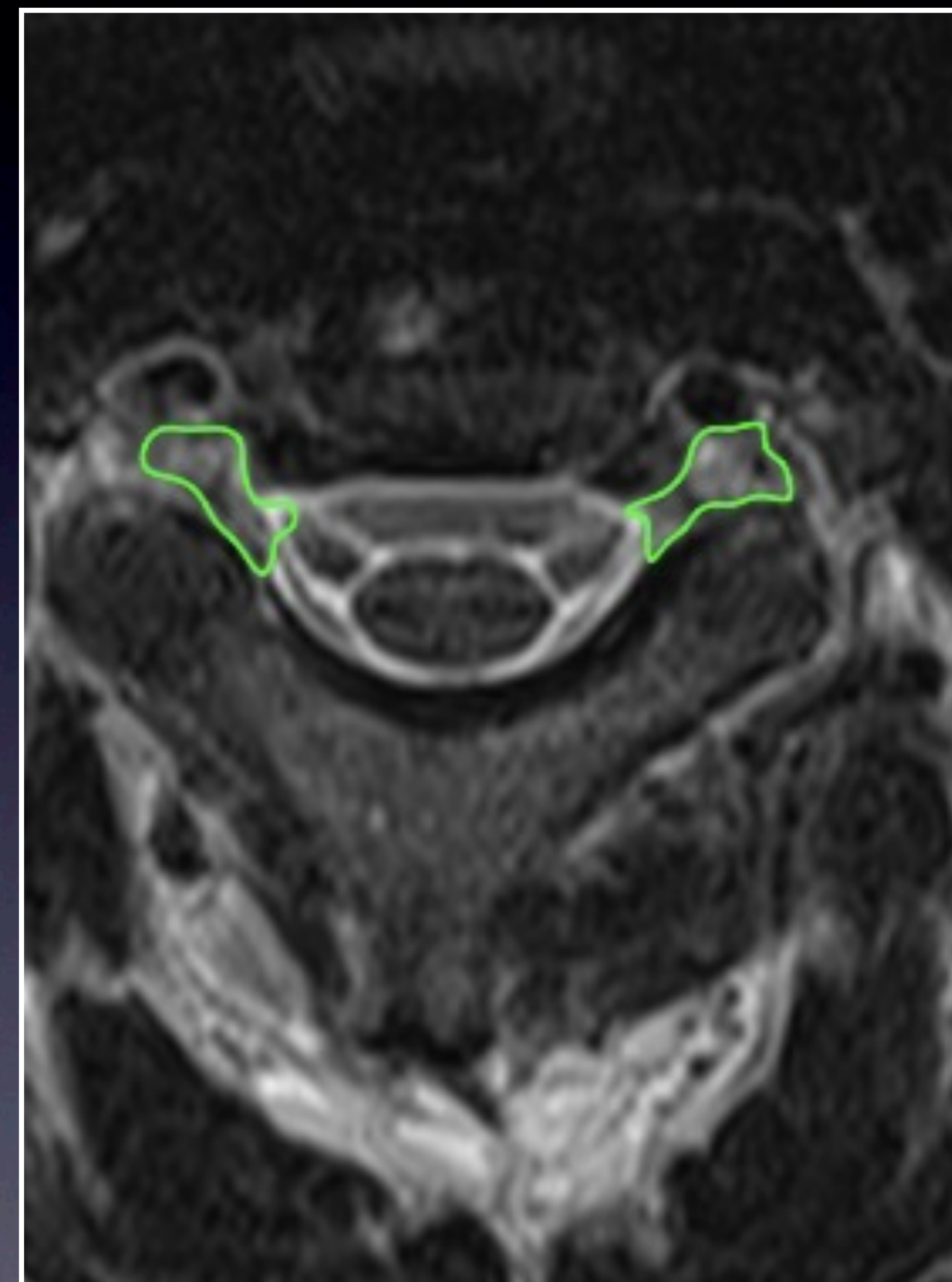
Oblique T_2 Weighted Sagittal



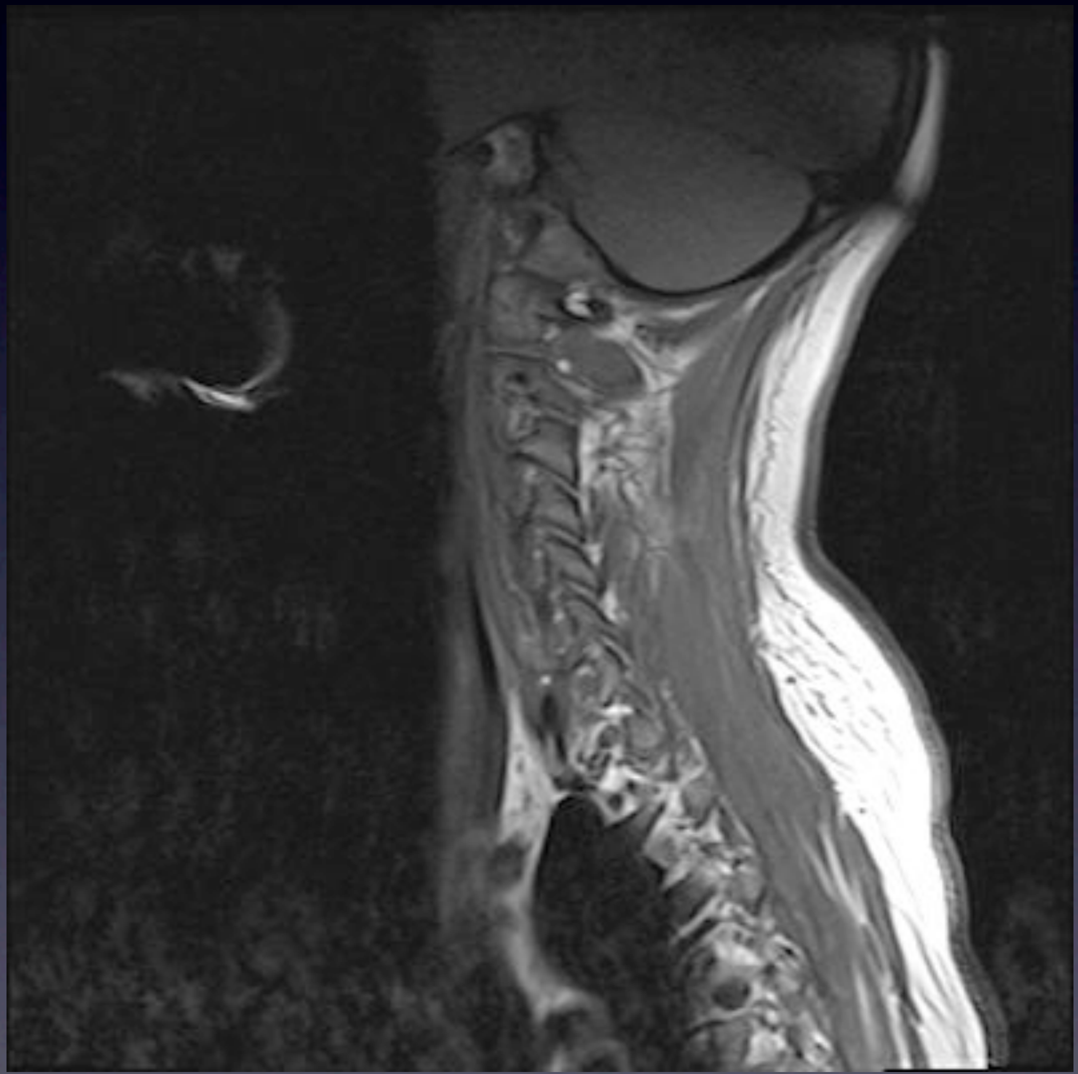
Conventional T_2 Weighted Sagittal

Axial Contours of Foramen

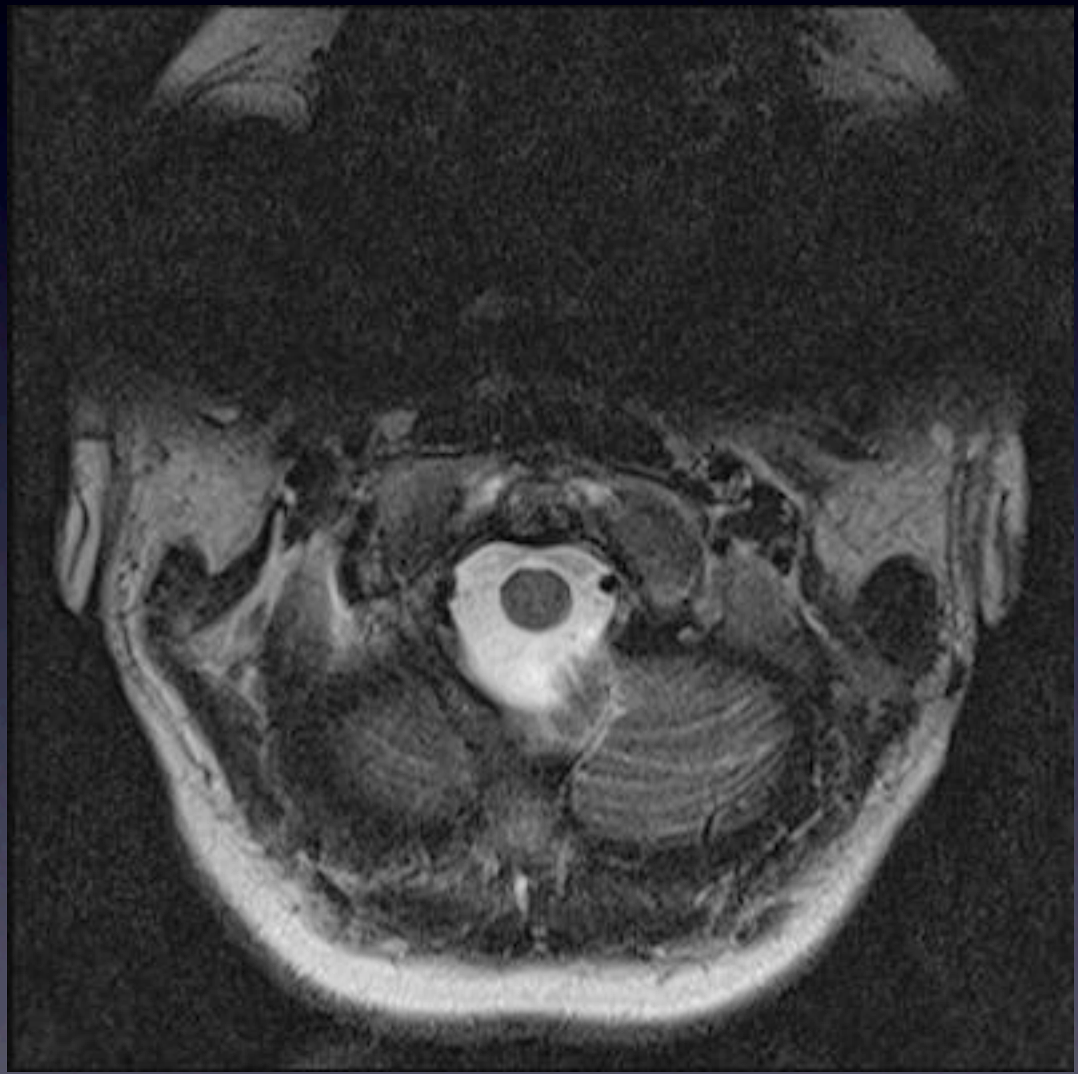




Additional Images (as video) Participant A

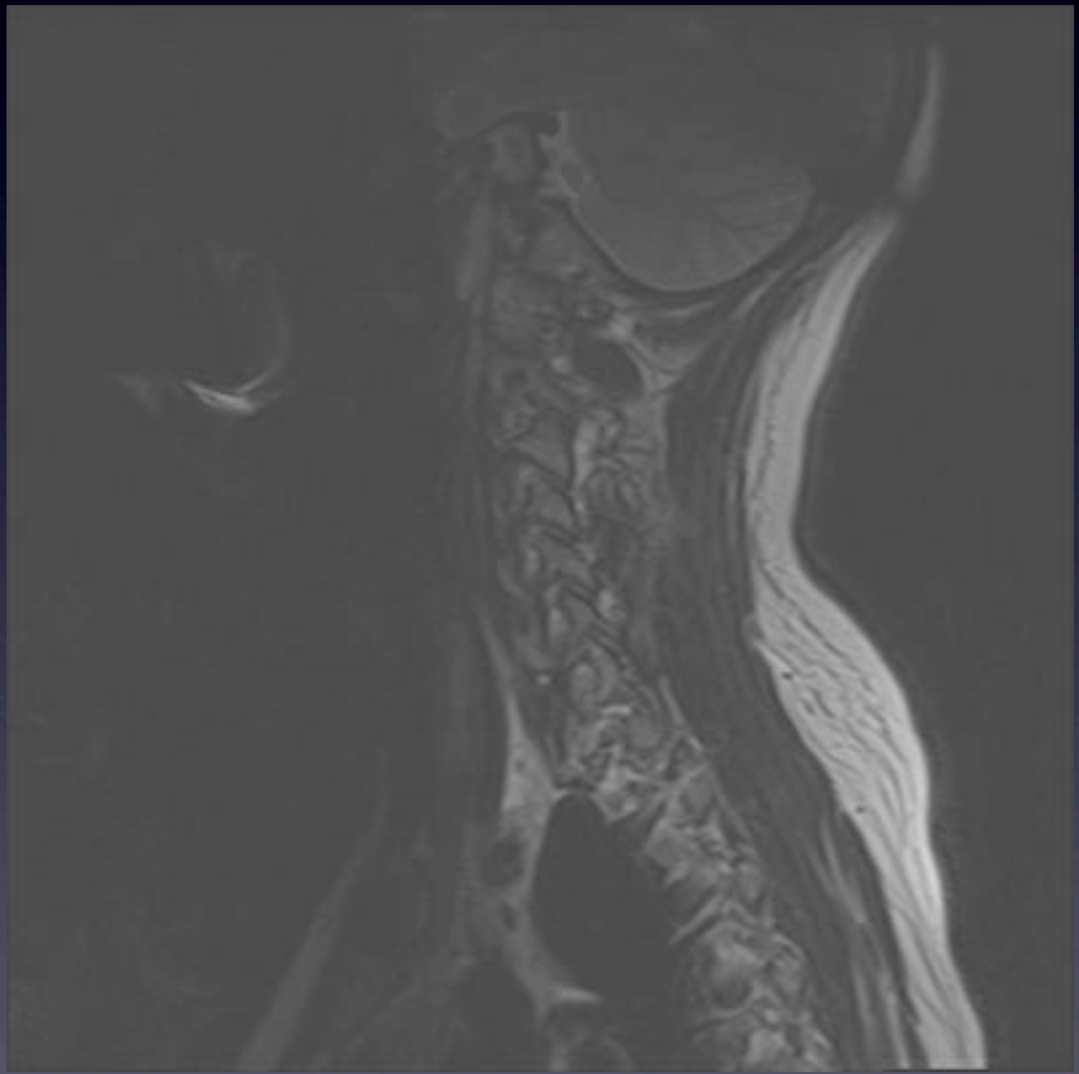


T_1 weighted Sagittal Data

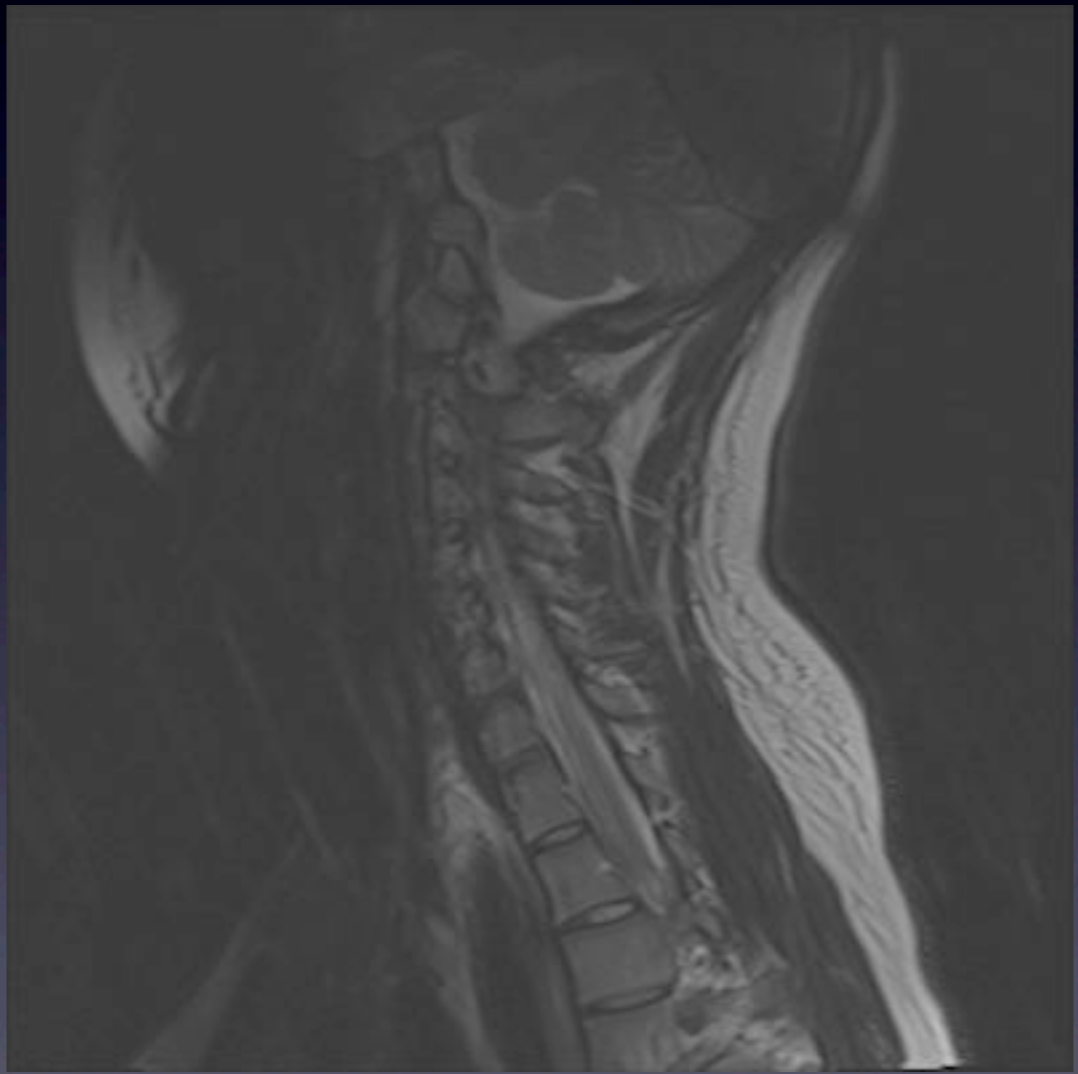


T_2 weighted Axial Data

Additional Images (as video)
Participant A

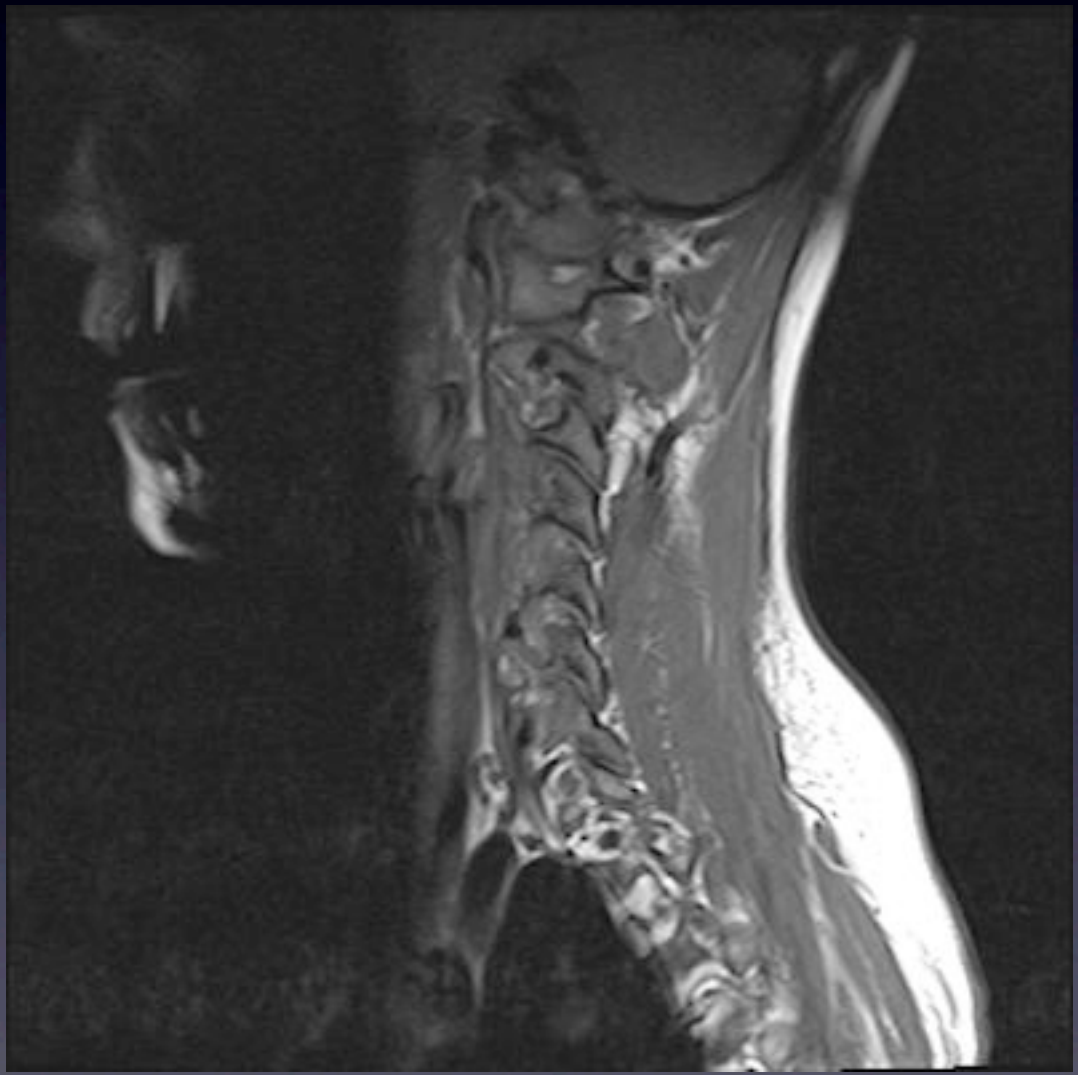


T_2 weighted Sagittal Data



T_2 weighted Sagittal Data (Oblique)

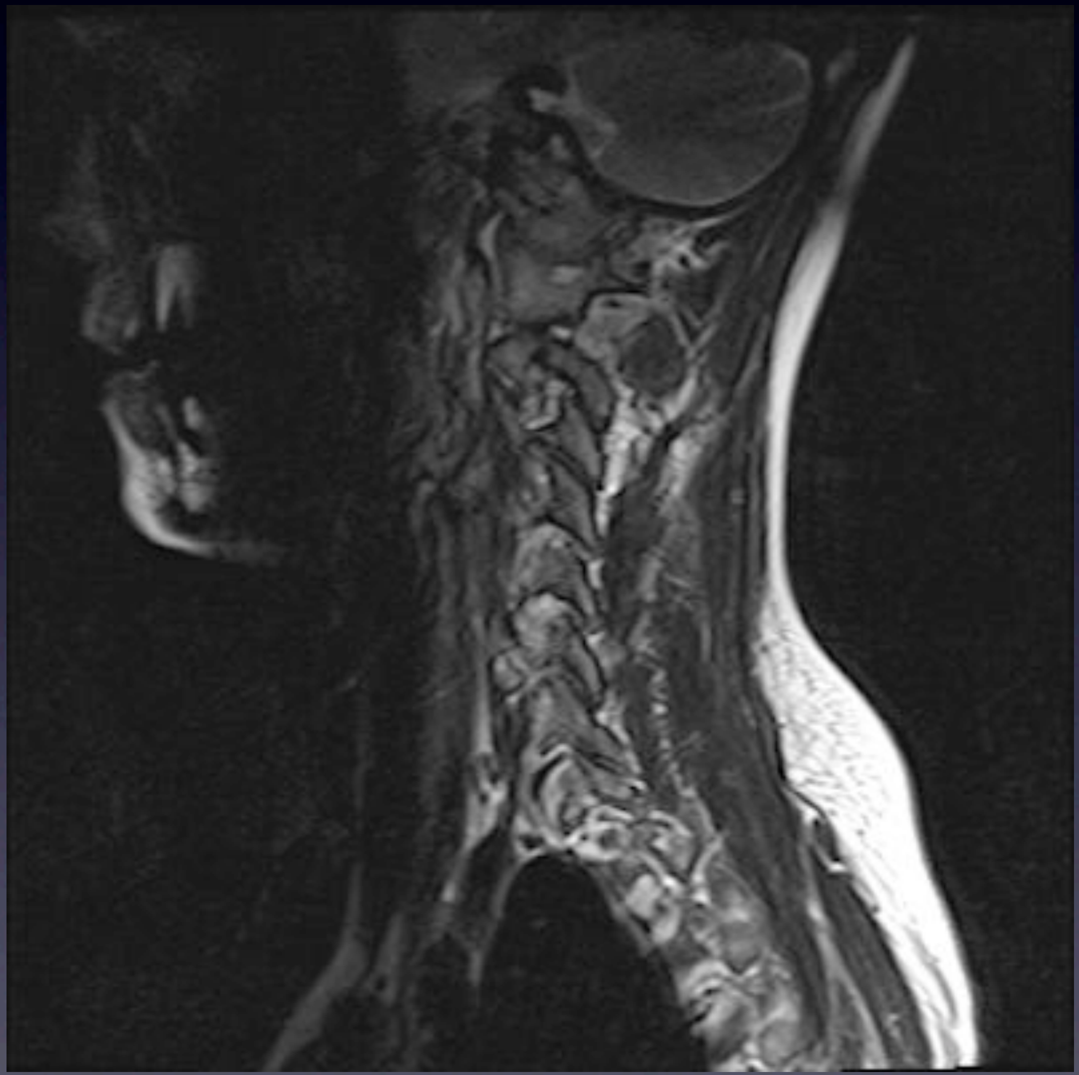
Additional Images (as video)
Participant B



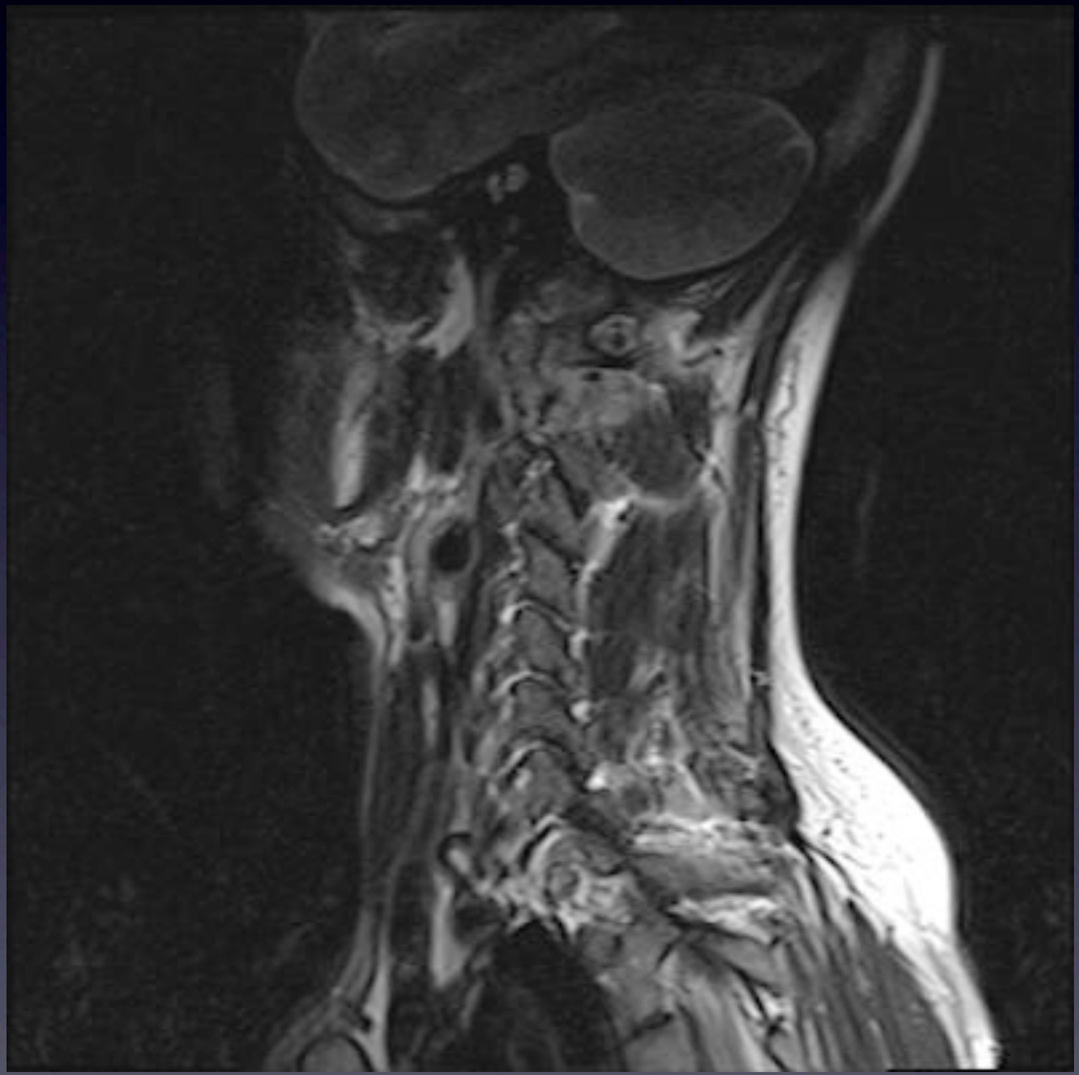
T_1 weighted Sagittal Data

T_2 weighted Axial Data

Additional Images (as video)
Participant B

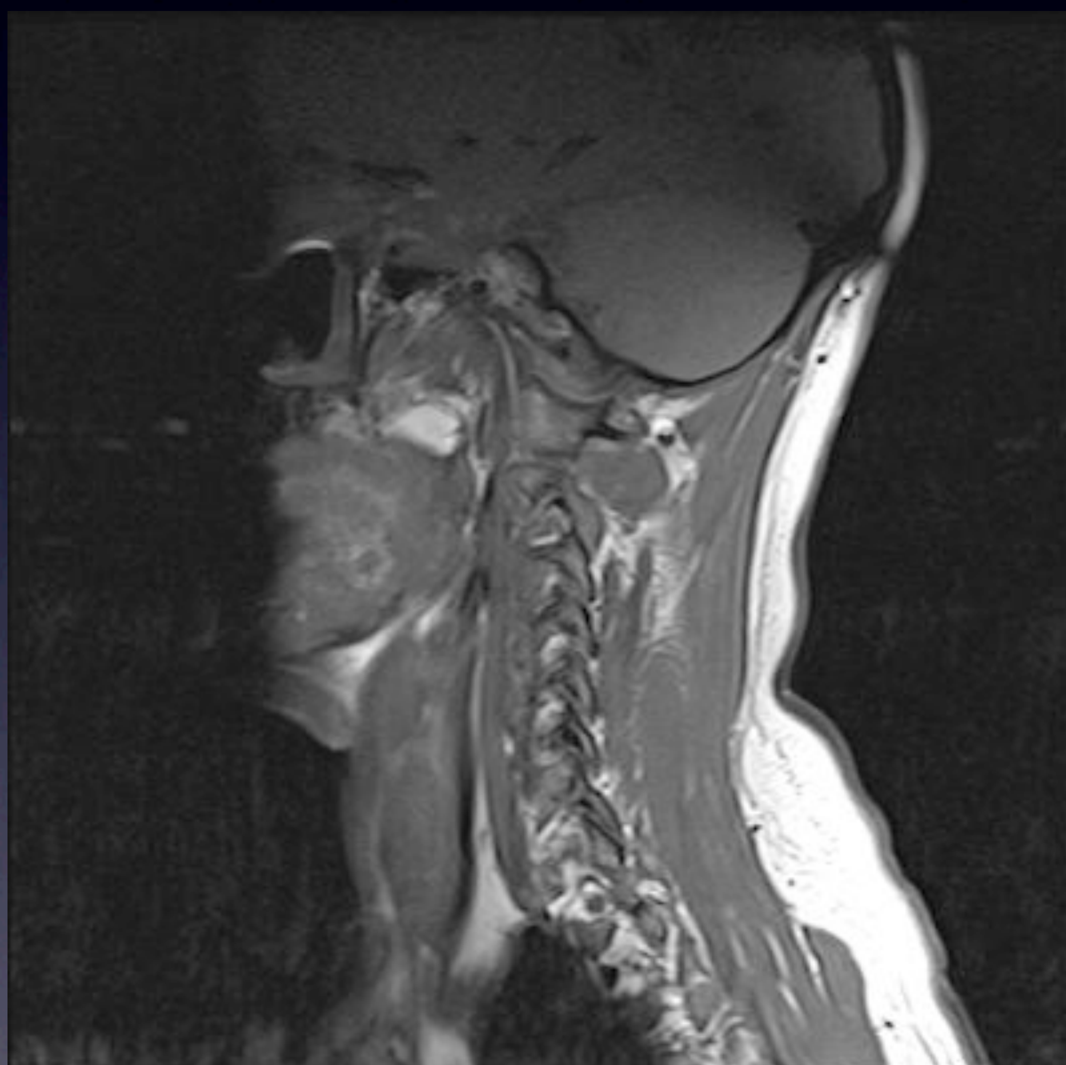


T_2 weighted Sagittal Data

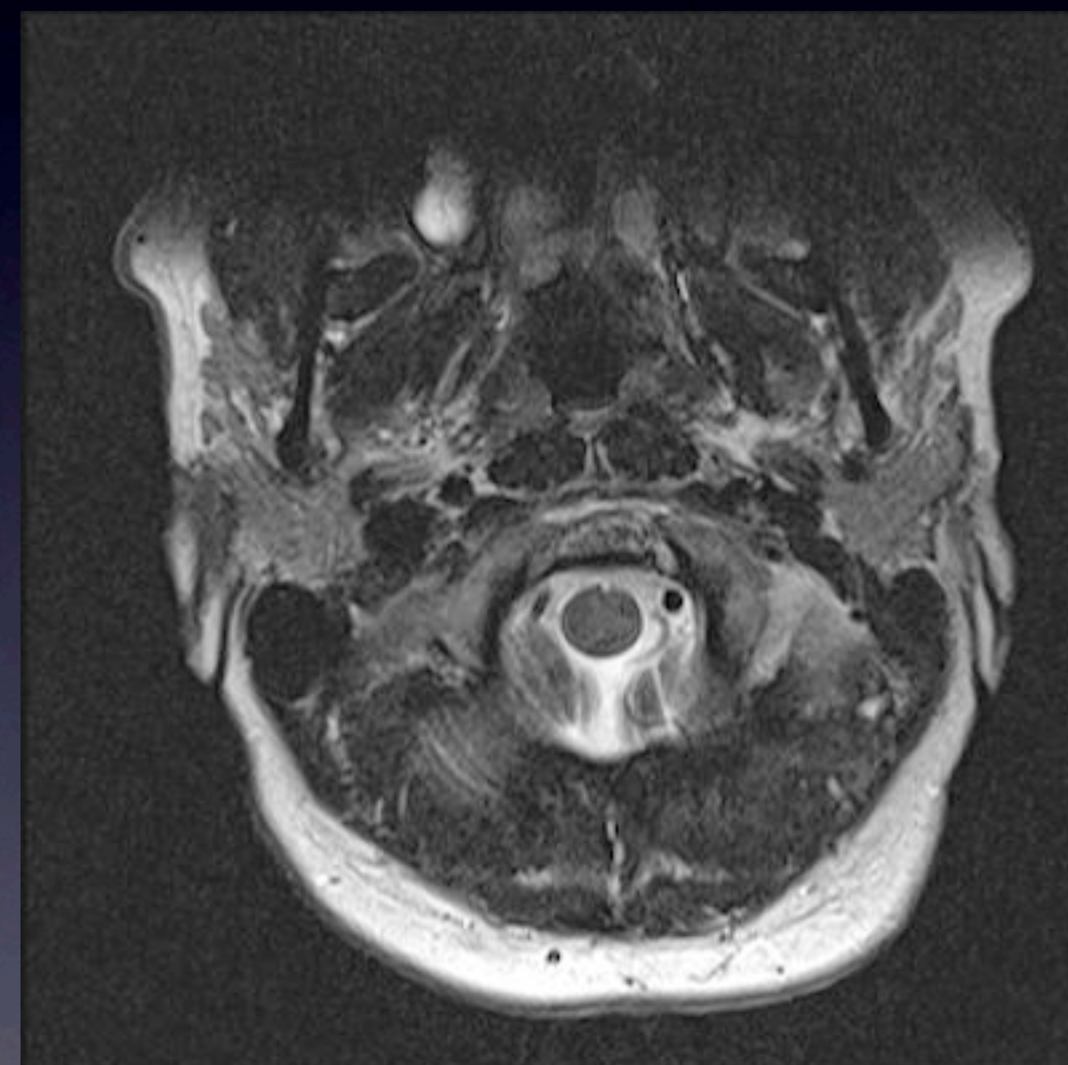


T_2 weighted Sagittal Data (Oblique)

Additional Images (as video)
Participant C

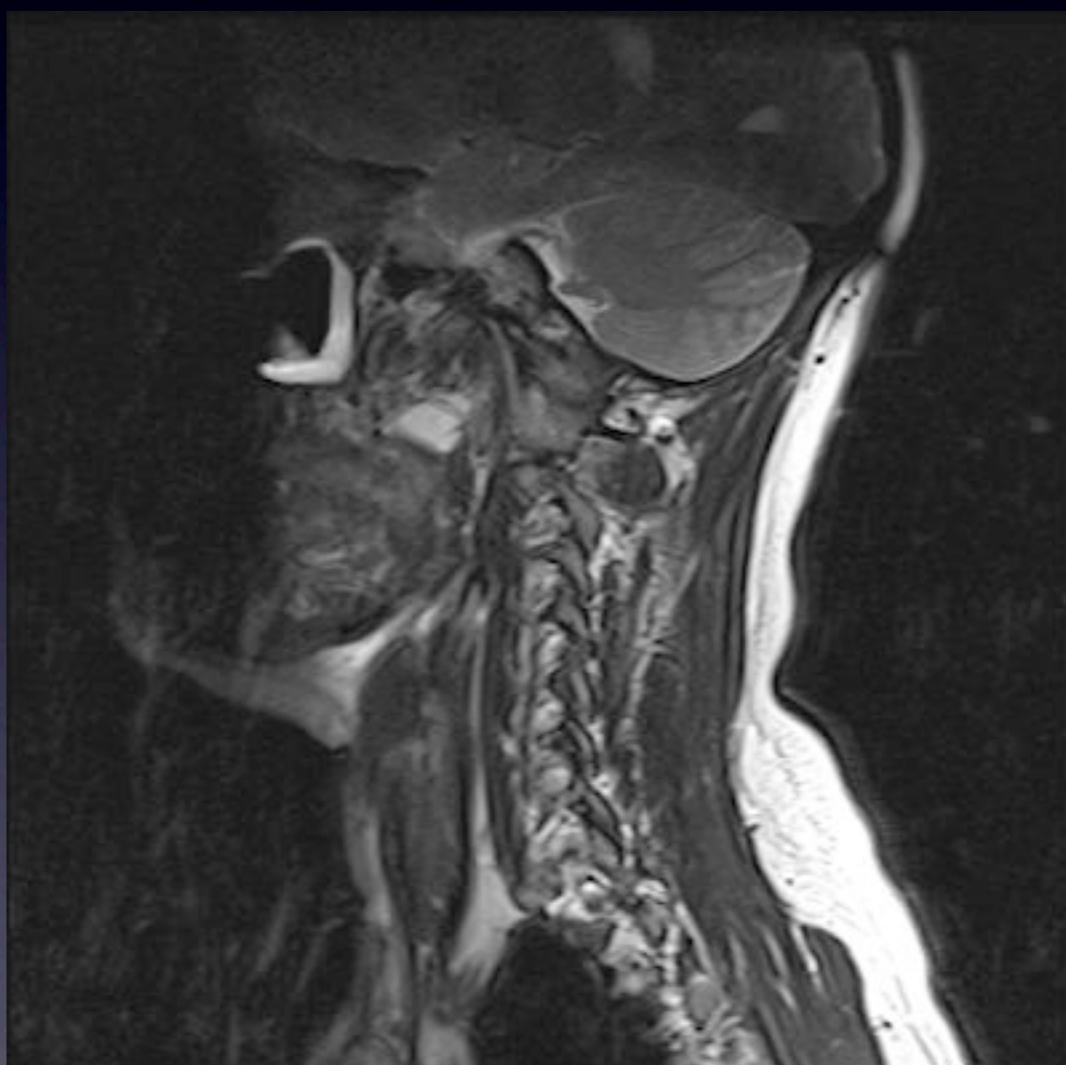


T_1 weighted Sagittal Data

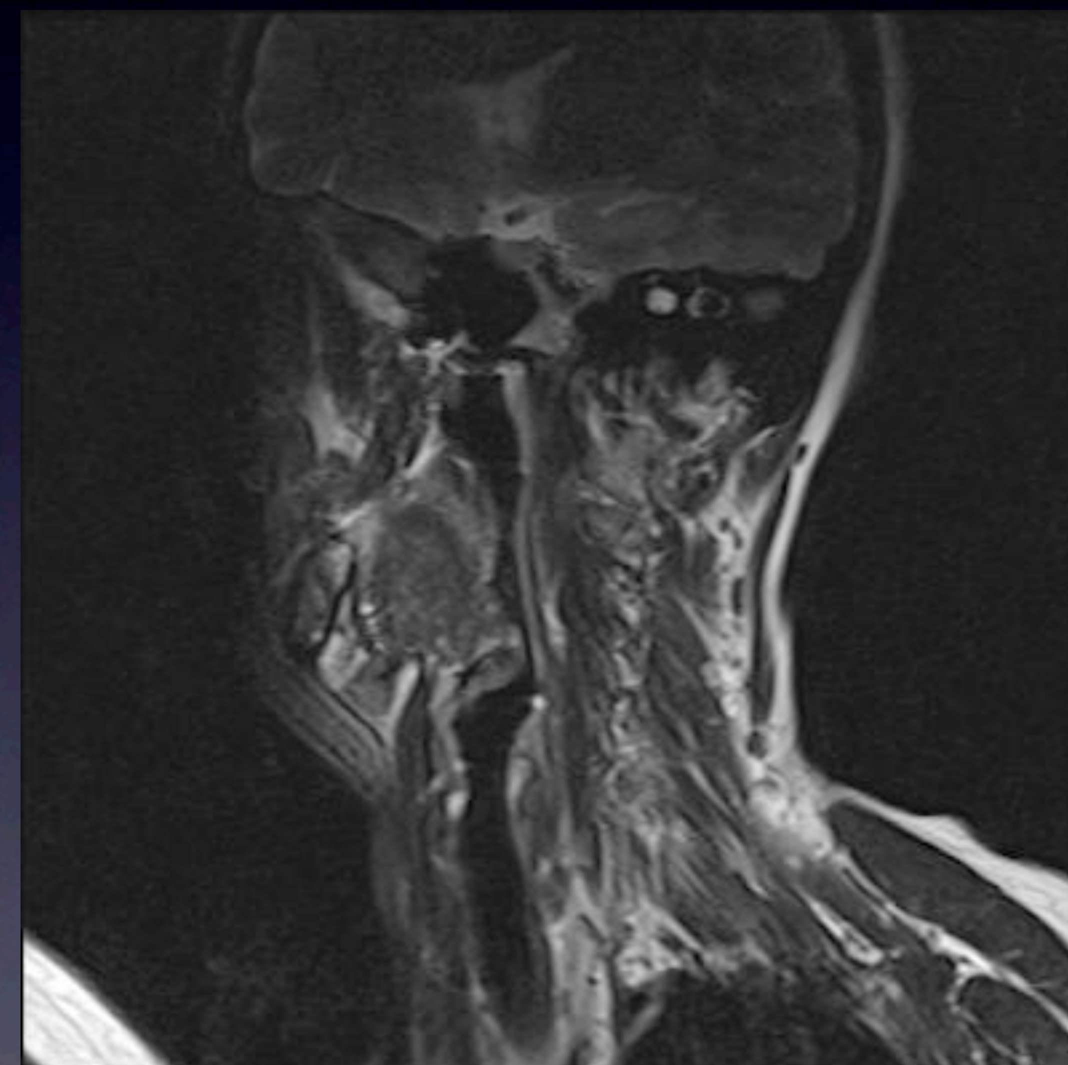


T_2 weighted Axial Data

Additional Images (as video) Participant D



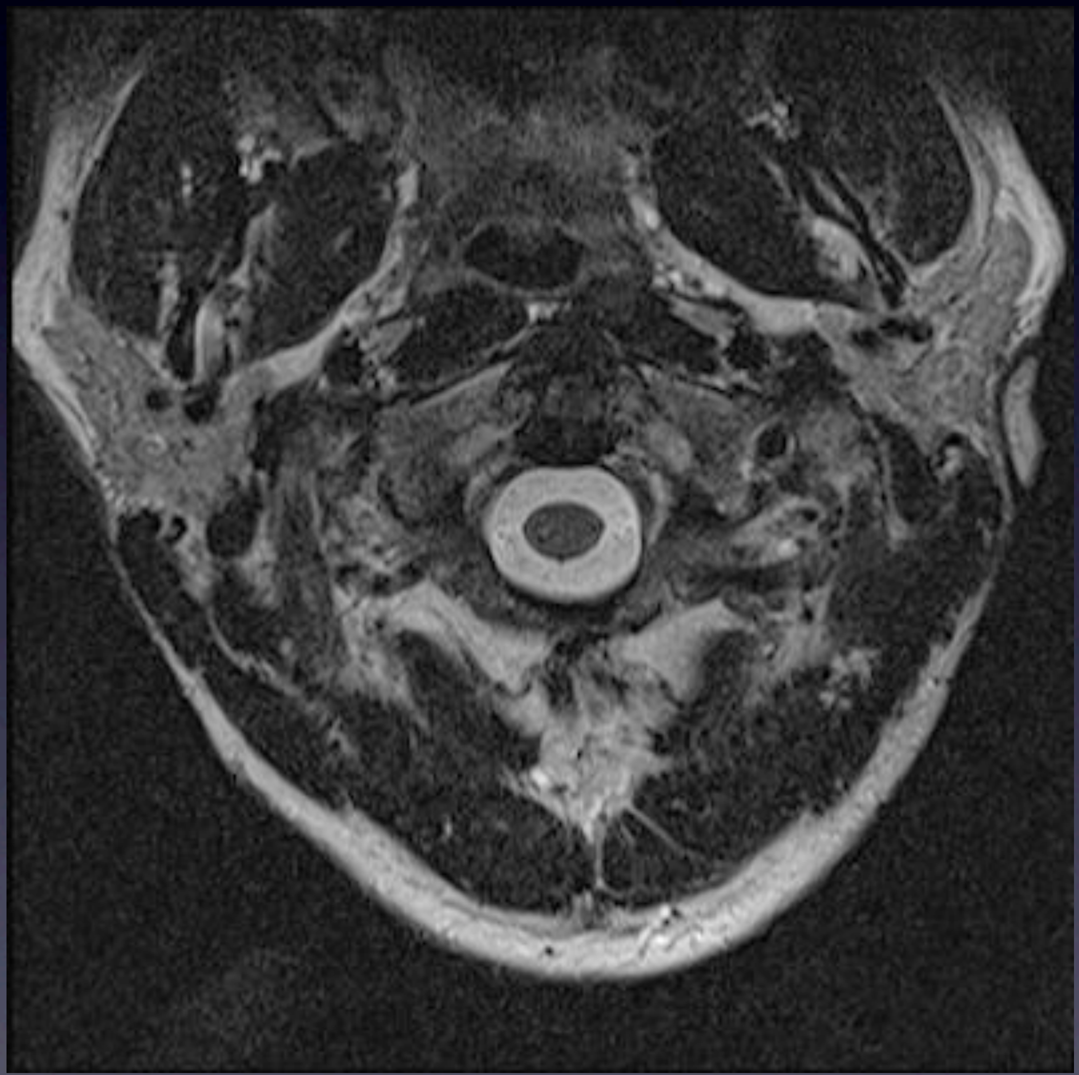
T_2 weighted Sagittal Data



T_2 weighted Sagittal Data (Oblique)

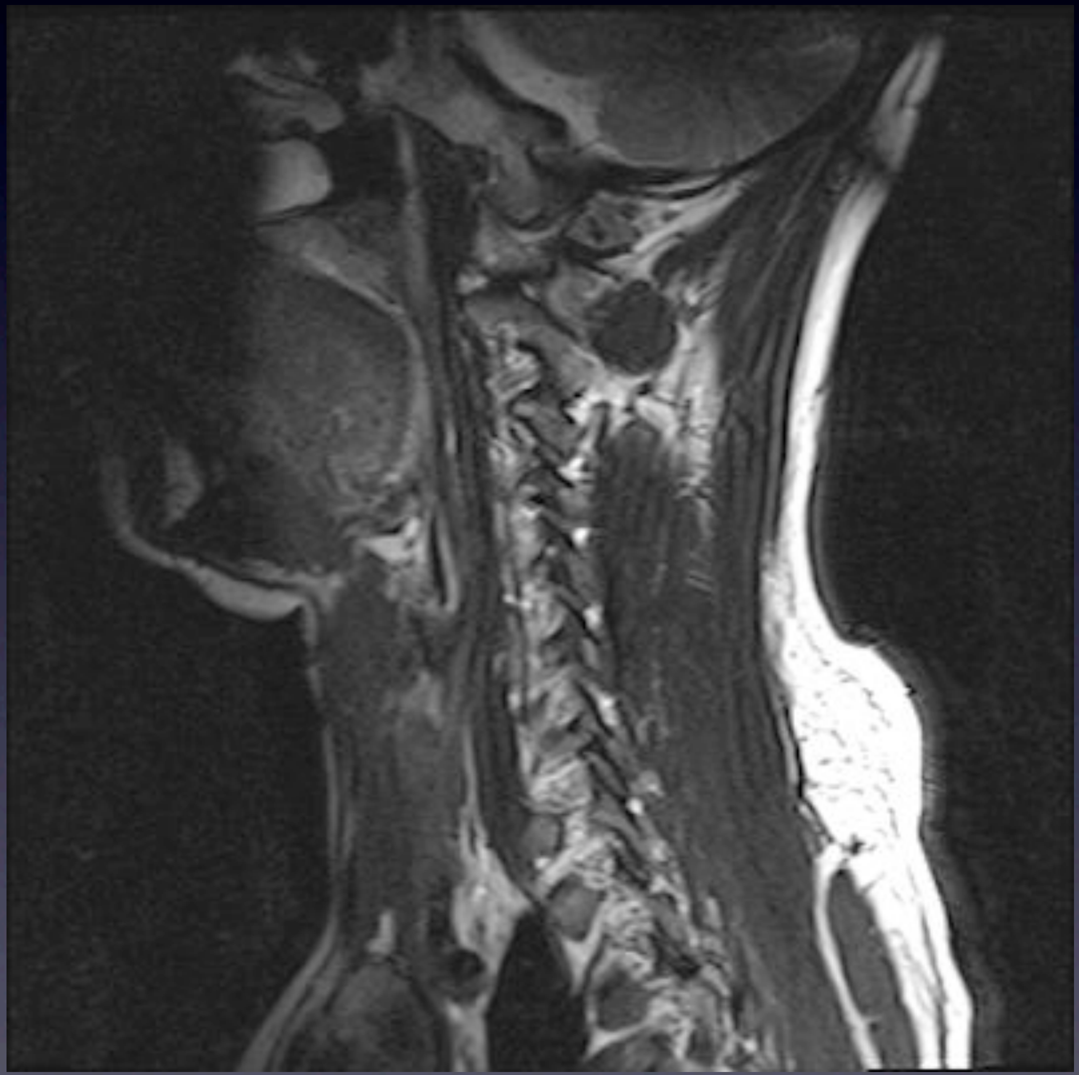
Additional Images (as video)
Participant D

T_1 weighted Sagittal Data

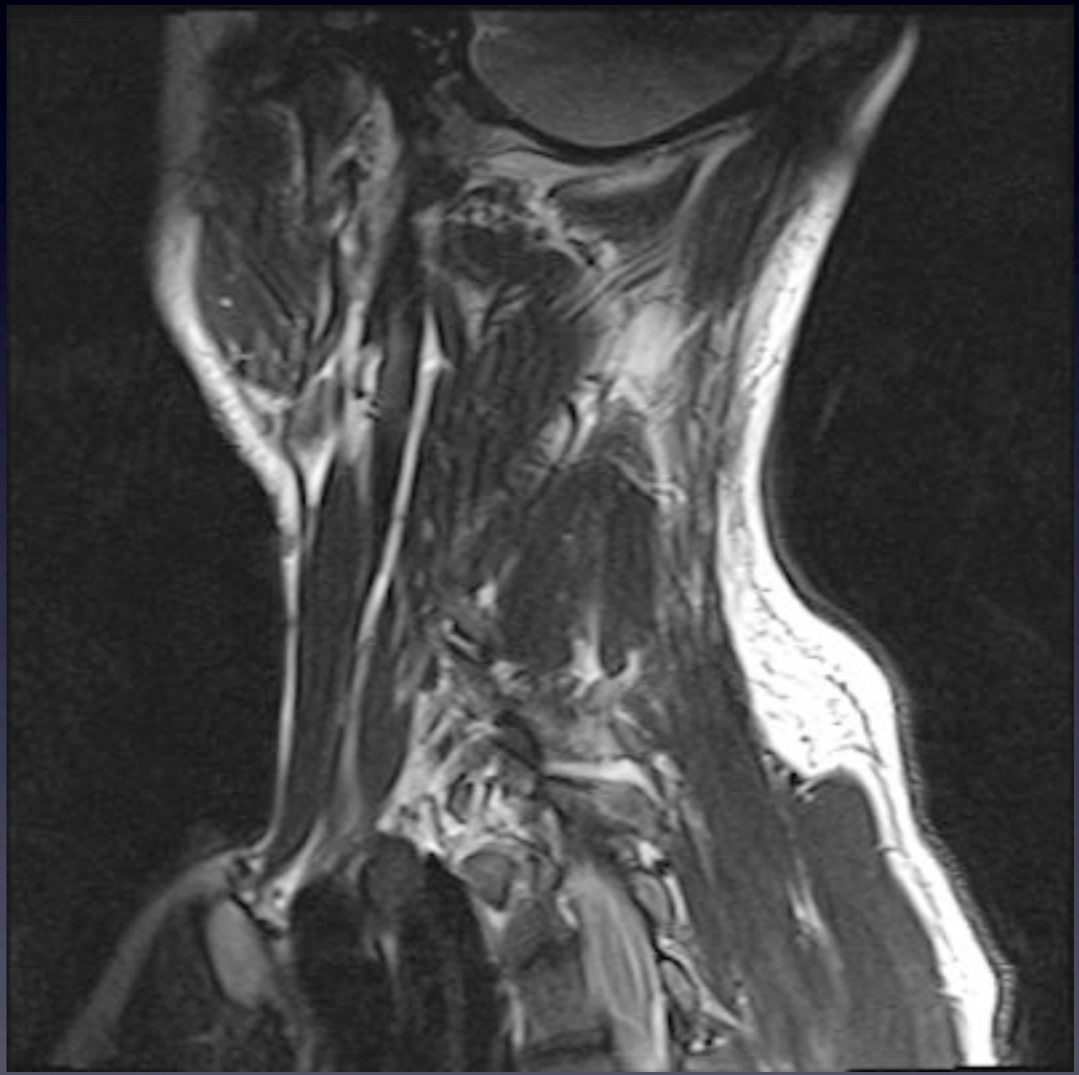


T_2 weighted Axial Data

Additional Images (as video) Participant D



T_2 weighted Sagittal Data



T_2 weighted Sagittal Data (Oblique)