



DICOM and Slicer: A Tutorial

Sonia Pujol, Ph.D.

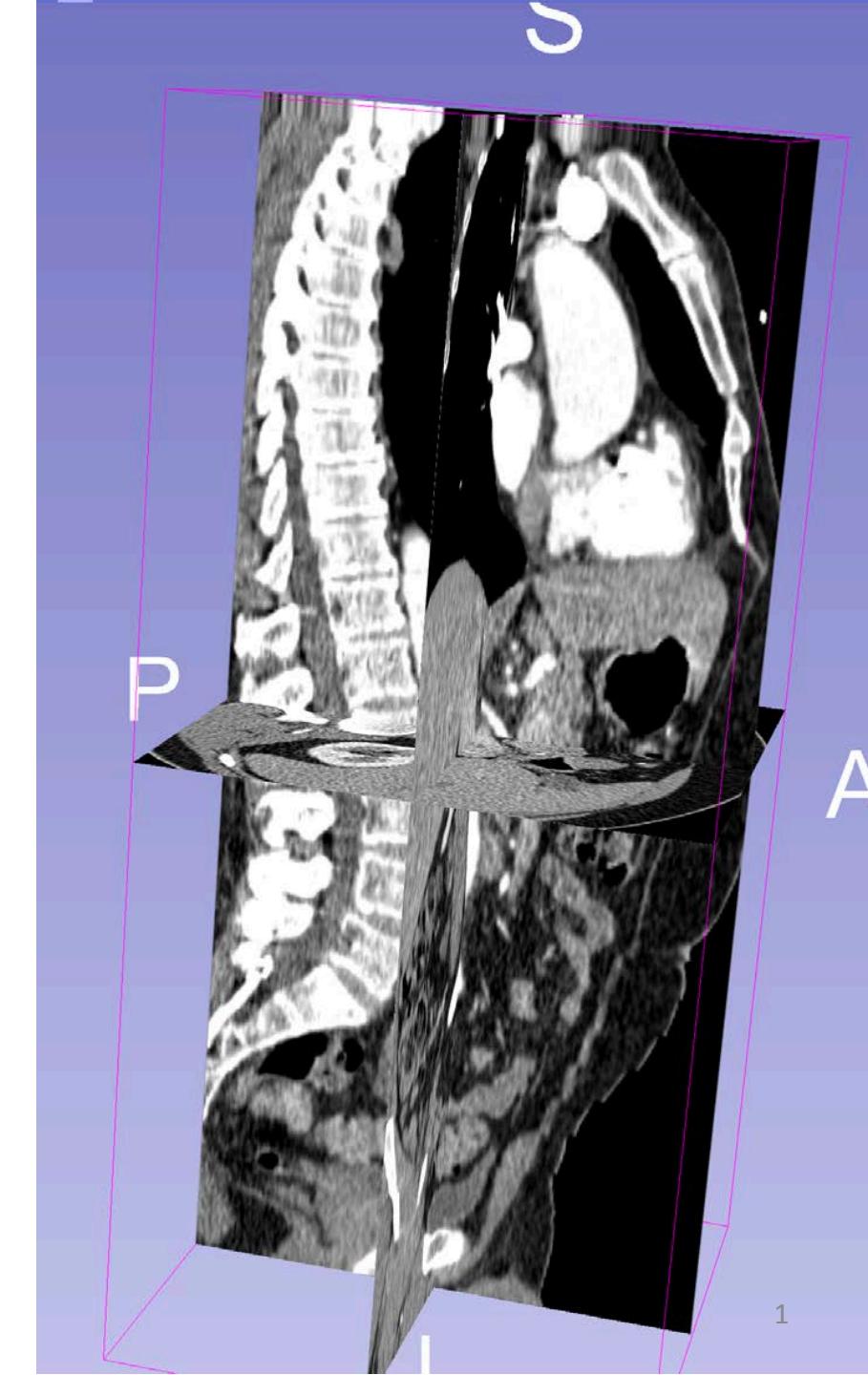
Assistant Professor of Radiology

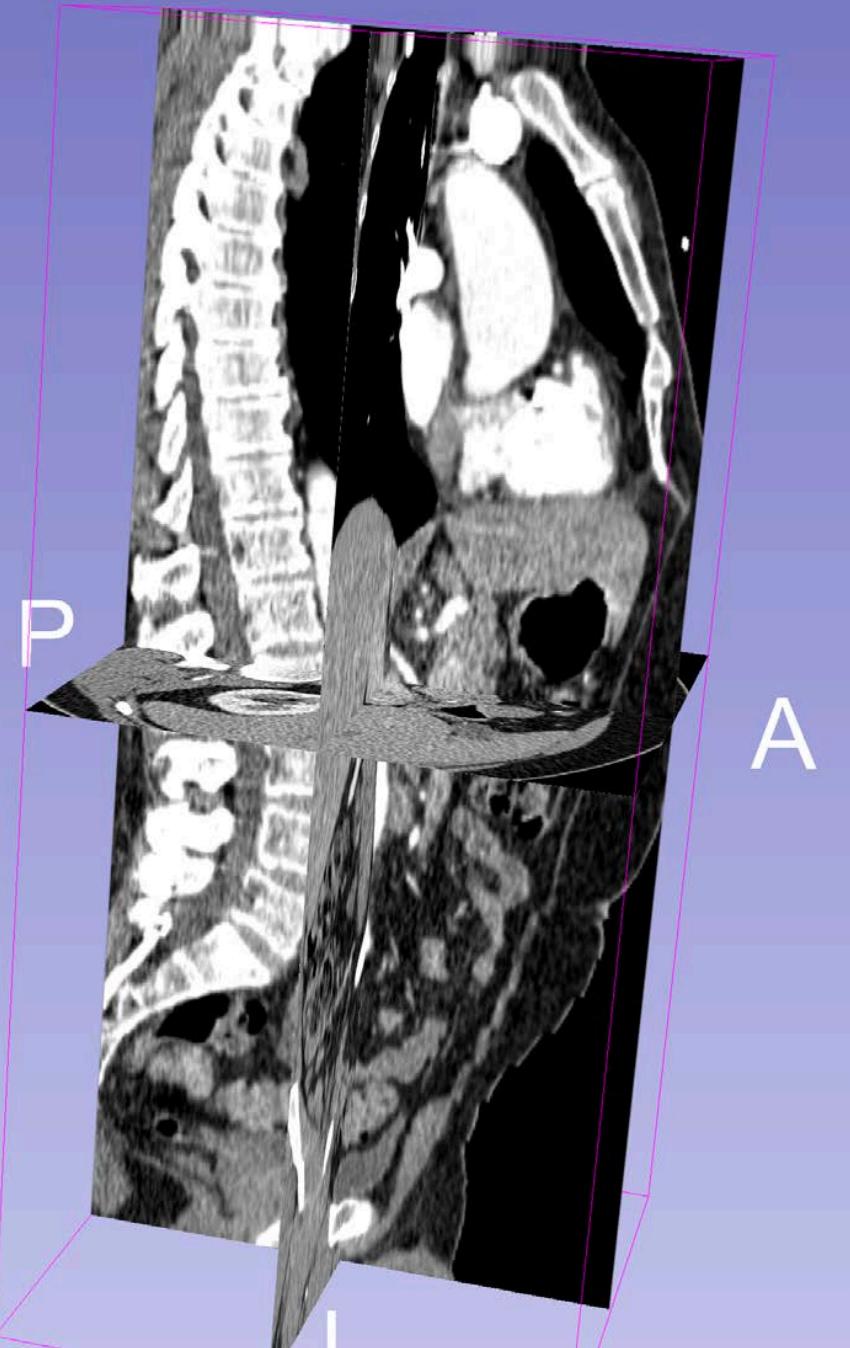
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Objective

This tutorial provides a basic introduction to the DICOM standard, and shows how to visualize DICOM images in 3D Slicer version 5.0



Tutorial material

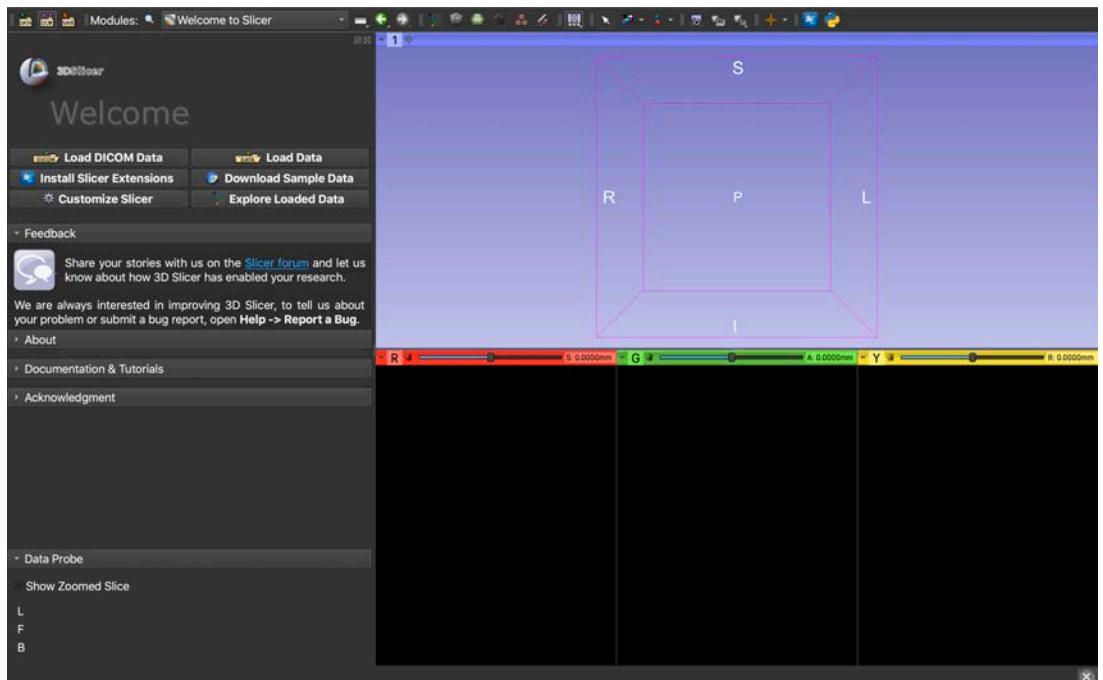
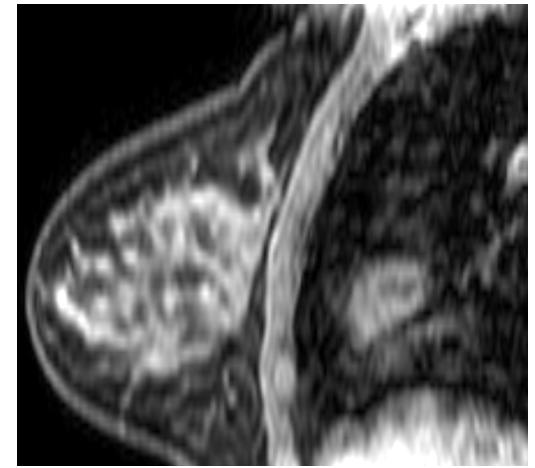
3D Slicer version 5.0

<https://download.slicer.org>

SlicerDICOMTutorialData

DICOM Torso CT

DICOM Breast MRI



Tutorial Outline



Part 1: Introduction to DICOM



Part 2: Loading and Visualizing DICOM data in 3D Slicer version 5.0

Disclaimer

- 3D Slicer is a free open source software application distributed under a BSD style license
- The software is not FDA approved or CE-Marked, and is for research use only



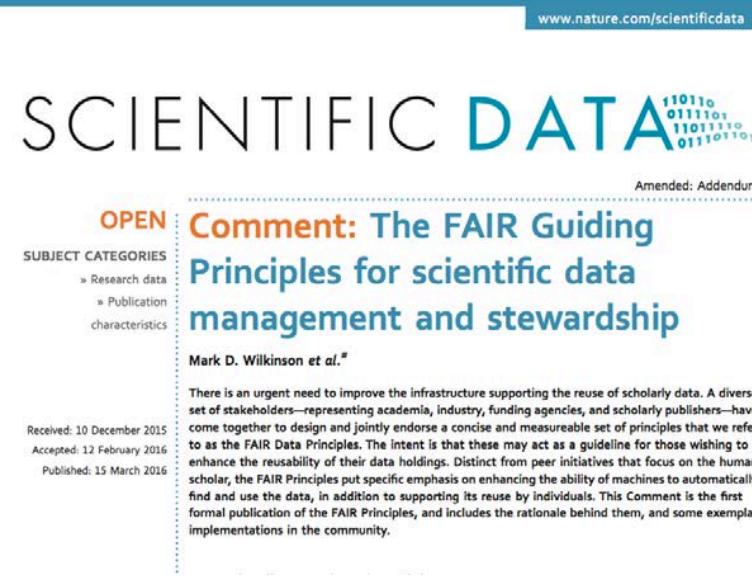
Part 1: Introduction to DICOM

Reproducible Science

- Reproducible science is critical to drive research and accelerate discoveries
- Open-source software tools such as 3D Slicer and data standards such as DICOM contribute to the reproducibility of scientific results in biomedical research



F.A.I.R. Principles



The FAIR Guiding Principles for scientific data management and stewardship.

Wilkinson et al. Sci. Data 2016

<http://go-fair.org/fair-principles>

- **Findable:** Data are easily findable
- **Accessible:** Users know how to access the data, including authentication and authorization
- **Interoperable:** Data can be integrated with other data and can interoperate with applications for storage and analysis
- **Reusable:** Data can be replicated or combined for new research

The DICOM standard

- DICOM (Digital Imaging and Communications in Medicine) is the international standard for handling, storing, printing and transmitting medical imaging data
- Clinical imaging equipment (CT scanners, MR scanners, X-Ray and ultrasound machines) generate DICOM files



DICOM History

- 1982: The American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) initiate standards for the interconnection of medical imaging devices
- 1985: Publication of the ACR-NEMA Digital Imaging and Communications Standards version 1.0
- 1988: Publication of the ACR-NEMA Digital Imaging and Communications Standards version 2.0
- 1993: Publication of the ACR-NEMA Standards version 3.0 also referred to as the Digital Imaging and Communication in Medicine (DICOM) standard

DICOM Today

- The DICOM standard is continuously being refined to address new community needs through multiple releases every year
- As of 2020/07/06, the DICOM standard is DICOM PS3 2020c and contains 4,000 pages
- DICOM Working Groups are established by the DICOM Standard Committee to develop the Standard for a particular modality, clinical domain or technical area (e.g. WG-16 Magnetic Resonance)

<http://dicomstandard.org>

FAIR Data and the DICOM Standard

www.nature.com/scientificdata

SCIENTIFIC DATA 1101110
0111101
11011110
011101101

OPEN

SUBJECT CATEGORIES
» Research data
» Publication characteristics

Amended: Addendum

Comment: The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson et al.*

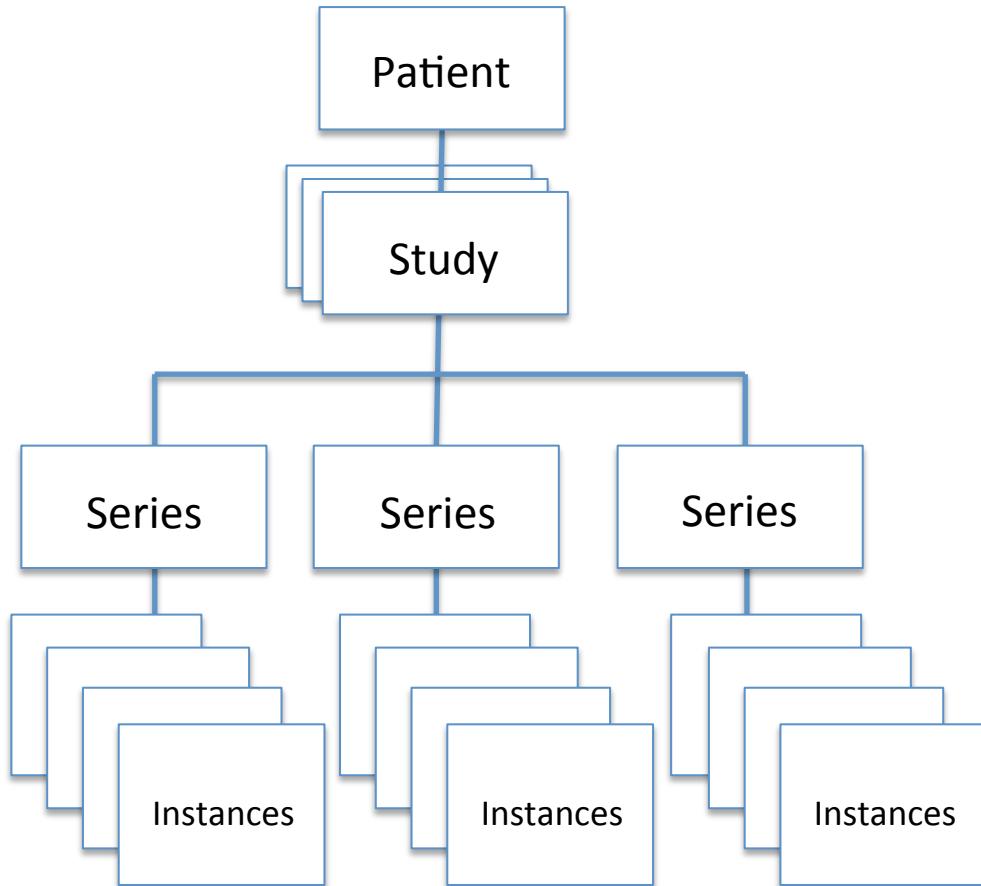
Received: 10 December 2015
Accepted: 12 February 2016
Published: 15 March 2016

There is an urgent need to improve the infrastructure supporting the reuse of scholarly data. A diverse set of stakeholders—representing academia, industry, funding agencies, and scholarly publishers—have come together to design and jointly endorse a concise and measurable set of principles that we refer to as the FAIR Data Principles. The intent is that these may act as a guideline for those wishing to enhance the reusability of their data holdings. Distinct from peer initiatives that focus on the human scholar, the FAIR Principles put specific emphasis on enhancing the ability of machines to automatically find and use the data, in addition to supporting its reuse by individuals. This Comment is the first formal publication of the FAIR Principles, and includes the rationale behind them, and some exemplar implementations in the community.



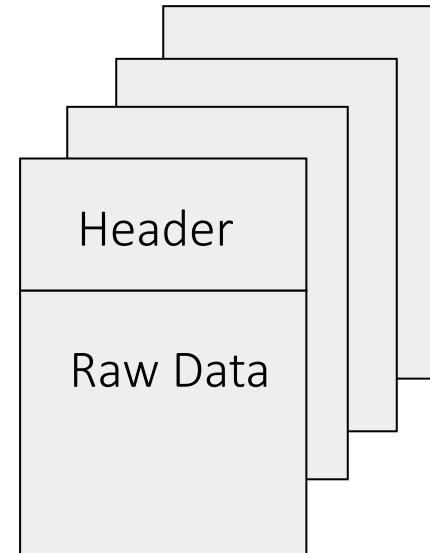
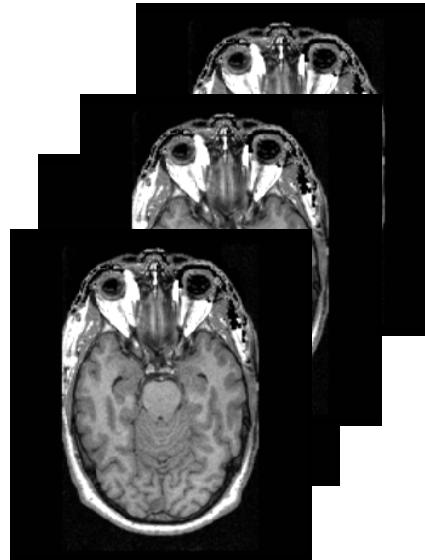
The DICOM Standard facilitates compliance of imaging data with FAIR principles

DICOM Data Model



- In the DICOM data model, a **DICOM Study** consists of several **DICOM Series**, and each **DICOM Series** contains **DICOM Instances**
- Each of the **DICOM Studies**, **Series** and **Instances** are assigned a **Unique Identifier (UID)**

Example of DICOM instances: DICOM MRI Image data

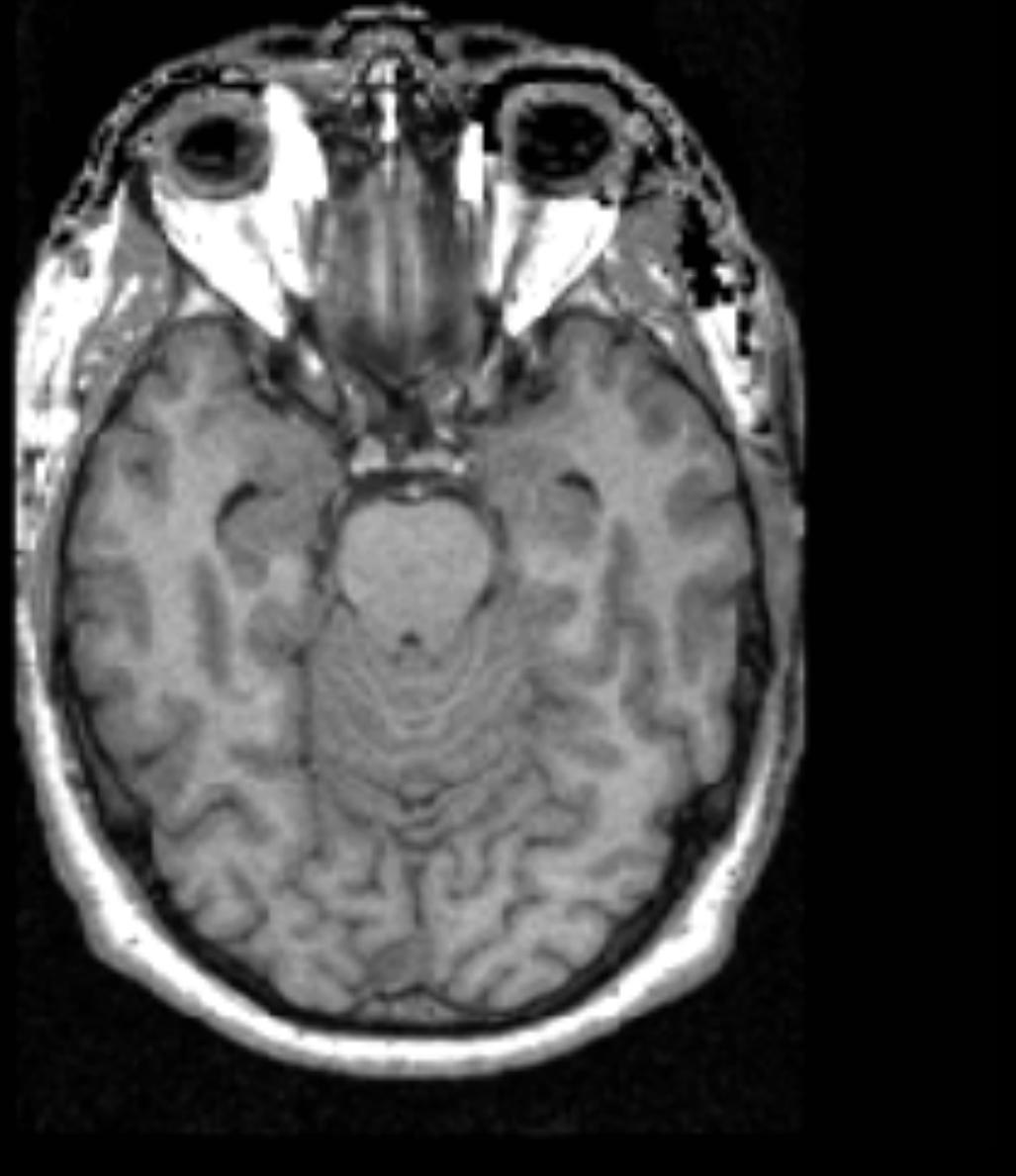


An MRI image is an example of DICOM Instance that consists of a **DICOM header** and an **image dataset**

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```

Example of DICOM header content

- The DICOM header contains metadata information on the patient, study and imaging data.
- Original data from the scanner tell users important elements about the acquisition
- The metadata information is accessible through DICOM tags
- DICOM tags uniquely identify DICOM attributes



0002
0002
0002
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0002

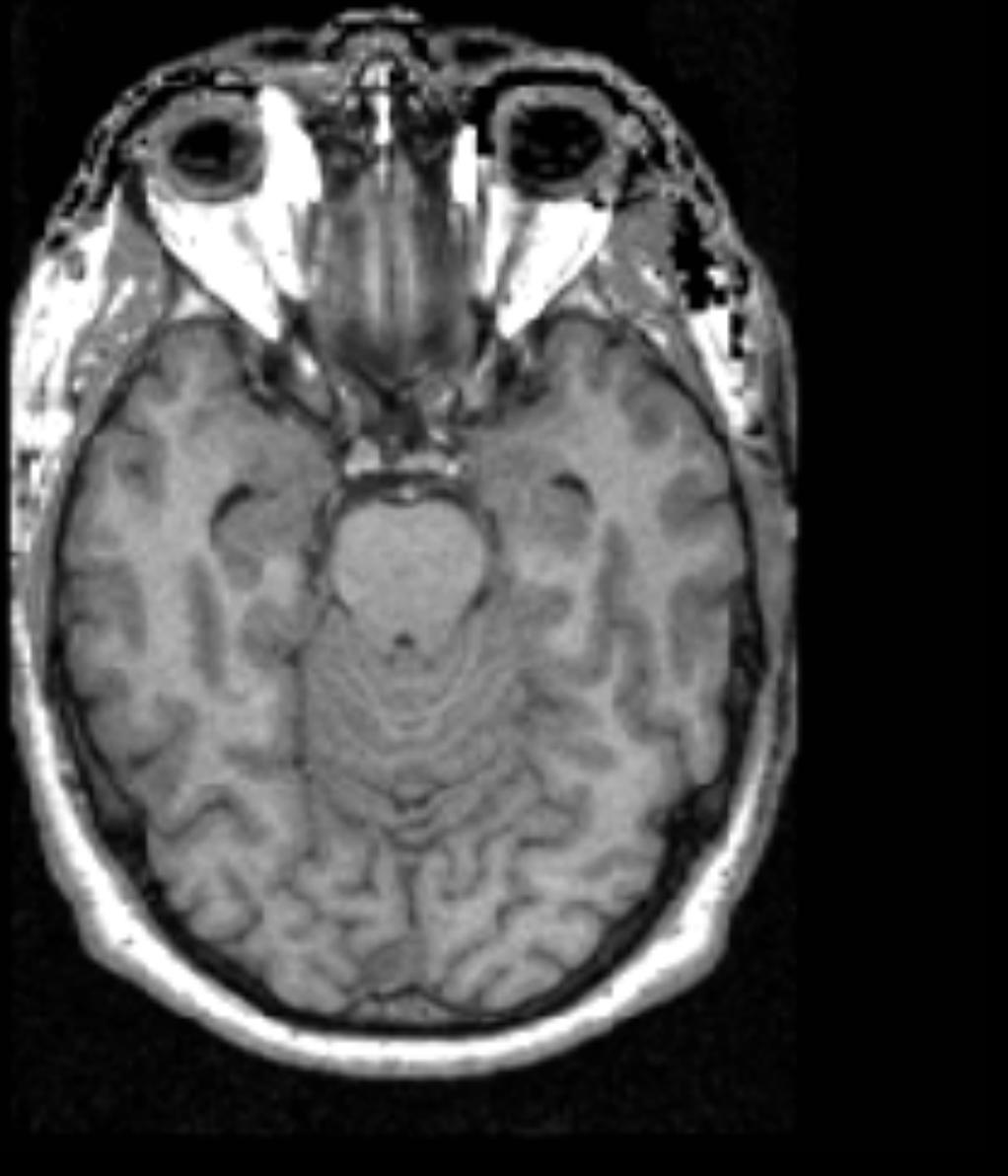
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7FE0,0010,Pixel Data=131072

HIPPA Patient privacy

The Health Insurance Portability and Accountability Act of 1996 (HIPAA) protects the privacy and security of certain health information

<http://www.hhs.gov/hipaa/index.html>

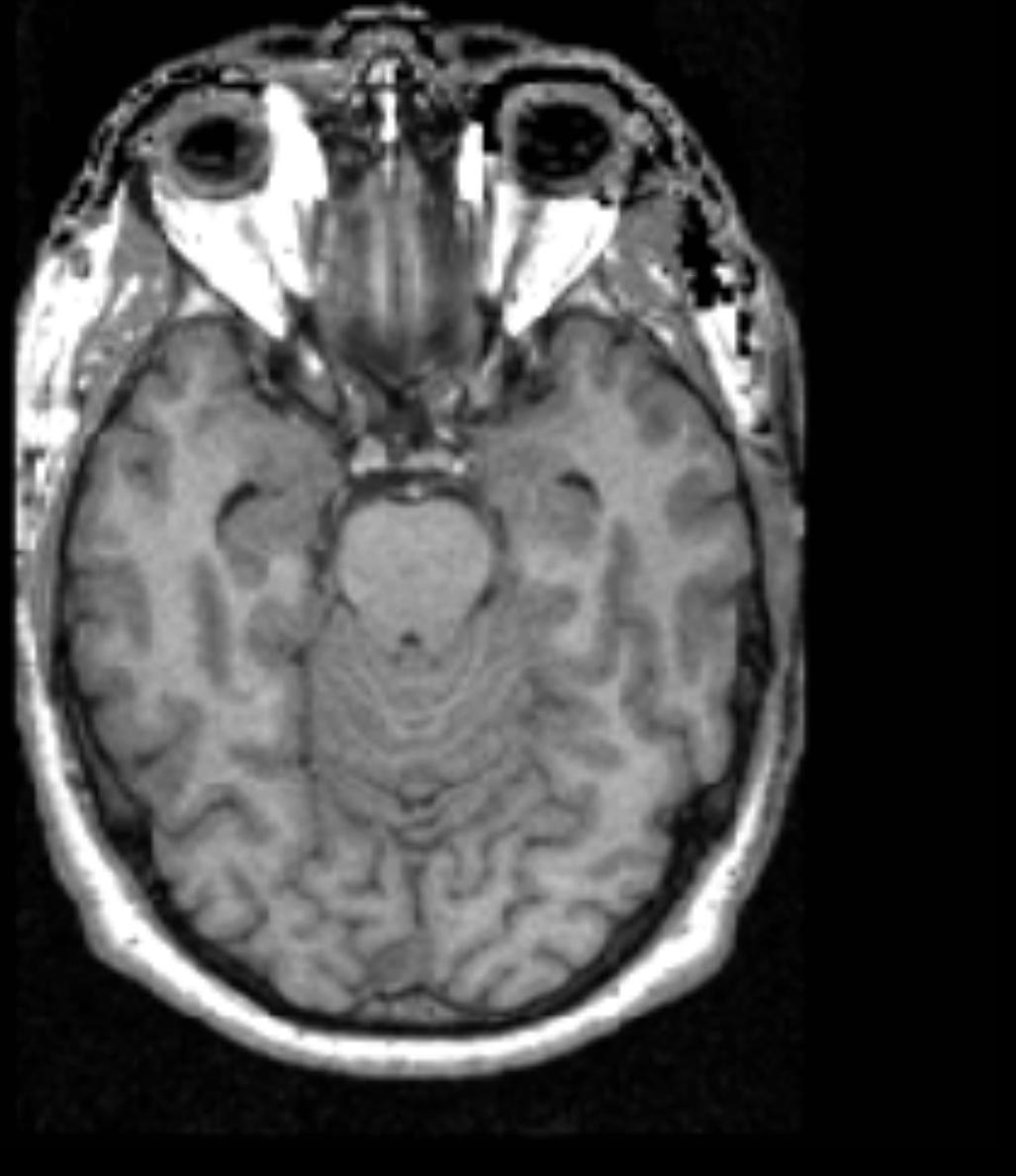
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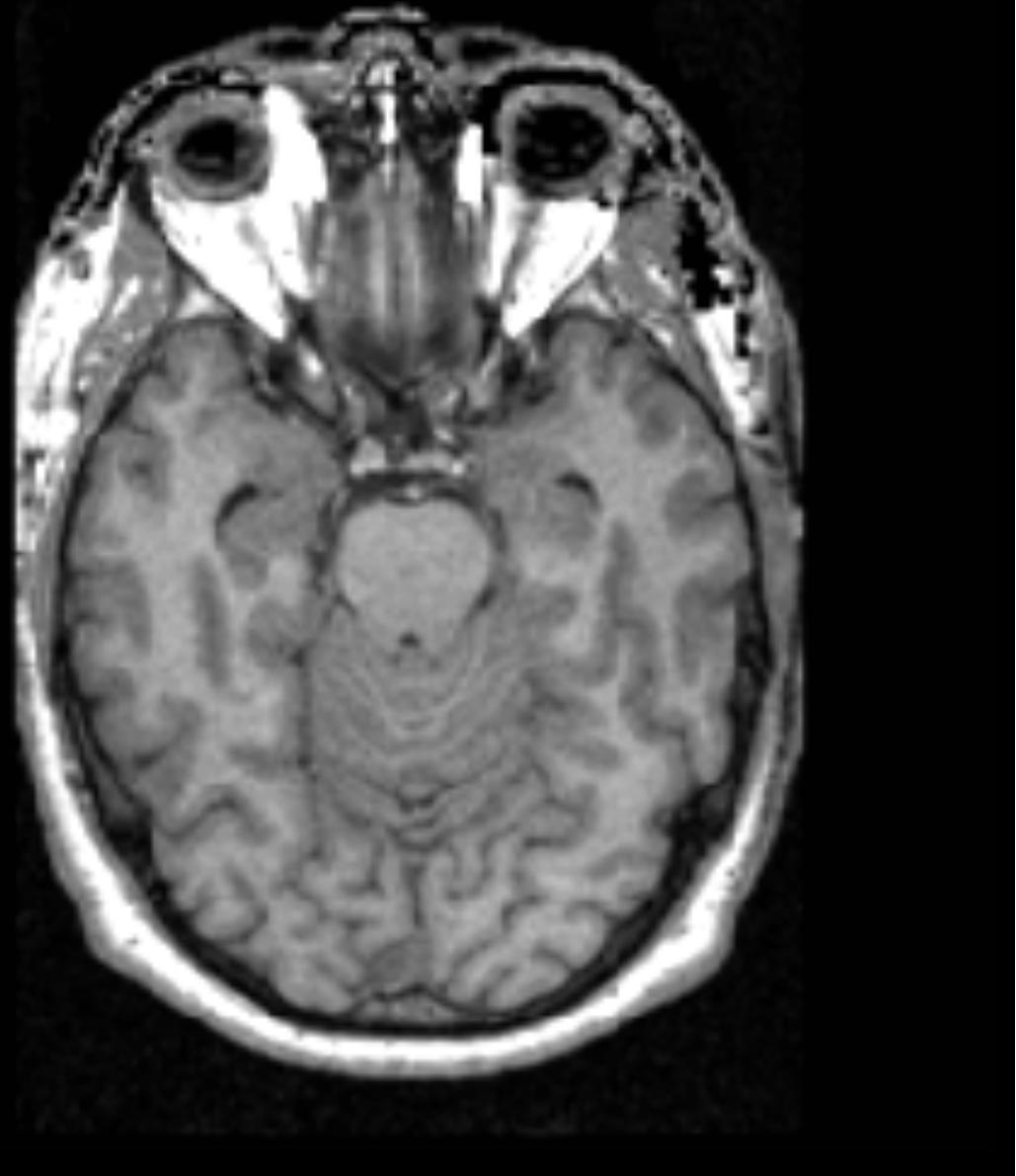
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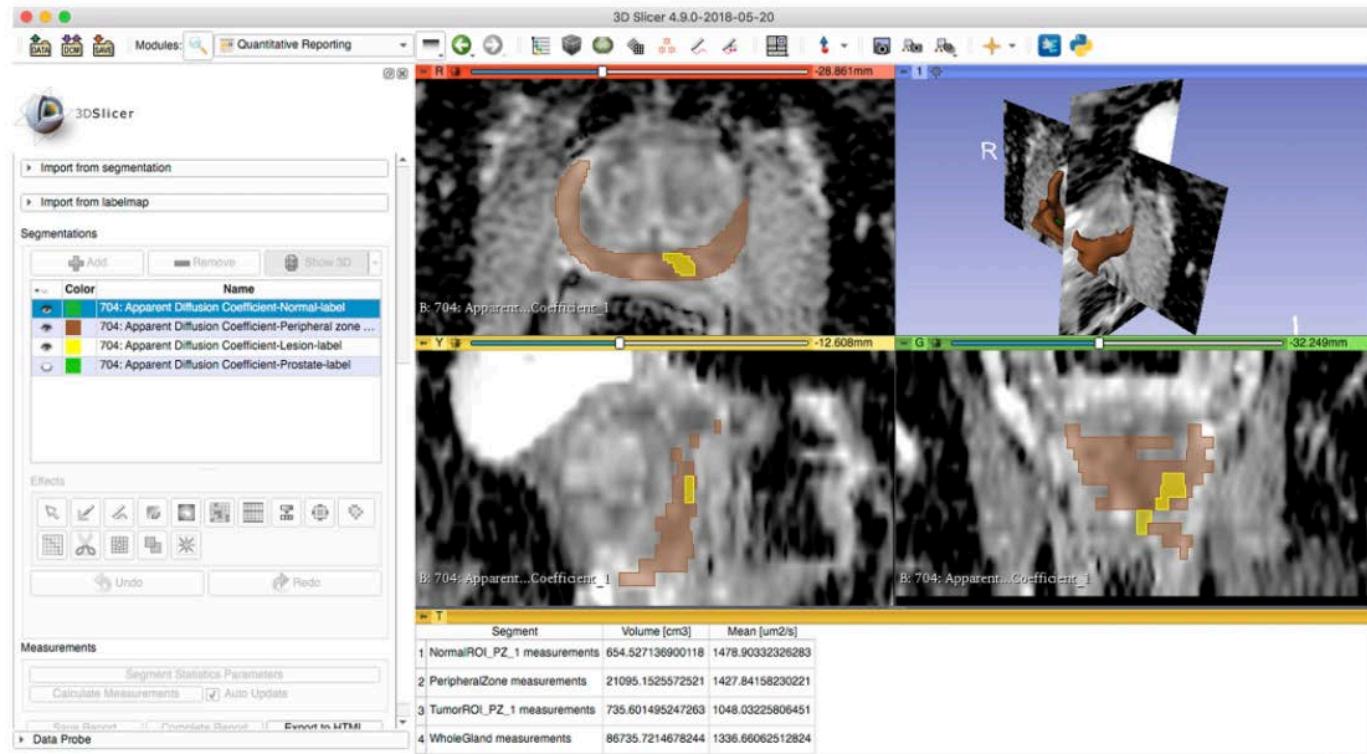
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7FE0,0010,Pixel Data=131072

Pixel Data

Standard DICOM Instances

- **DICOM images** produced by imaging equipment: single DICOM MRI slices, DICOM CT volume, DICOM multi-frame objects (fMRI experiment)
- **DICOM Segmentation Object (SEG):** voxels labelled in regions of interest (ROIs)
- **DICOM Structured Report (SR):** clinical information (e.g. diagnosis, pathology, surgery, etc.), measurements computed from segmented ROIs



Segmented structure	SegmentedPropertyCategoryCodeSequence	SegmentedPropertyTypeCodeSequence	AnatomicRegionSequence
Prostate gland	("T-D000A", "SRT", "Anatomical Structure")	("T-9200B", "SRT", "Prostate")	NA
Peripheral zone of the prostate gland	("T-D000A", "SRT", "Anatomical Structure")	("T-D05E4", "SRT", "Peripheral zone of the prostate")	NA
Lesion in the peripheral zone of the prostate gland	("M-01000", "SRT", "Morphologically Altered Structure")	("M-01100", "SRT", "Lesion")	("T-D05E4", "SRT", "Peripheral zone of the prostate")
Normal tissue in the peripheral zone of the prostate gland	("T-D0050", "SRT", "Tissue")	("G-A460", "SRT", "Normal")	("T-D05E4", "SRT", "Peripheral zone of the prostate")

Measured structure	Finding	Finding Site
Prostate gland *	(T-F6078, SRT, "Entire Gland")	("T-9200B", "SRT", "Prostate")
Peripheral zone of the prostate gland	(R-404A4, SRT, "Entire")	("T-D05E4", "SRT", "Peripheral zone of the prostate")
Lesion in the peripheral zone of the prostate gland	(R-42037, SRT, "Abnormal")	("T-D05E4", "SRT", "Peripheral zone of the prostate")
Normal tissue of peripheral zone of the prostate gland	("G-A460", "SRT", "Normal")	("T-D05E4", "SRT", "Peripheral zone of the prostate")

Examples of Standard DICOM Instances

DICOM Images

Prostate MRI Images

DICOM Segmented Structures

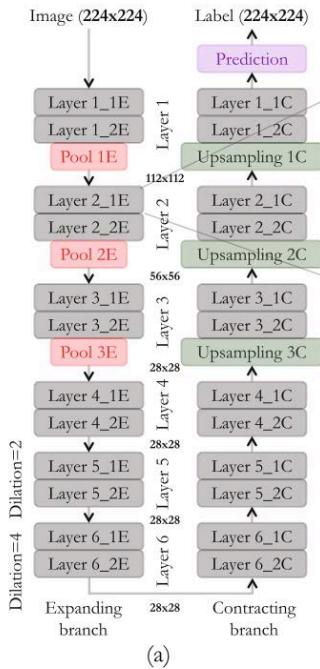
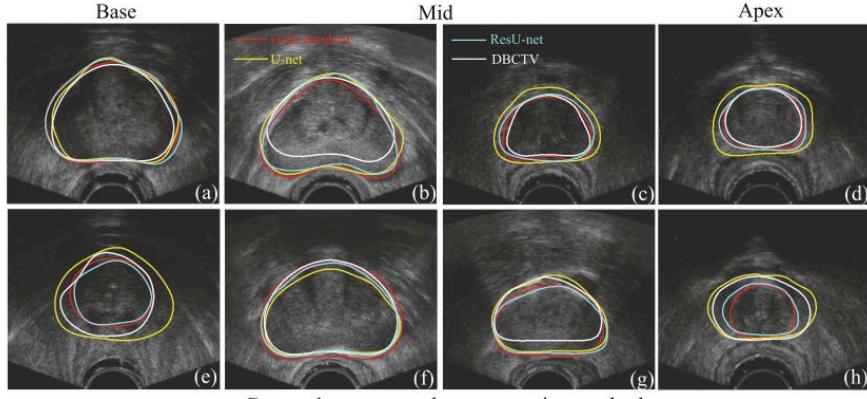
Prostate gland, peripheral zone, lesion, normal tissue

Measurements

Volumes of prostate gland, peripheral zone, lesion, normal tissue

DICOM Terminology

- DICOM provides support for annotation and segmentation objects
- DICOM Structured Reports enable provenance tracking
- DICOM derived data can be stored on a DICOM server or on other archive (e.g. TCIA) with permission and is compliant with FAIR principles

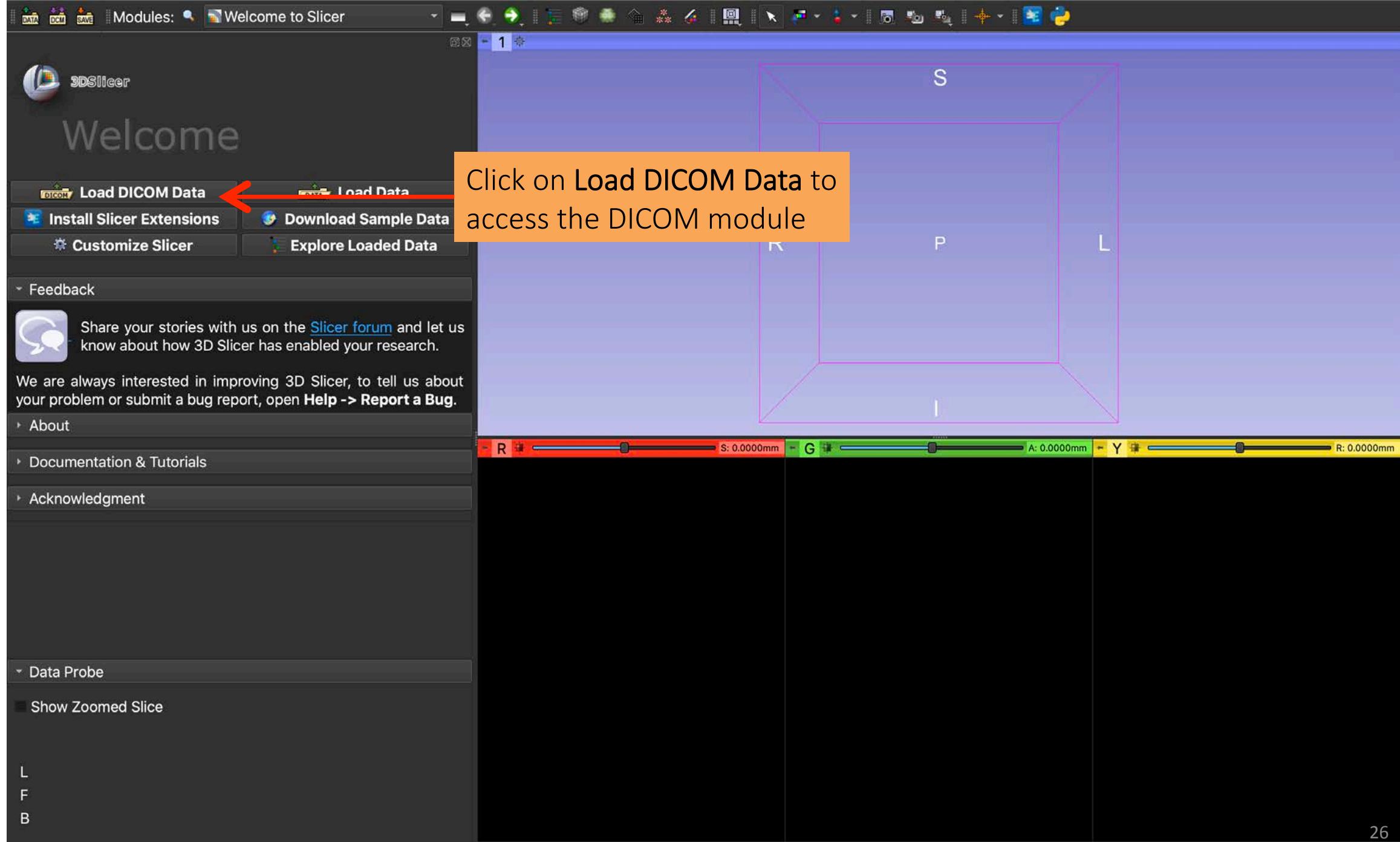


DICOM for AI Studies

- DICOM defines **syntax rules** and **vocabularies** that enable easy extraction of knowledge from the data
- The DICOM framework for medical imaging data management enables the automation of cohort formation and maximizes the interoperability of the data for AI studies



Part 2: Loading and Visualizing DICOM data in 3D Slicer version 5.0



The DICOM database follows the DICOM model hierarchy organized in patients, studies and series

Patients

Studies

Series

DICOM Data Reader Warnings

Uncheck All Examine Load

Advanced

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3DSlicer

Modules: DICOM

PATIENTS STUDIES SERIES

Patient name Patient ID Birth date Sex Studies Last study c Date add e

Import DICOM files Show DICOM database

Loaded data Node

DICOM networking DICOM database settings

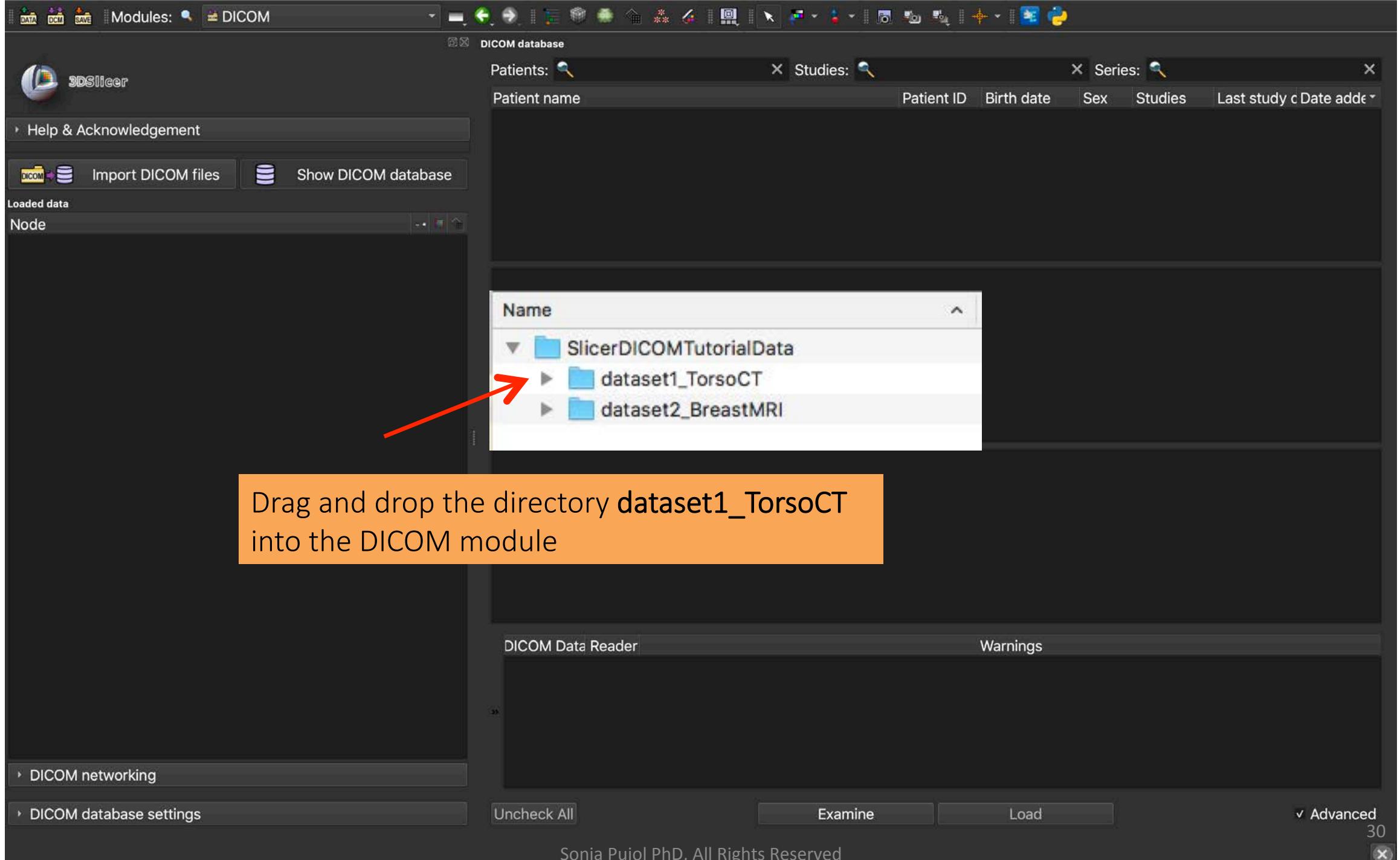
27



Dataset #1

Torso CT

Loading a DICOM dataset in Slicer



The screenshot shows the 3DSlicer interface with the DICOM module open. The top menu bar includes 'DATA', 'DCM', 'SAVE', 'Modules:', and 'DICOM'. The main window displays a 'DICOM database' with three tabs: 'Patients', 'Studies', and 'Series'. The 'Patients' tab shows a list of patients with columns for 'Patient name', 'Patient ID', 'Birth date', 'Sex', 'Studies', and 'Last study Date added'. The row for 'patient1' is selected. The 'Studies' tab shows a list of studies with columns for 'Study date', 'Study ID', 'Study description', 'Series', and 'Date added'. The row for 'CT Thorax Abdomen' is selected. The 'Series' tab shows a list of series with columns for 'Series #', 'Series description', 'Modality', 'Size', 'Count', and 'Date added'. The row for 'CT_Thorax_Abdomen' is selected. A green callout box with the text 'Slicer displays the corresponding study and series' points to the 'Studies' and 'Series' tabs. An orange callout box with the text 'Click on patient1 in the list of patients' points to the 'Patient name' column in the 'Patients' table. Red arrows connect the text boxes to their respective target areas.

3DSlicer

DATA DCM SAVE Modules: DICOM

Patients: Studies: Series:

Patient name Patient ID Birth date Sex Studies Last study Date added

patient1 patient1_ID 1 Wed Jun 1 2005 2020...842

Study date Study ID Study description Series Date added

20050601 6936864 CT Thorax Abdomen 1 202...843

Series # Series description Modality Size Count Date added

6 CT_Thorax_Abdomen CT 512x512 291 202...843

DICOM Data Reader Warnings

6: ... Scalar Volume

DICOM networking

DICOM database settings

Uncheck All Examine Load Advanced

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3DSlicer DICOM Modules: DICOM

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
patient1	patient1_ID			1	Wed Jun 1 2005	2020...842

Import DICOM files Show DICOM database

Loaded data Node

Study date Study ID Study description Series Date added

20050601	6936864	CT Thorax Abdomen	1	202...843
----------	---------	-------------------	---	-----------

Series # Series description Modality Size Count Date added

6	CT_Thorax_Abdomen	CT	512x512	291	202...843
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DICOM Data Reader Warnings

✓ 6: ... Scalar Volume

Click on Examine

Uncheck All Examine Load Advanced

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3DSlicer DICOM Modules: DICOM

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
patient1	patient1_ID			1	Wed Jun 1 2005	2020...842

Import DICOM files Show DICOM database

Loaded data Node

Study date Study ID Study description Series Date added

20050601	6936864	CT Thorax Abdomen	1	202...843
----------	---------	-------------------	---	-----------

Series # Series description Modality Size Count Date added

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DICOM Data Reader Warnings

6: ... Scalar Volume

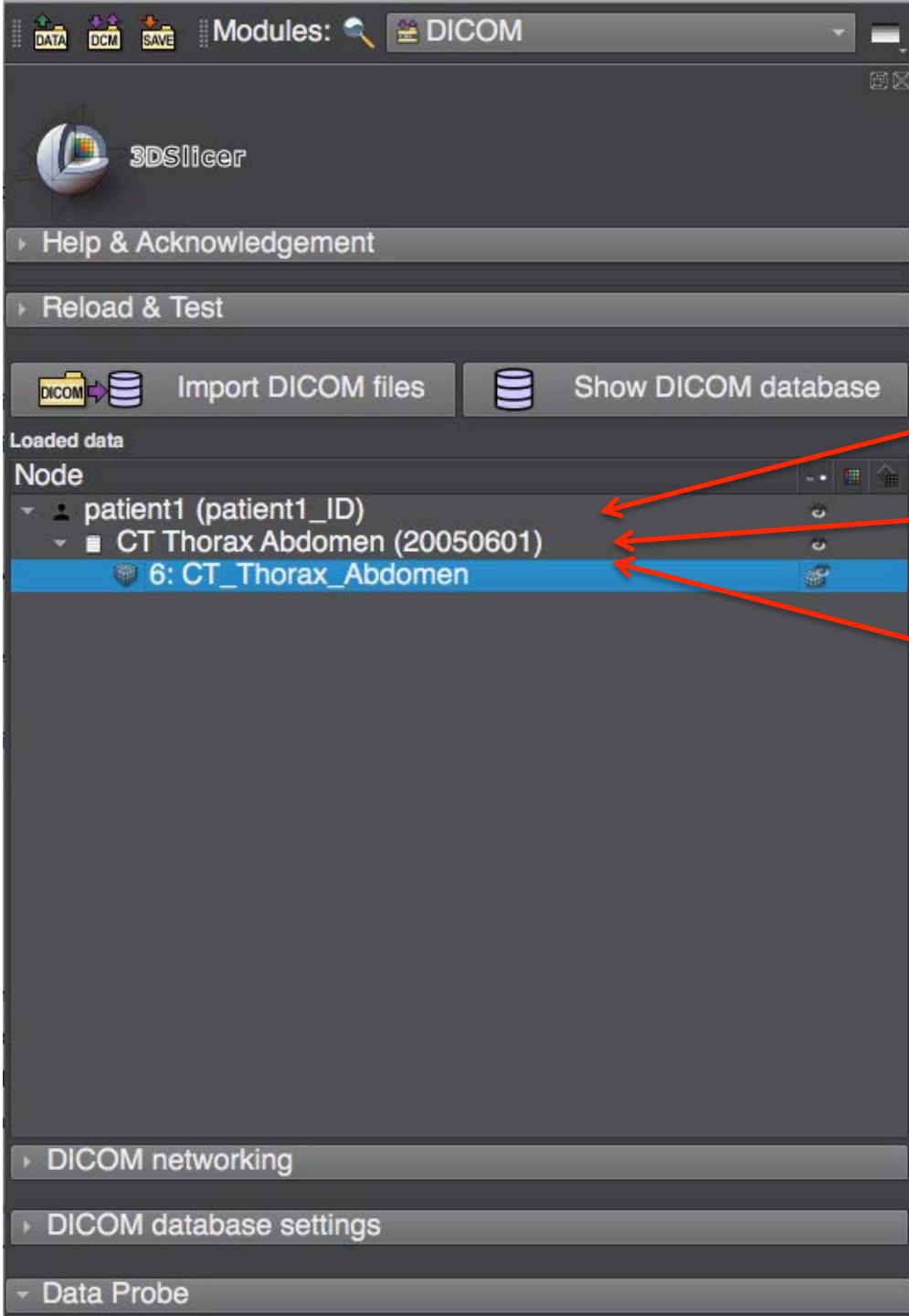
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Uncheck All Examine Load Advanced

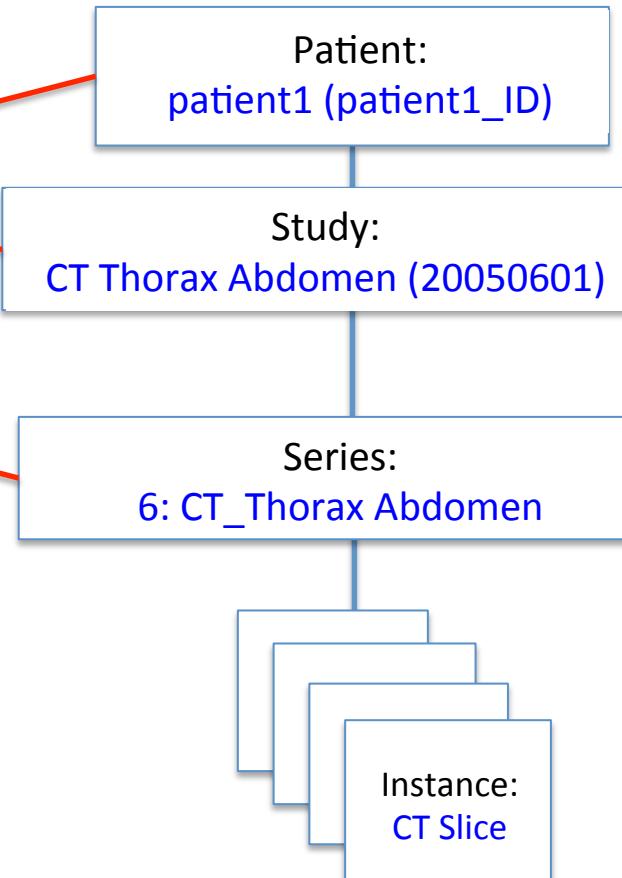
DICOM networking DICOM database settings

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The DICOM dataset is loaded into Slicer as a patient-study-series DICOM hierarchy



Visualizing a DICOM dataset in Slicer

The screenshot shows the 3DSlicer DICOM module interface. At the top, there's a toolbar with various icons. Below it, the main window has a title bar "DICOM" and a "DICOM database" tab. A red arrow points from the text in the center of the image to the "DICOM database" tab. The interface includes a "Loaded data" tree view on the left, a "Series # 6" dropdown in the center, and a "DICOM" dropdown on the right. An orange callout box contains the instruction: "Click on the Slicer GUI icon to display the list of Slicer layouts and select Conventional". To the right of the callout, the "DICOM" dropdown is open, showing a list of layout options. The "Series # 6" dropdown also has a list of series numbers. On the far right, there are two tables: one for "Studies" and one for "Modality".

Click on the Slicer GUI icon to display the list of Slicer layouts and select Conventional

DICOM database

Patients

Patient name

patient1

Conventional

Conventional Widescreen

Conventional Quantitative

Four-Up

Four-Up Table

Four-Up Quantitative

Dual 3D

Triple 3D

3D only

3D Table

One-Up Quantitative

Red slice only

Yellow slice only

Green slice only

Tabbed 3D

Tabbed slice

Compare

Compare Widescreen

Compare Grid

Three over three

Three over three Quantitative

Four over four

Two over two

Side by side

Four by three slice

Four by two slice

Three by three slice

Series #

6

Modality

Size

Count

Date added

CT

512x512

291

2020...273

DICOM

Uncheck All

Examine

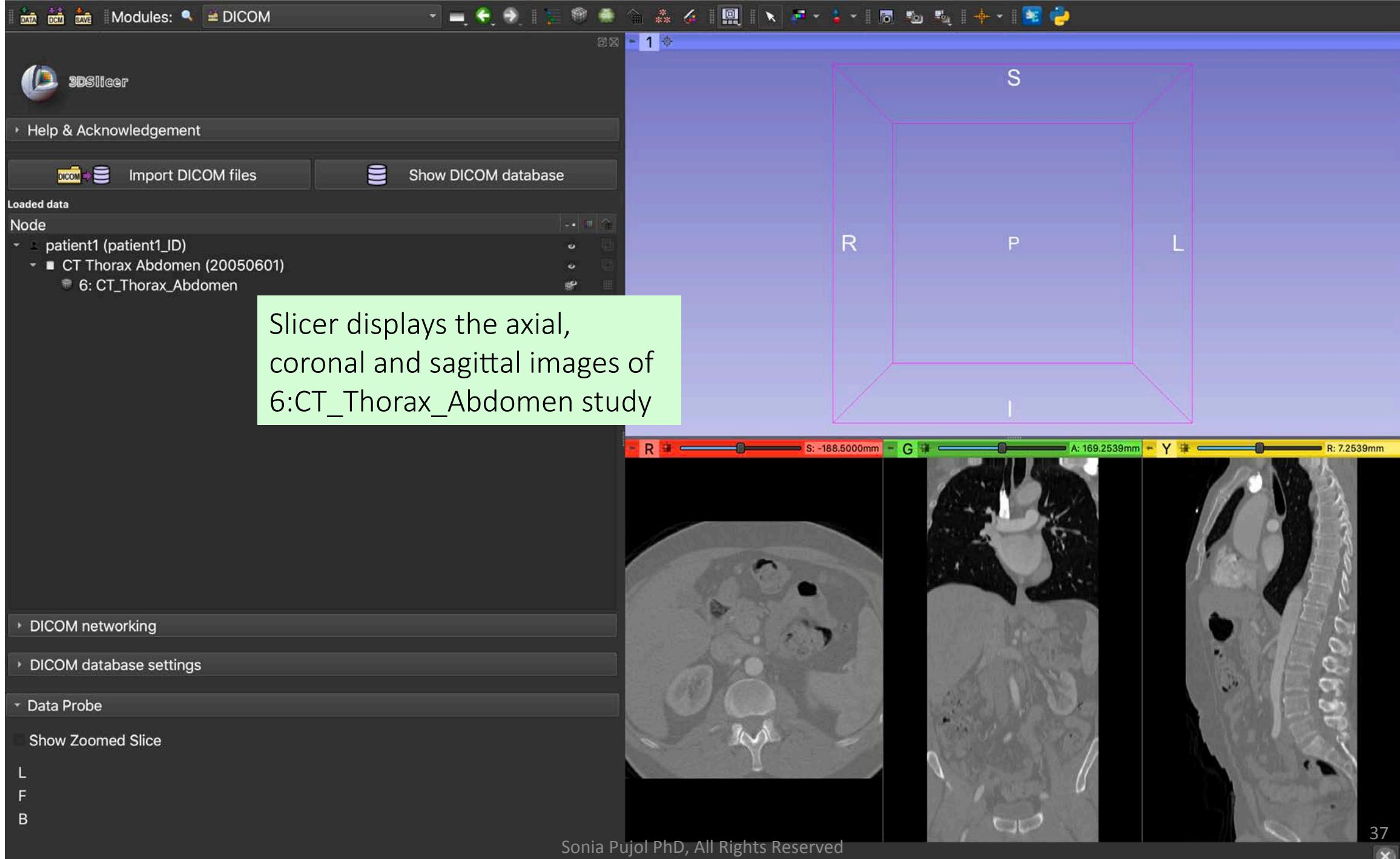
Load

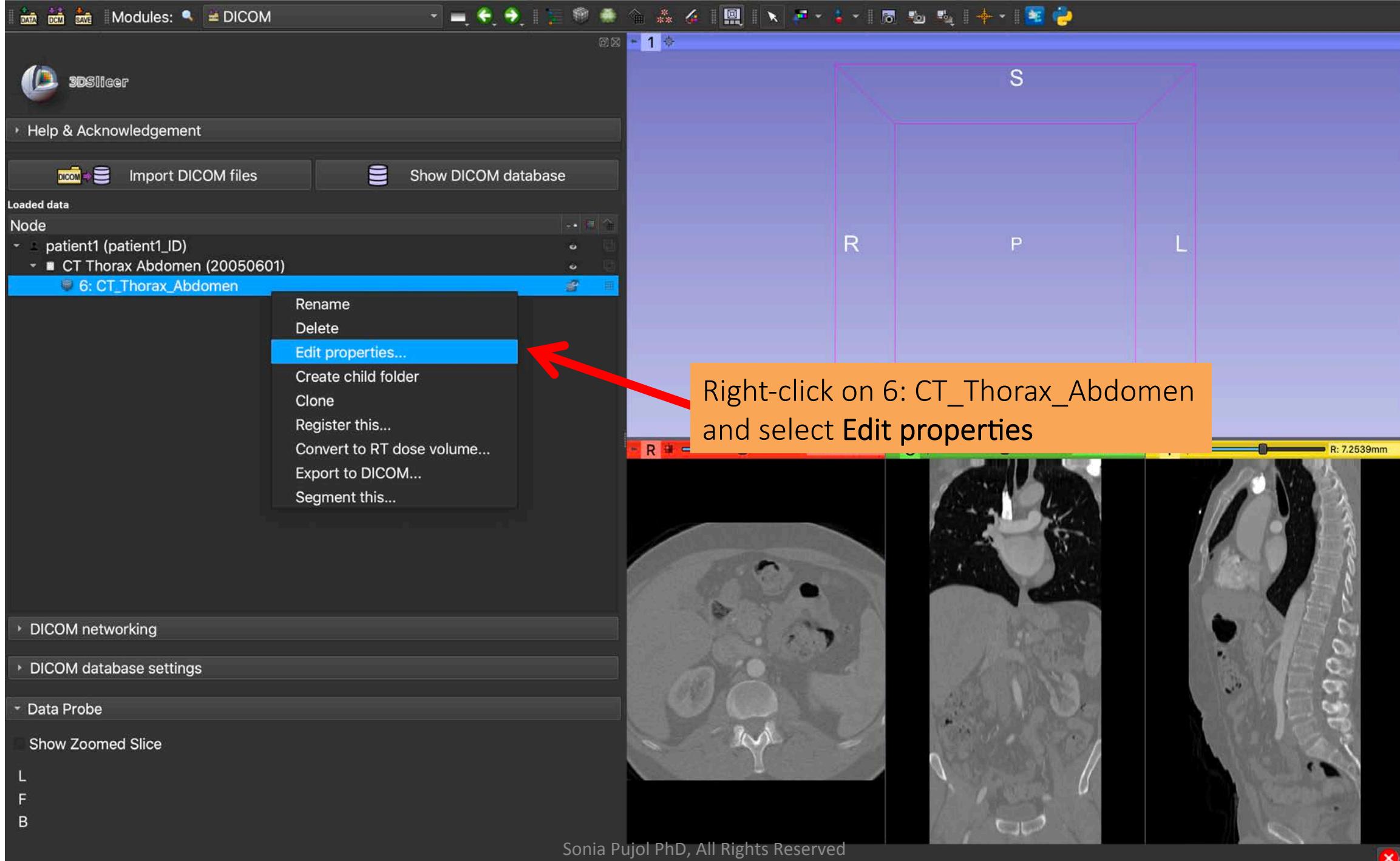
Advanced

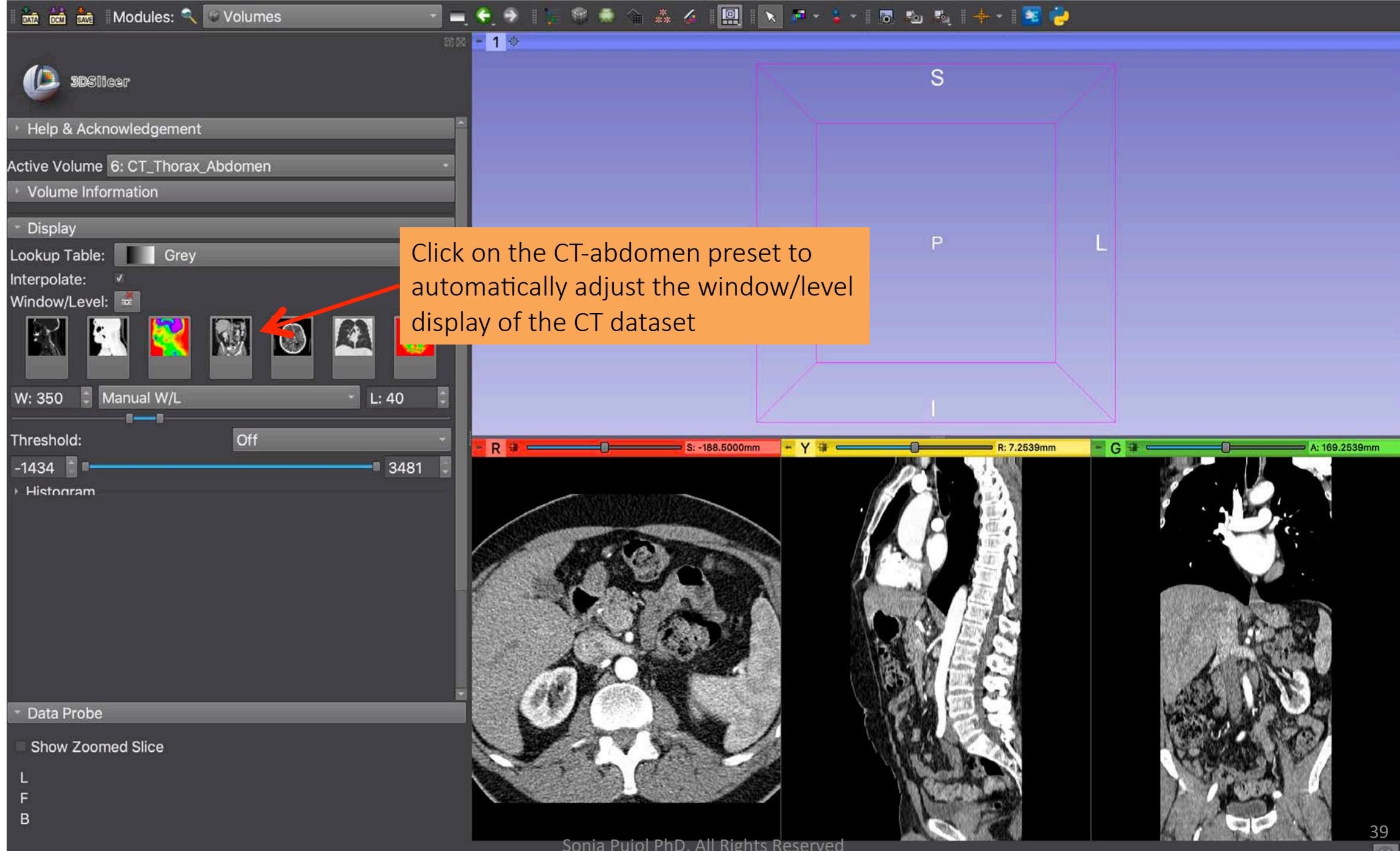
DICOM networking

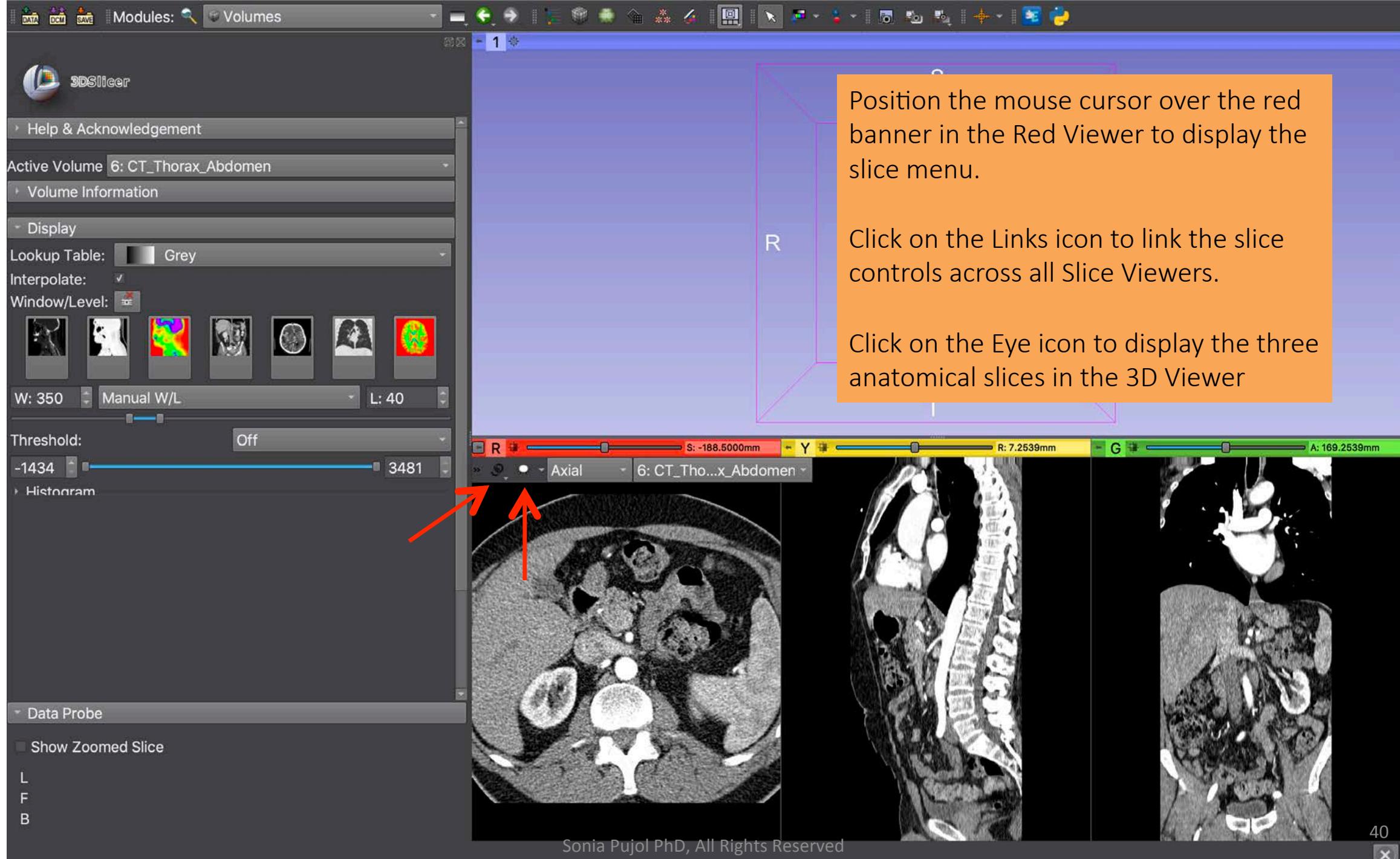
DICOM database settings

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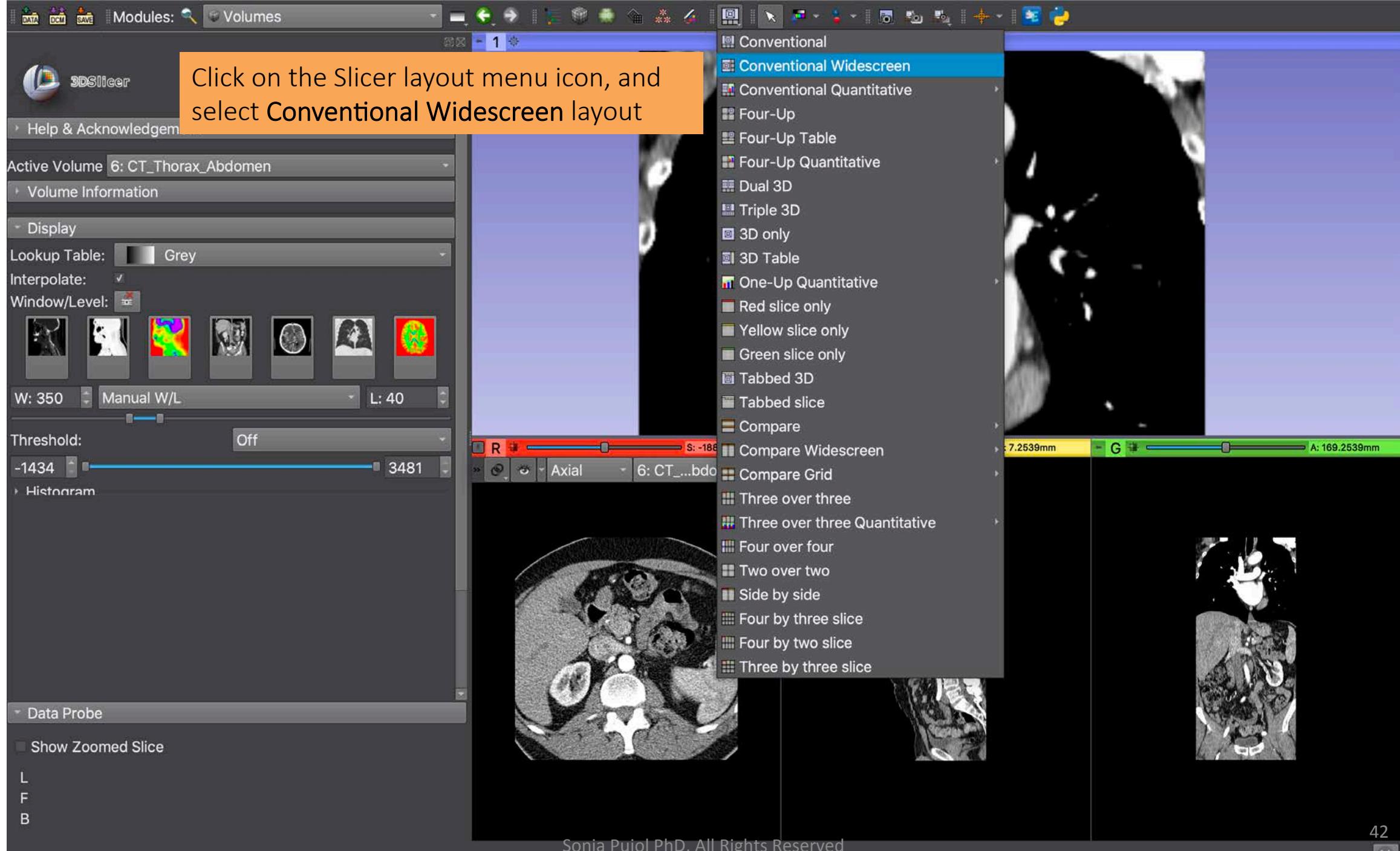




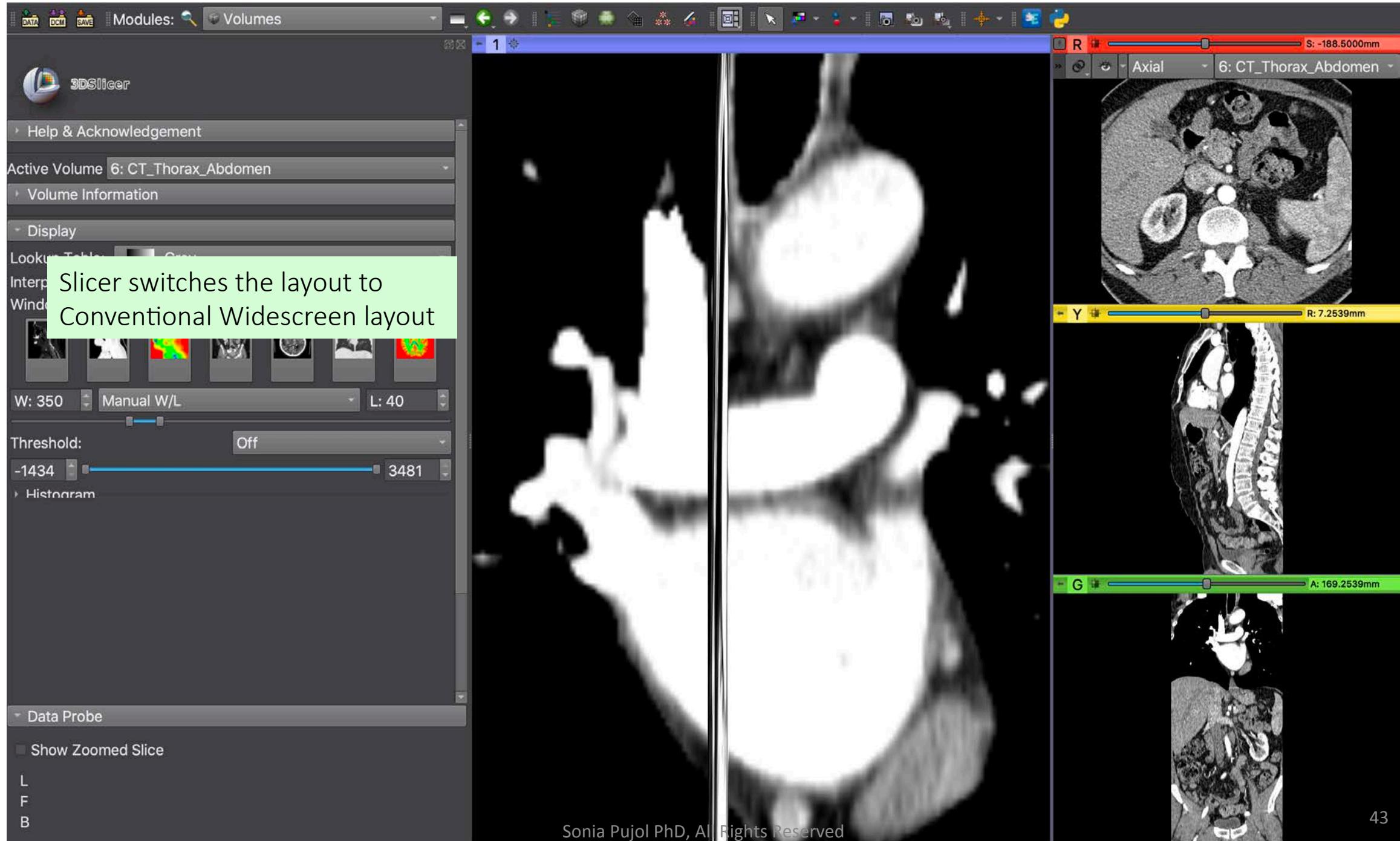


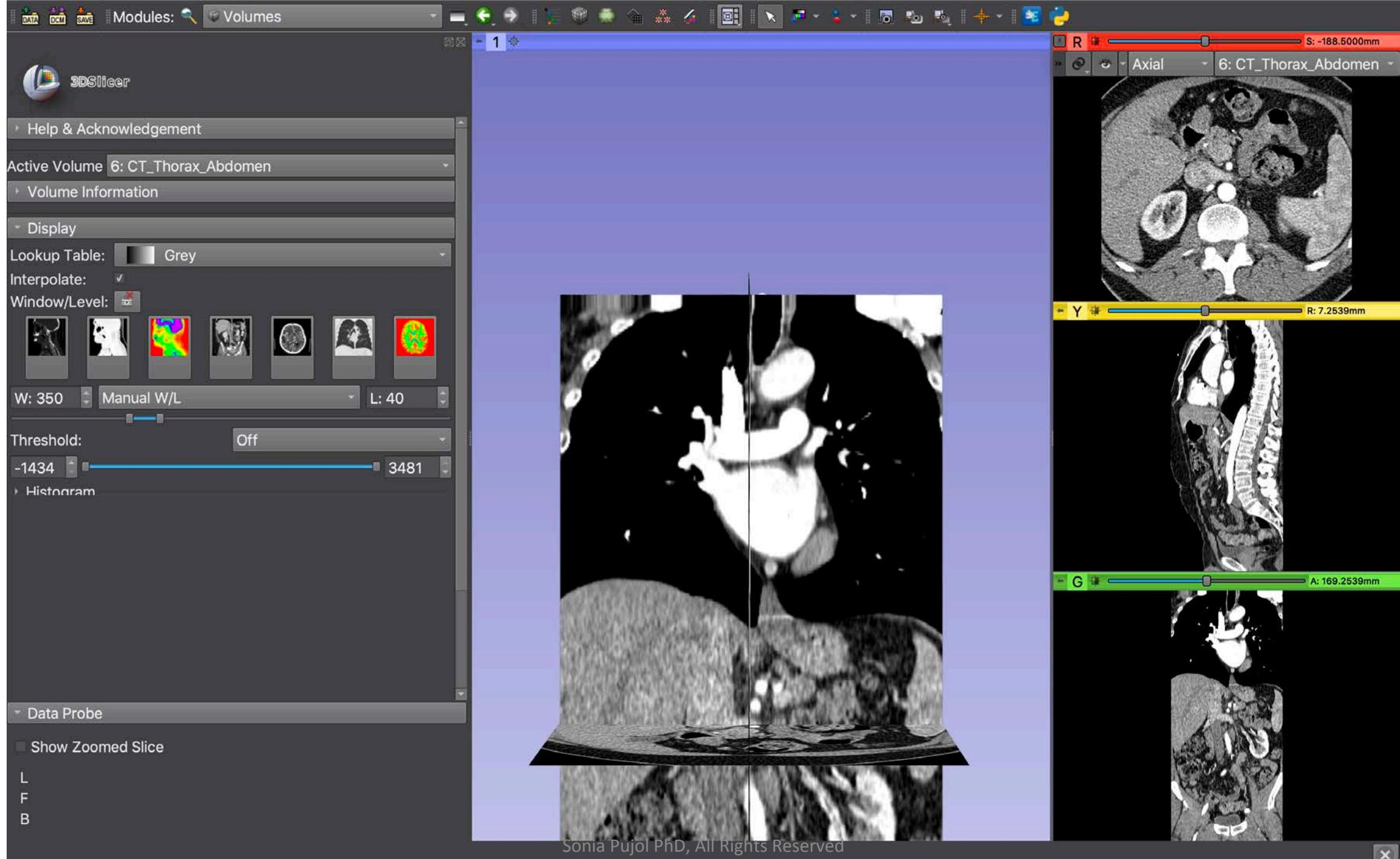


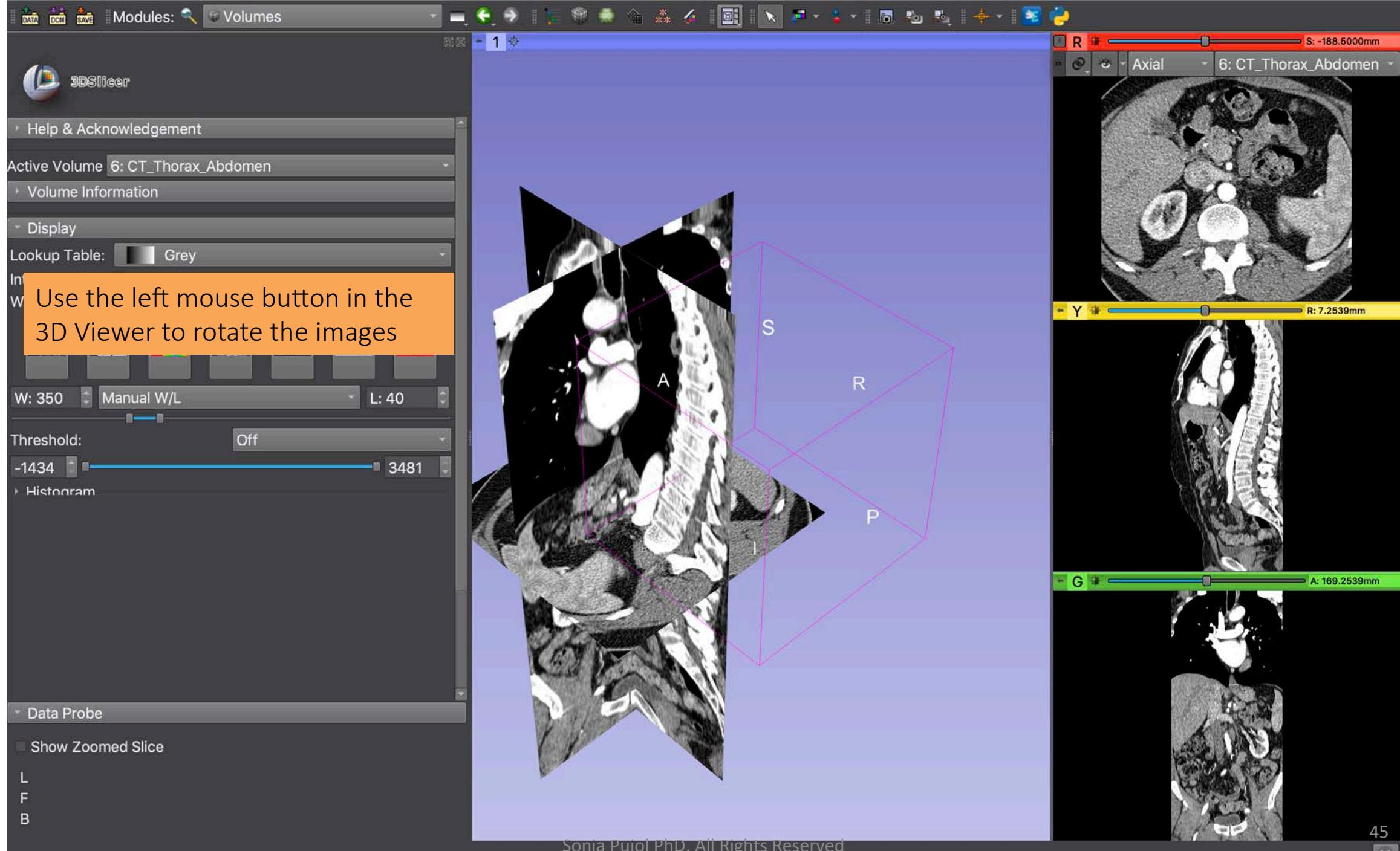


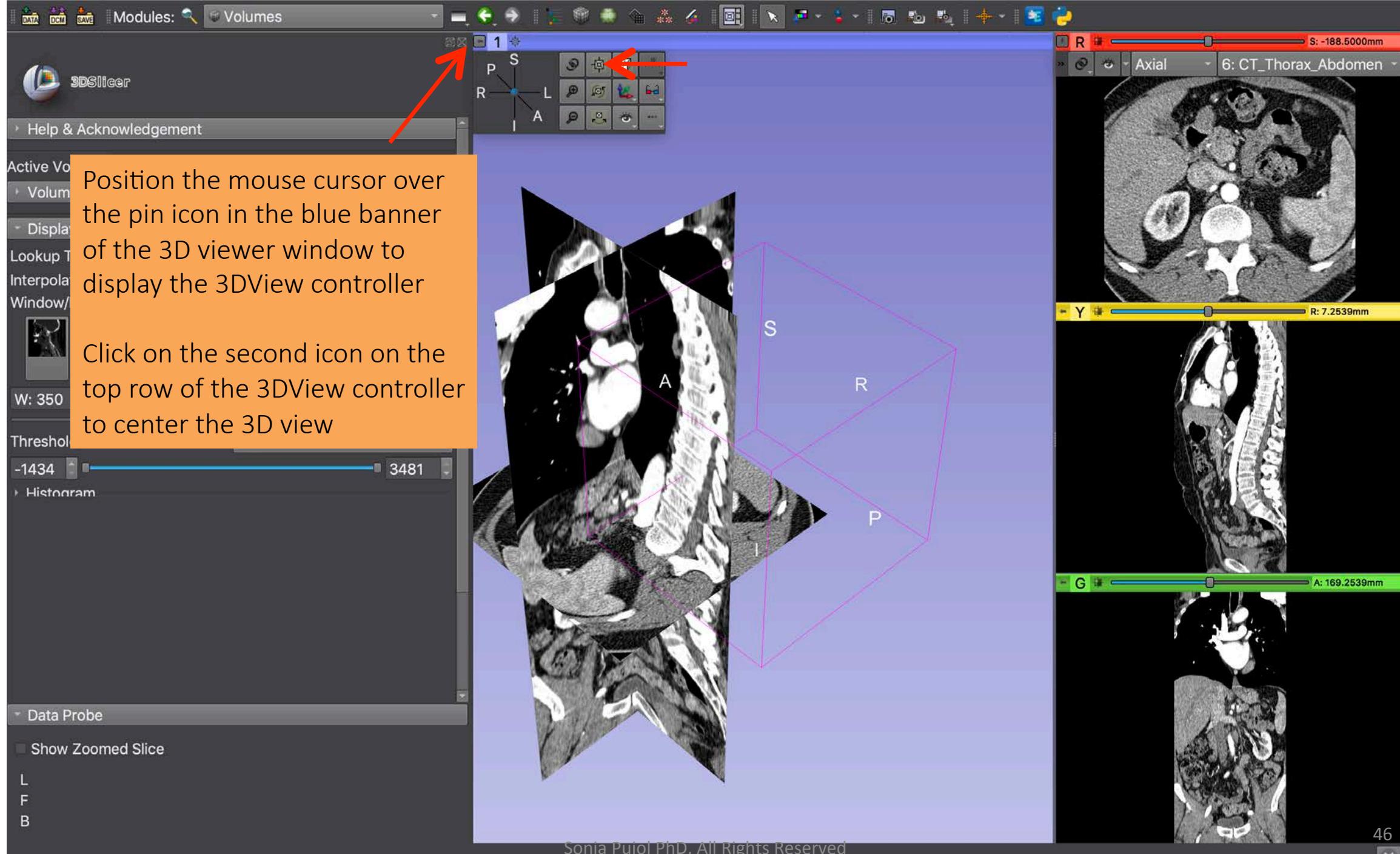


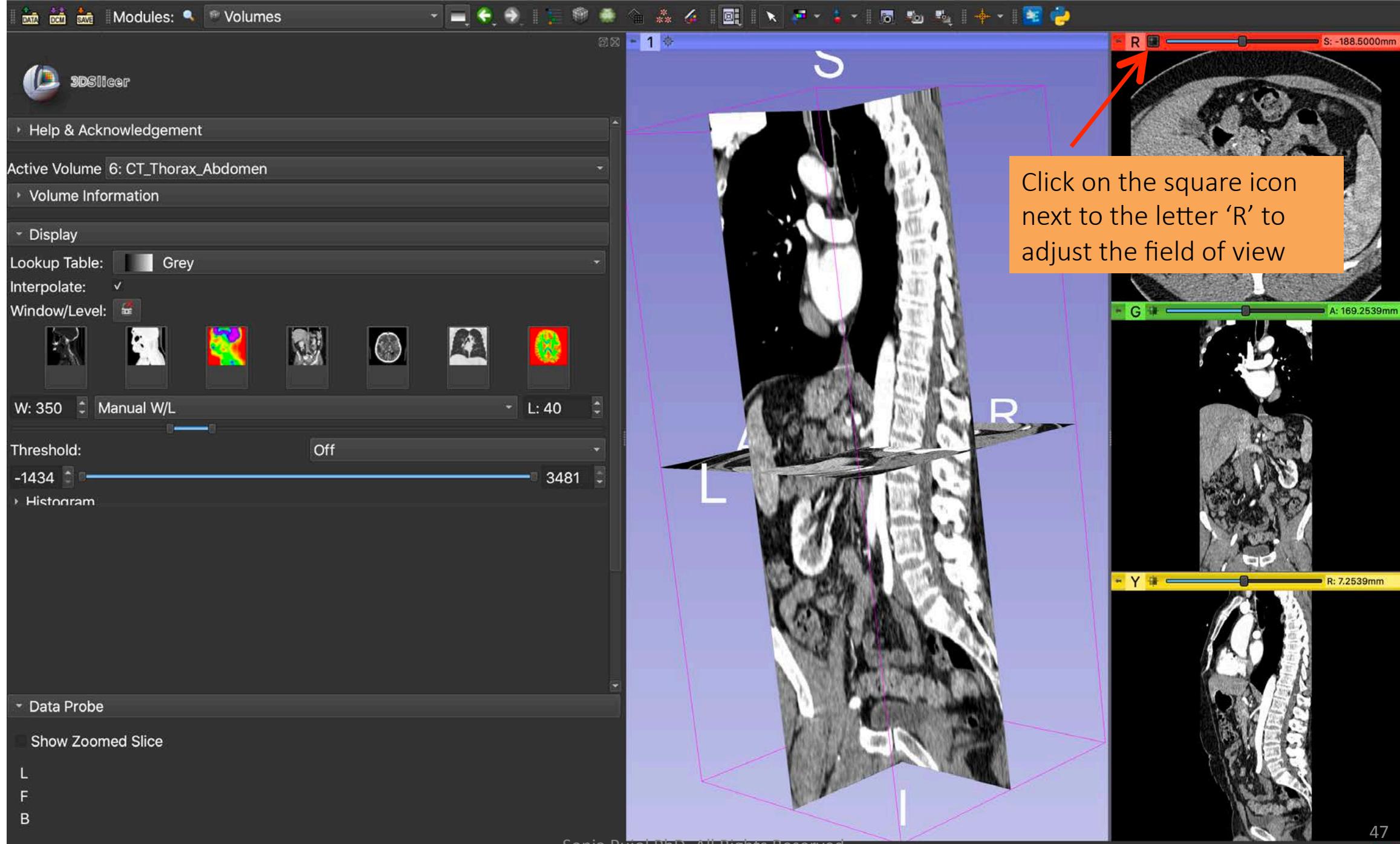
Click on the Slicer layout menu icon, and select **Conventional Widescreen** layout

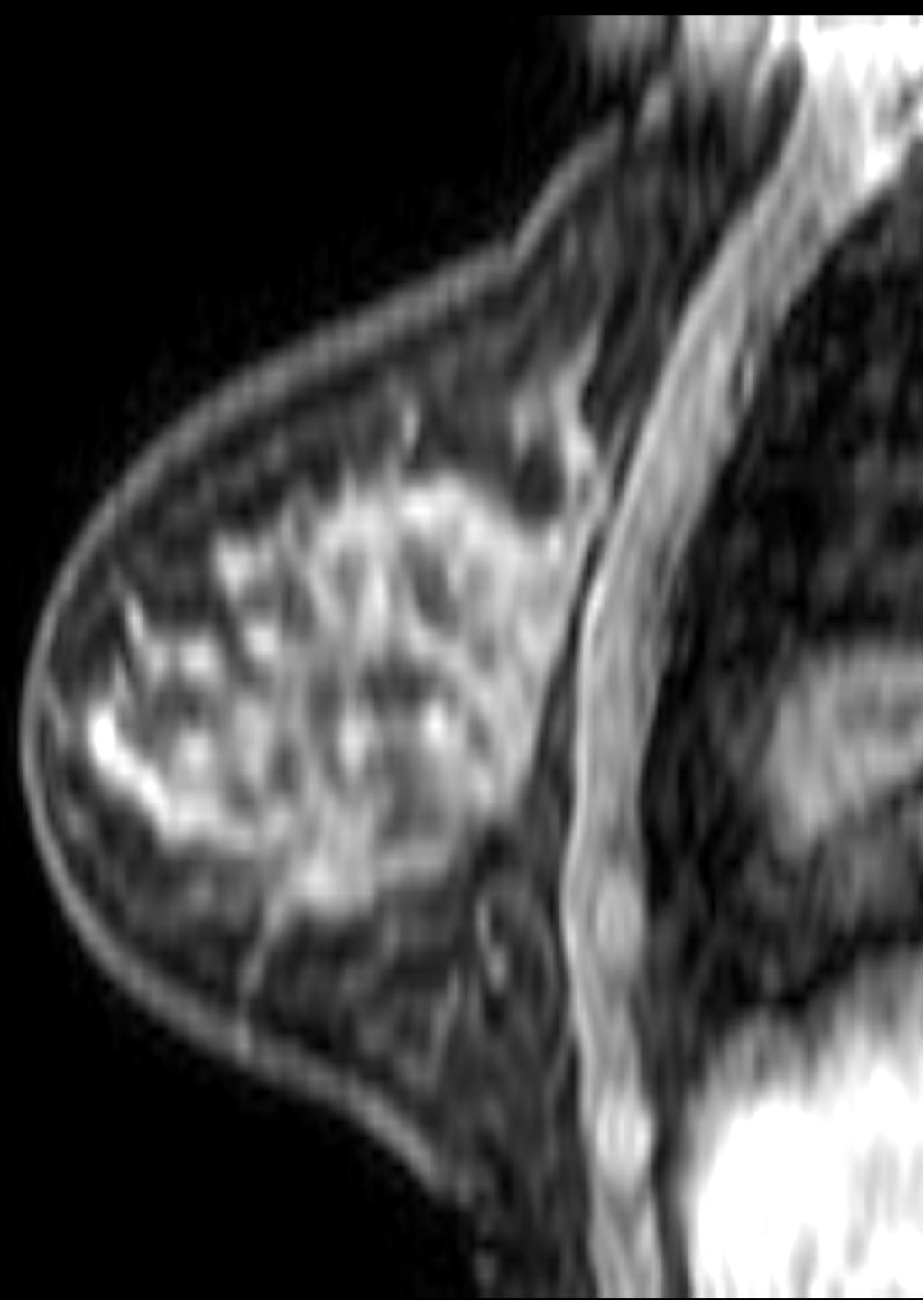












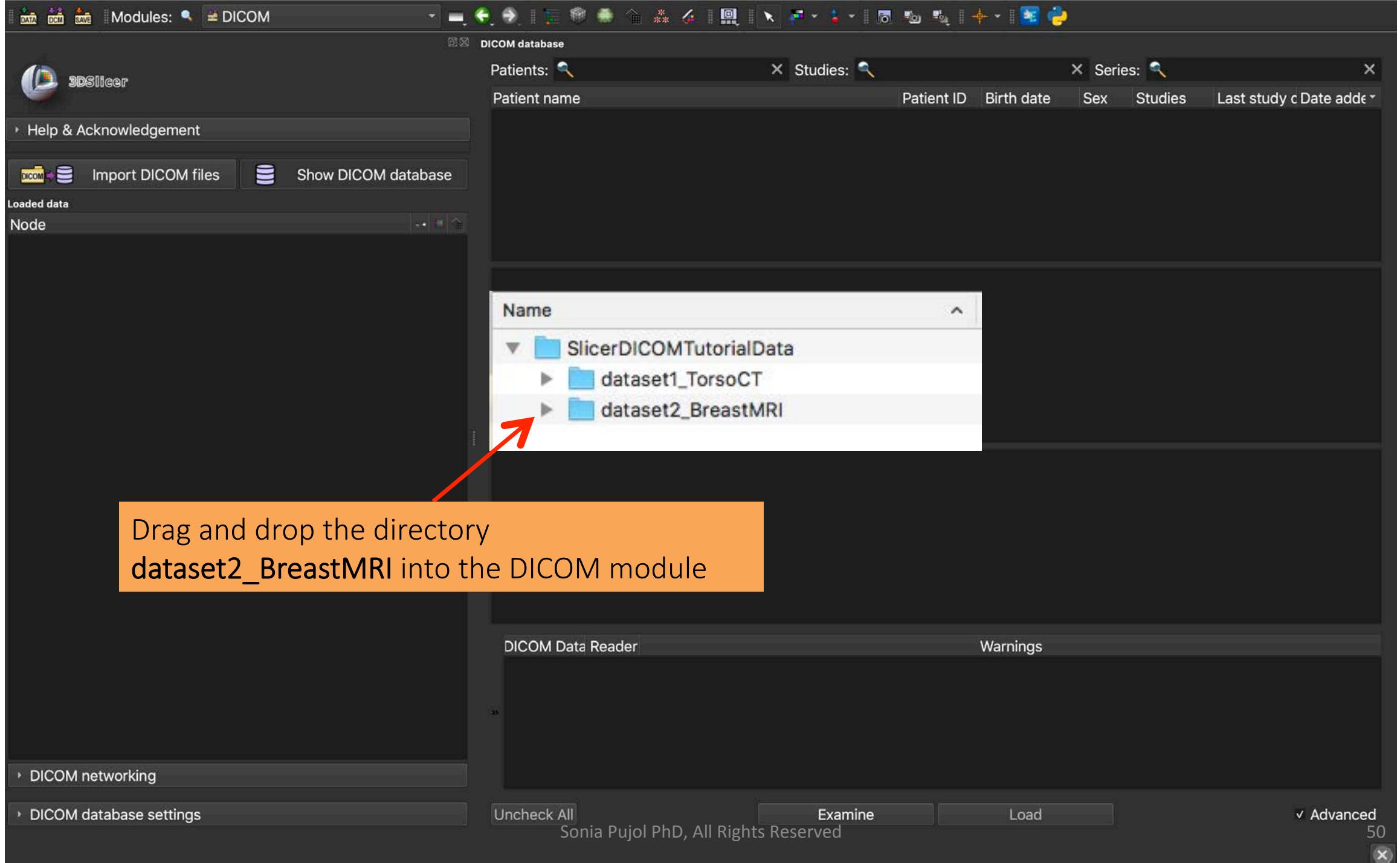
Dataset #2

Breast MRI

Breast MRI Dataset

- The Breast MRI dataset is part of the BREAST-DIAGNOSIS collection of The Cancer Imaging Archive (TCIA) of the National Cancer Institute
- The dataset was acquired on patient with right breast infiltrating ductal carcinoma
- The DICOM images consist of one study and three series: T2, STIR and BLISS

Bloch, B. Nicolas, Jain, Ashali, & Jaffe, C. Carl. (2015). Data From BREAST-DIAGNOSIS. The Cancer Imaging Archive. <http://doi.org/10.7937/K9/TCIA.2015.SDNRQXXR>



Slicer imports the dataset2_BreastMRI directory into the DICOM database

The directory contains 1 patient, 1 study and 3 series

Import completed: added 1 patients, 1 studies, 3 series, 1008 instances.

DICOM networking DICOM database settings

Uncheck All Examine Load Advanced

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Click on the PatientID
BreastDx-01-0005 to
display the study and the
three T2W, STIR and BLISS
series

Click on Examine

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
	BreastDx-01-0005		F	1	Tue Nov 11 2008	2020...583
patient1	patient1_ID			1	Wed Jun 1 2005	2020...273

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020...583

Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020...583
401	STIR SENSE	MR	528x528	84	2020...221
801	AX BLISS_AUTO SENSE	MR	528x528	840	202...646

DICOM Data Reader Warnings

DICOM networking DICOM database settings Uncheck All Examine Load Advanced 52

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DATA DCM SAVE Modules: DICOM

3DSlicer

Help & Acknowledgement

Import DICOM files Show DICOM database

Loaded data

Node

- patient1 (patient1_ID)
 - CT Thorax Abdomen (20050601)
 - 6: CT_Thorax_Abdomen

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study	Date added
	BreastDx-01-0005		F	1	Tue Nov 11 2008	2020...583
patient1	patient1_ID			1	Wed Jun 1 2005	2020...273

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020...583

Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020...583
401	STIR SENSE	MR	528x528	84	2020...221
801	AX BLISS_AUTO SENSE	MR	528x528	840	202...646

Click on the double arrow to display the list of DICOM readers

DICOM Data Reader Warnings

- 301: T2W_TSE SENSE Scalar Volume
- 401: STIR SENSE Scalar Volume
- AX BLISS_AUTO SENSE ... MultiVolume

801: AX BLISS_AUTO ... Scalar Volume Images are not equally spaced (a difference of 2 vs 0 in spacings ...
AX BLISS_AUTO SENSE ... MultiVolume

Uncheck All Examine Load Advanced

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The screenshot shows the 3DSlicer application interface. On the left, there's a sidebar with "DICOM" and "Import DICOM files" buttons, and a "Show DICOM database" button. Below that is a "Loaded data" section with a tree view showing "patient1 (patient1_ID)" and "CT Thorax Abdomen (20050601)". A red arrow points from a green callout box labeled "The list of DICOM plugins appear" towards the bottom left of the interface.

DICOM database

Patients: **Studies:** **Series:**

Patient name	Patient ID	Birth date	Sex	Studies	Last study date	Date added
patient1	BreastDx-01-0005		F	1	Tue Nov 11 2008	2020-0...28.583
	patient1_ID			1	Wed Jun 1 2005	2020-0...43.273

Study date	Study ID	Study description	Series	Date added
20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020-0...28.583

Series #	Series description	Modality	Size	Count	Date added
301	T2W_TSE SENSE	MR	528x528	84	2020-0...28.583
401	STIR SENSE	MR	528x528	84	2020-0...29.221
801	AX BLISS_AUTO SENSE	MR	528x528	840	2020-0...28.646

DICOM Data	Reader	Warnings
301: T2W_TSE SENSE	Scalar Volume	
401: STIR SENSE	Scalar Volume	
AX BLISS_AUTO SENSE - as a 10 ...	MultiVolume	
801: AX BLISS_AUTO SENSE	Scalar Volume	Images are not equally spaced (a difference of 2 vs 0 in spacing...)
AX BLISS_AUTO SENSE - as a 10 ...	MultiVolume	
AX BLISS_AUTO_SFNSF - as a 10 ...	MultiVolume	

DICOMPETSVPlugin
 DICOMParametricMapPlugin
 DICOMRWVMPPlugin
 DICOMScalarVolumePlugin
 DICOMSegmentationPlugin
 DICOMSlicerDataBundlePlugin
 DICOMTID1500Plugin
 DICOMVolumeSequencePlugin
 DicomRtImportExportPlugin
 DicomSrlmportExportPlugin
 MultiVolumeImporterPlugin

DICOM networking

DICOM database settings

Advanced

Slicer DICOM Plugins

- ✓ DICOMPETSUVPlugin
- ✓ DICOMParametricMapPlugin
- ✓ DICOMRWVMPPlugin
- ✓ DICOMScalarVolumePlugin
- ✓ DICOMSegmentationPlugin
- ✓ DICOMSlicerDataBundlePlugin
- ✓ DICOMTID1500Plugin
- ✓ DICOMVolumeSequencePlugin
- ✓ DicomRtImportExportPlugin
- ✓ DicomSroImportExportPlugin
- ✓ MultiVolumeImporterPlugin

- Slicer implements a list of DICOM plugins to handle a diverse set of DICOM data objects
- These plugins need to be enabled in order to read specific DICOM data objects such DICOM RT data or DICOM DWI data

3DSlicer

DICOM database

Patients: Studies: Series:

Patient name	Patient ID	Birth date	Sex	Studies	Last study date	Date added
patient1	BreastDx-01-0005		F	1	Tue Nov 11 2008	2020-0...28.583
	patient1_ID			1	Wed Jun 1 2005	2020-0...43.273

Import DICOM files Show DICOM database

Loaded data

Node

- patient1 (patient1_ID)
 - CT Thorax Abdomen (20050601)
 - 6: CT_Thorax_Abdomen

Study date Study ID Study description Series Date added

20081111		MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST	3	2020-0...28.583
----------	--	---	---	-----------------

Series # Series description Modality Size Count Date added

301	T2W_TSE SENSE	MR	528x528 84	2020-0...28.583
401	STIR SENSE	MR	528x528 84	2020-0...29.221
801	AX BLISS_AUTO SENSE	MR	528x528 840	2020-0...28.646

✓ DICOMPETSUVPPlugin ✓ DICOParametricMapPlugin ✓ DICOMRWVMPPlugin ✓ DICOMScalarVolumePlugin ✓ DICOMSegmentationPlugin ✓ DICOMSlicerDataBundlePlugin ✓ DICOMTID1500Plugin ✓ DICOMVolumeSequencePlugin ✓ DicomRtImportExportPlugin ✓ DicomSrlImportExportPlugin ✓ MultiVolumeImporterPlugin

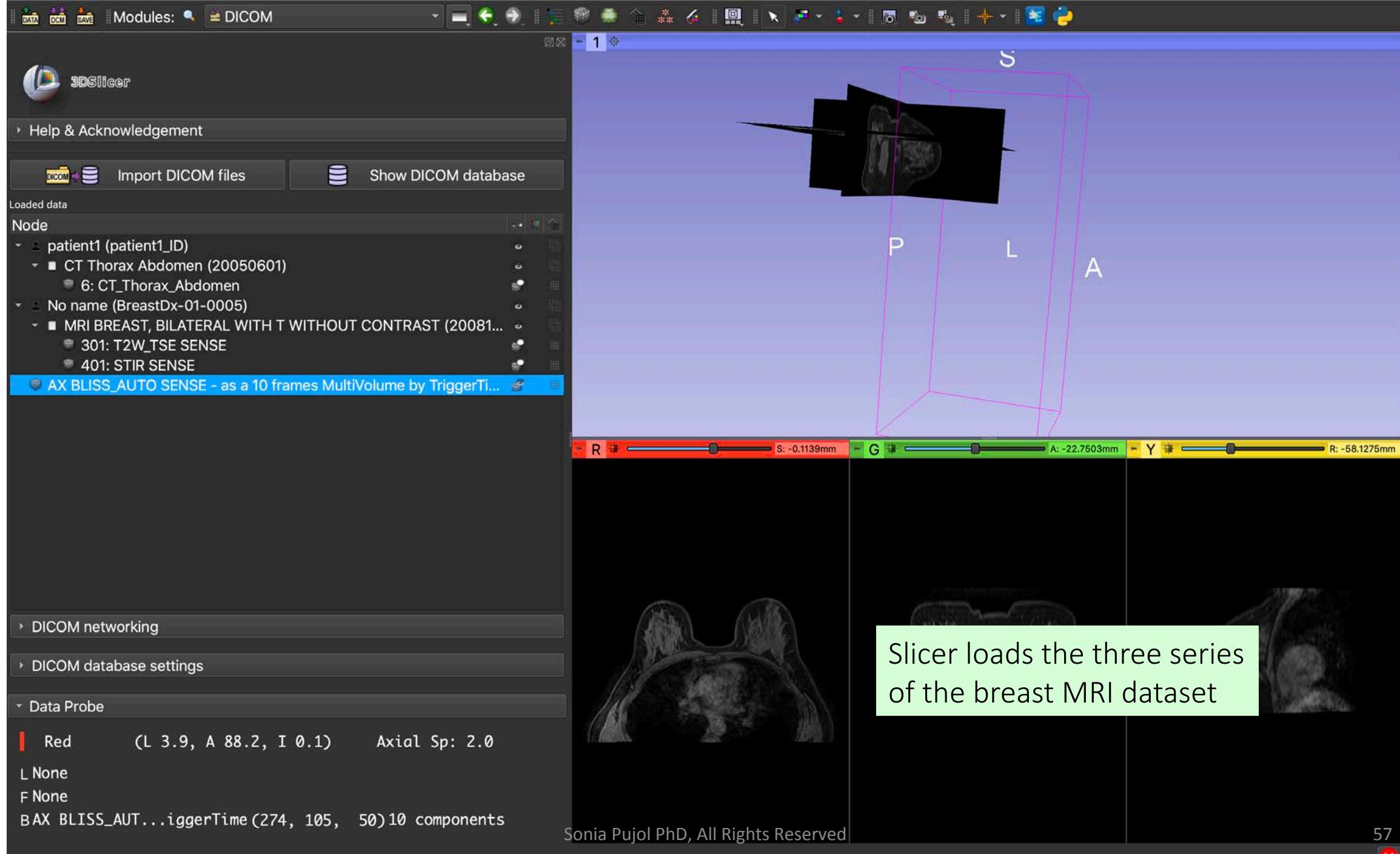
301: T2W_TSE SENSE ✓ 401: STIR SENSE ✓ AX BLISS_AUTO SENSE - as a 10 ... MultiVolume
801: AX BLISS_AUTO SENSE Scalar Volume Images are not equally spaced (a difference of 2 vs 0 in spacing...) AX BLISS_AUTO SENSE - as a 10 ... MultiVolume AX BLISS_AUTO SENSE - as a 10 ... MultiVolume

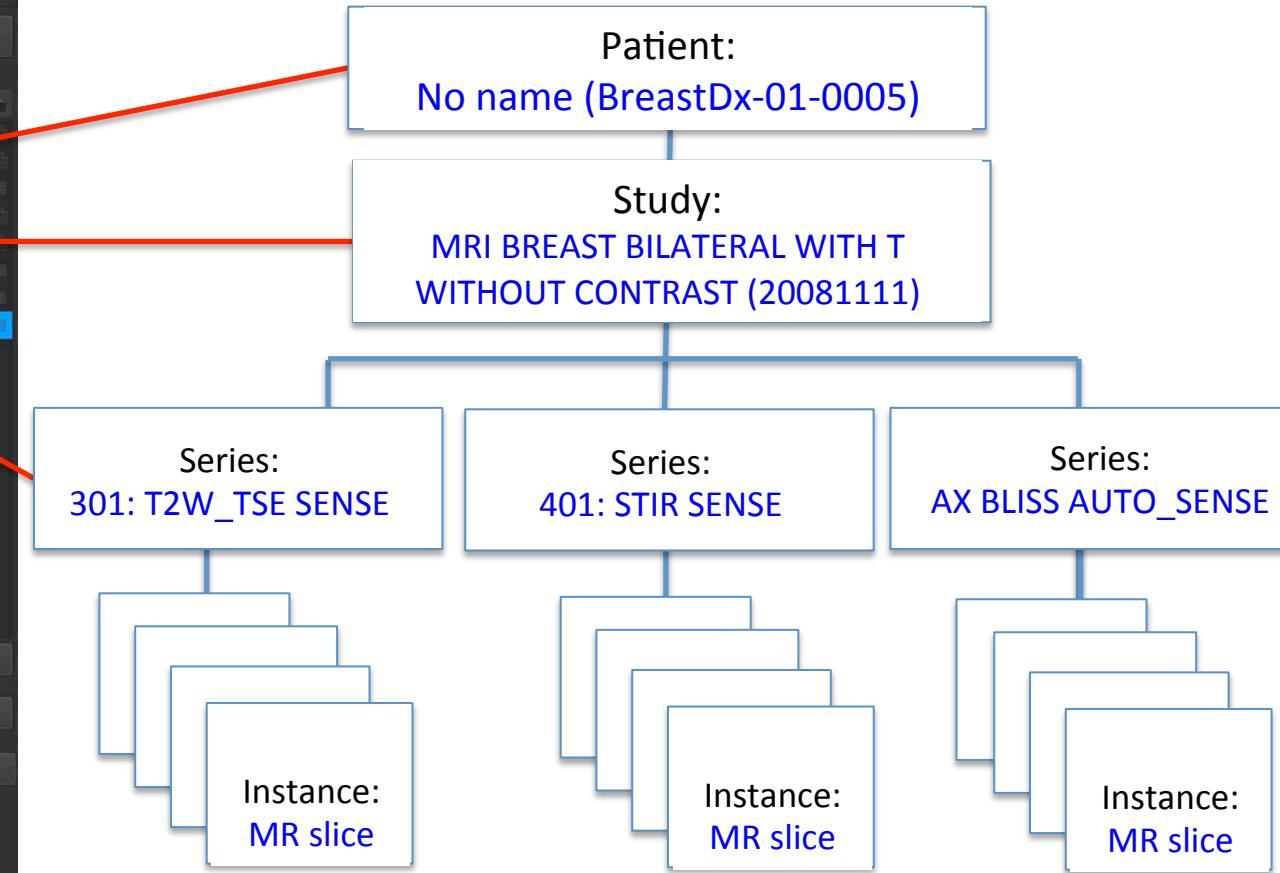
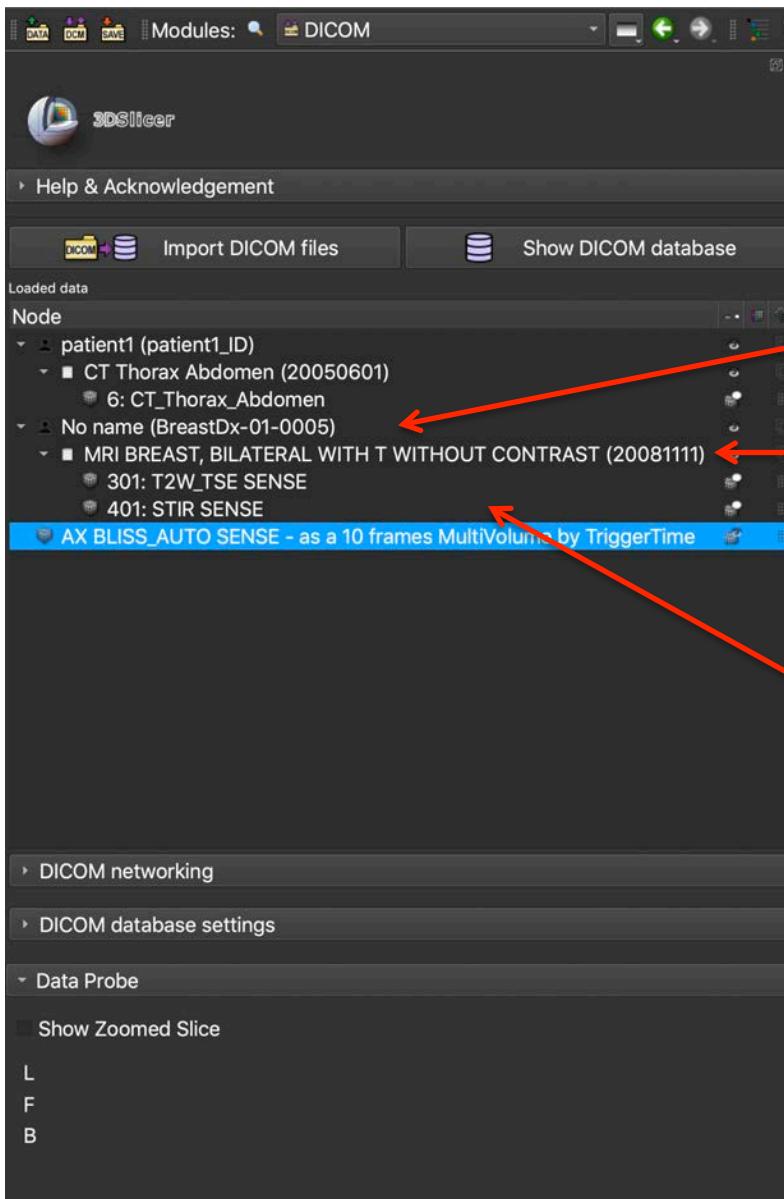
Uncheck All Examine Load Advanced

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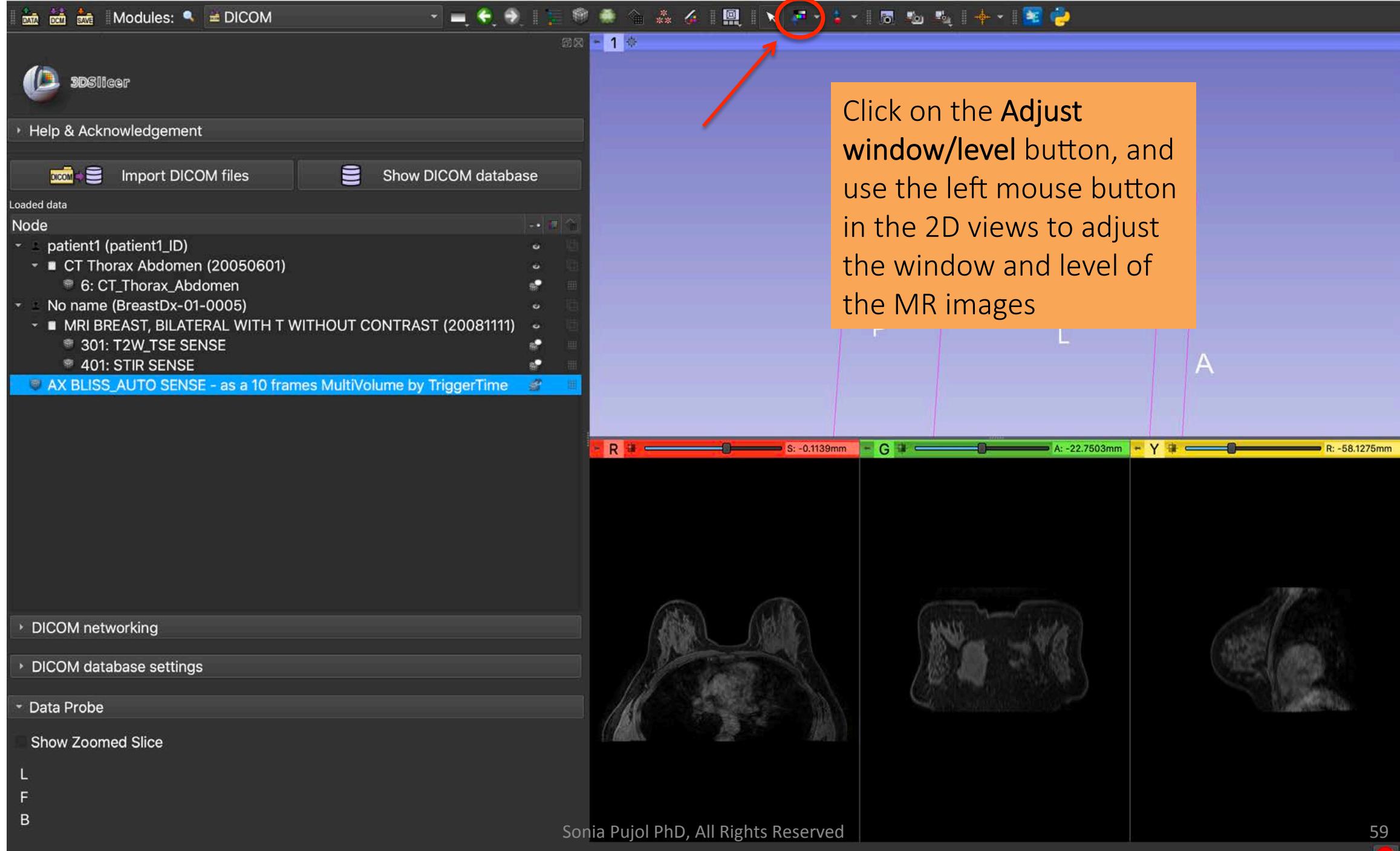
Click on Load to load the data into Slicer

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DICOM data are loaded into Slicer as a patient-study-series hierarchy





3DSlicer

Help & Acknowledgement

Import DICOM files Show DICOM database

Loaded data

Node

- patient1 (patient1_ID)
 - CT Thorax Abdomen (20050601)
 - 6: CT_Thorax_Abdomen- No name (BreastDx-01-0005)
 - MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST (20081111)
 - 301: T2W_TSE SENSE
 - 401: STR SENSE

AX BLISS_AUTO SENSE - as a 10 frames MultiVolume by TriggerTime

DICOM networking

DICOM database settings

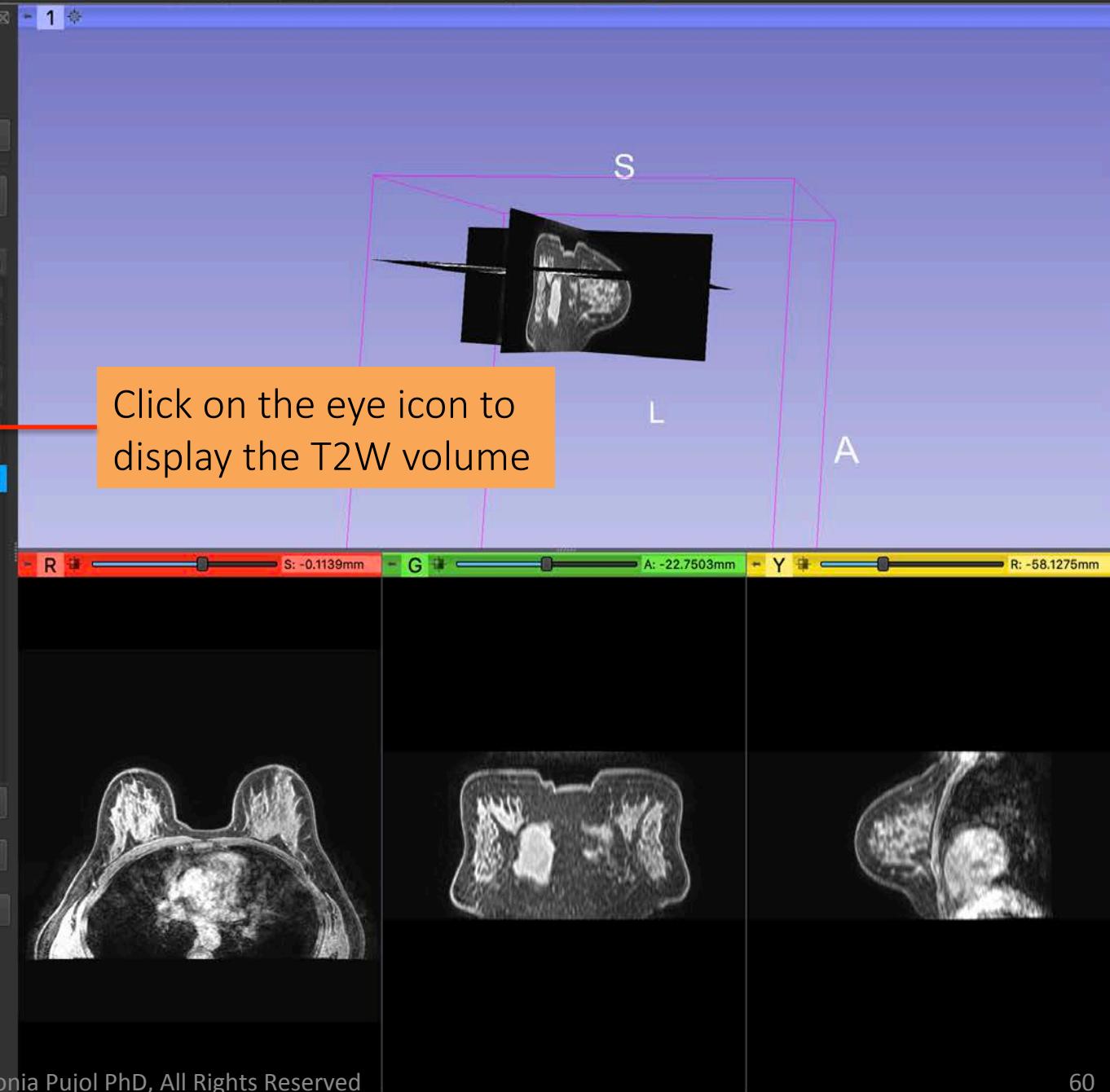
Data Probe

Red (R 106.3, P 16.4, I 0.1) Axial Sp: 2.0

L None

F None

B AX BLISS_AUT...ggerTime(117, 254, 50) 10 components





Help & Acknowledgement

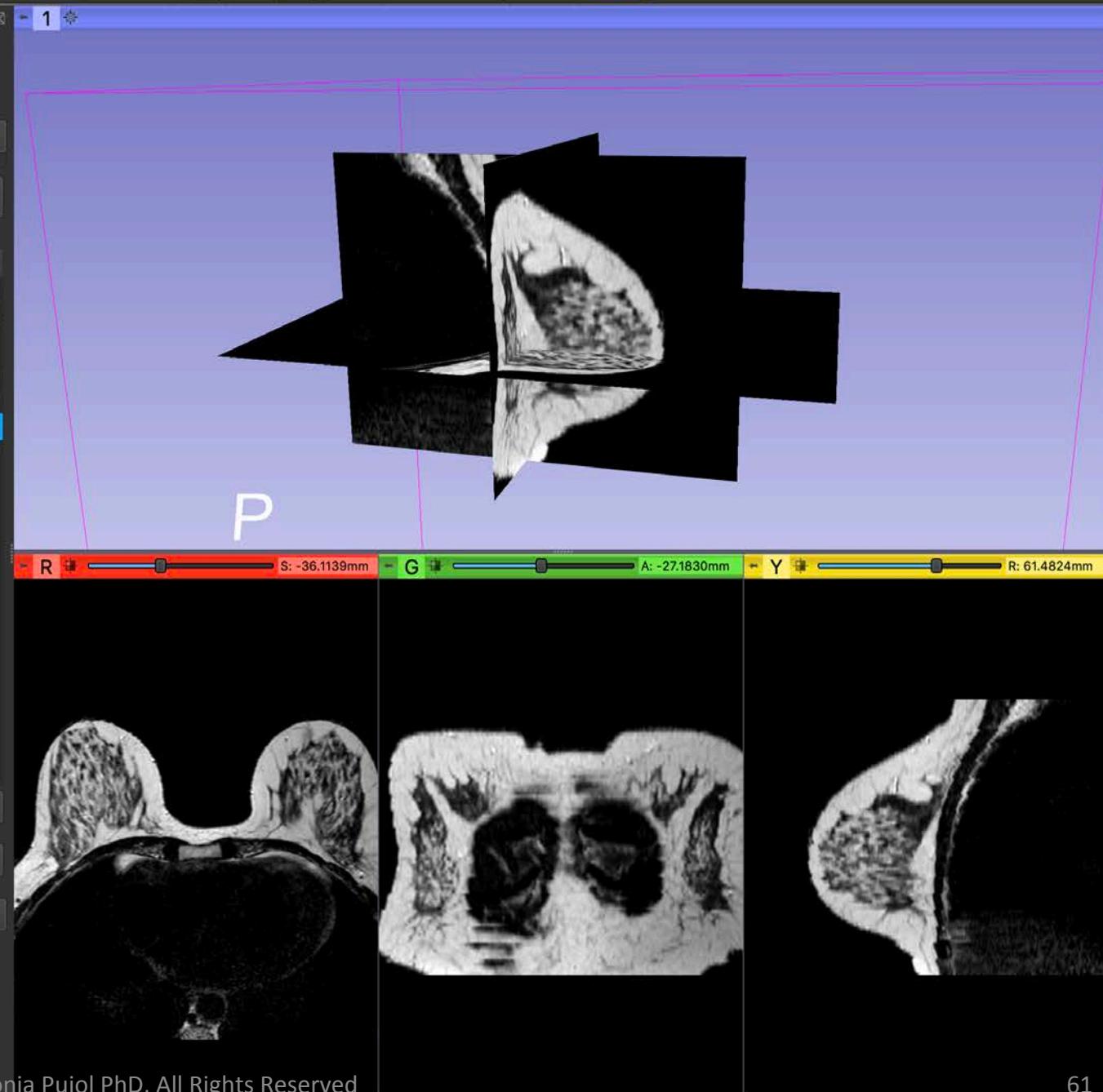
Import DICOM files

Show DICOM database

Loaded data

Node

- patient1 (patient1_ID)
 - CT Thorax Abdomen (20050601)
 - 6: CT_Thorax_Abdomen
 - No name (BreastDx-01-0005)
 - MRI BREAST, BILATERAL WITH T WITHOUT CONTRAST (20081111)
 - 301: T2W_TSE SENSE
 - 401: STIR SENSE
 - AX BLISS_AUTO SENSE - as a 10 frames MultiVolume by TriggerTime



Slicer displays the
T2W_TSE volume in
the viewer

DICOM networking

DICOM database settings

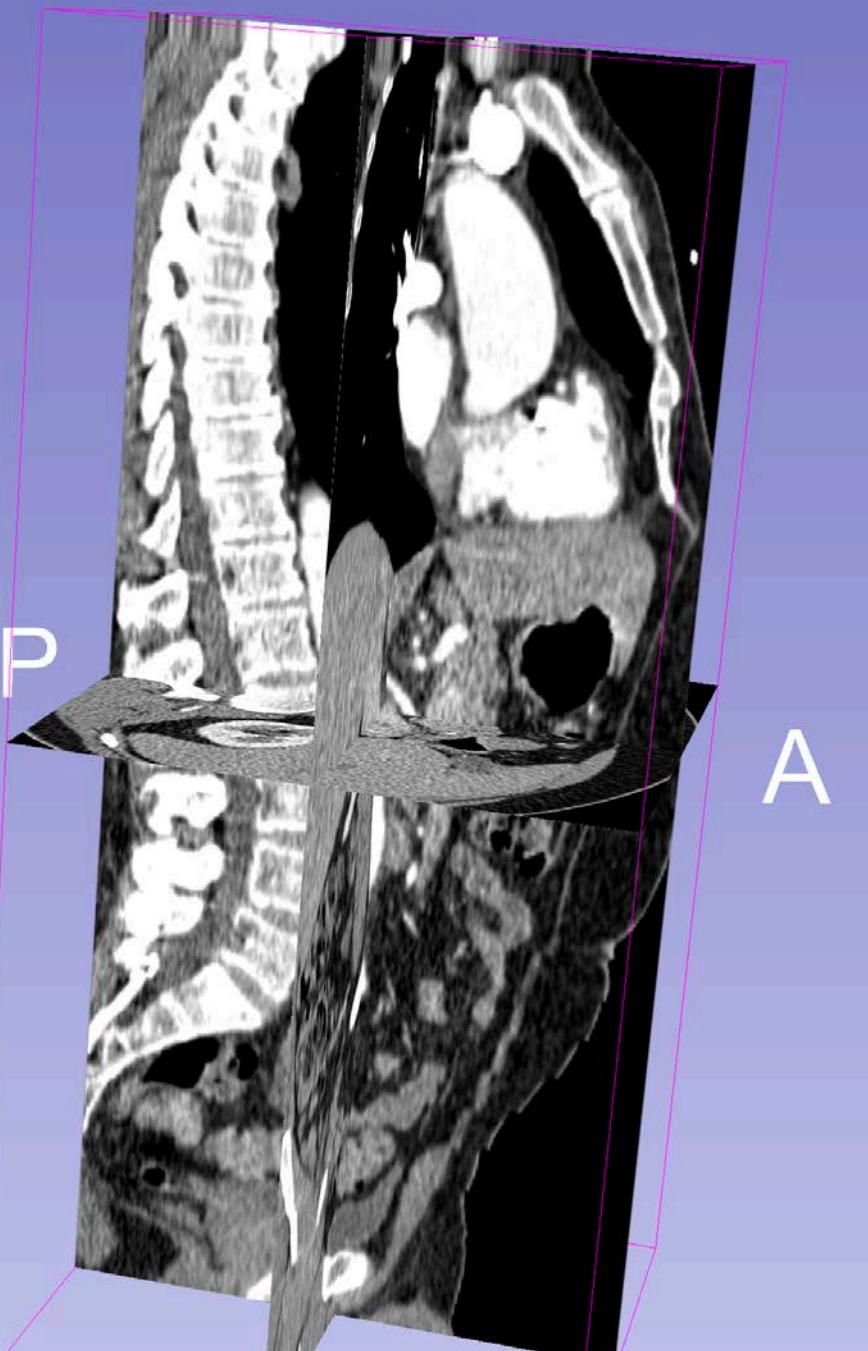
Data Probe

Show Zoomed Slice

L

F

B



Conclusion

- 3D Slicer and the DICOM standard enable compliance with the FAIR principles for biomedical research
- By enabling interoperability between research and clinical environment, 3D Slicer and the DICOM standard lower the inherent barriers to the translation of research advances to patient care

Acknowledgments

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