Segmentation for 3D printing

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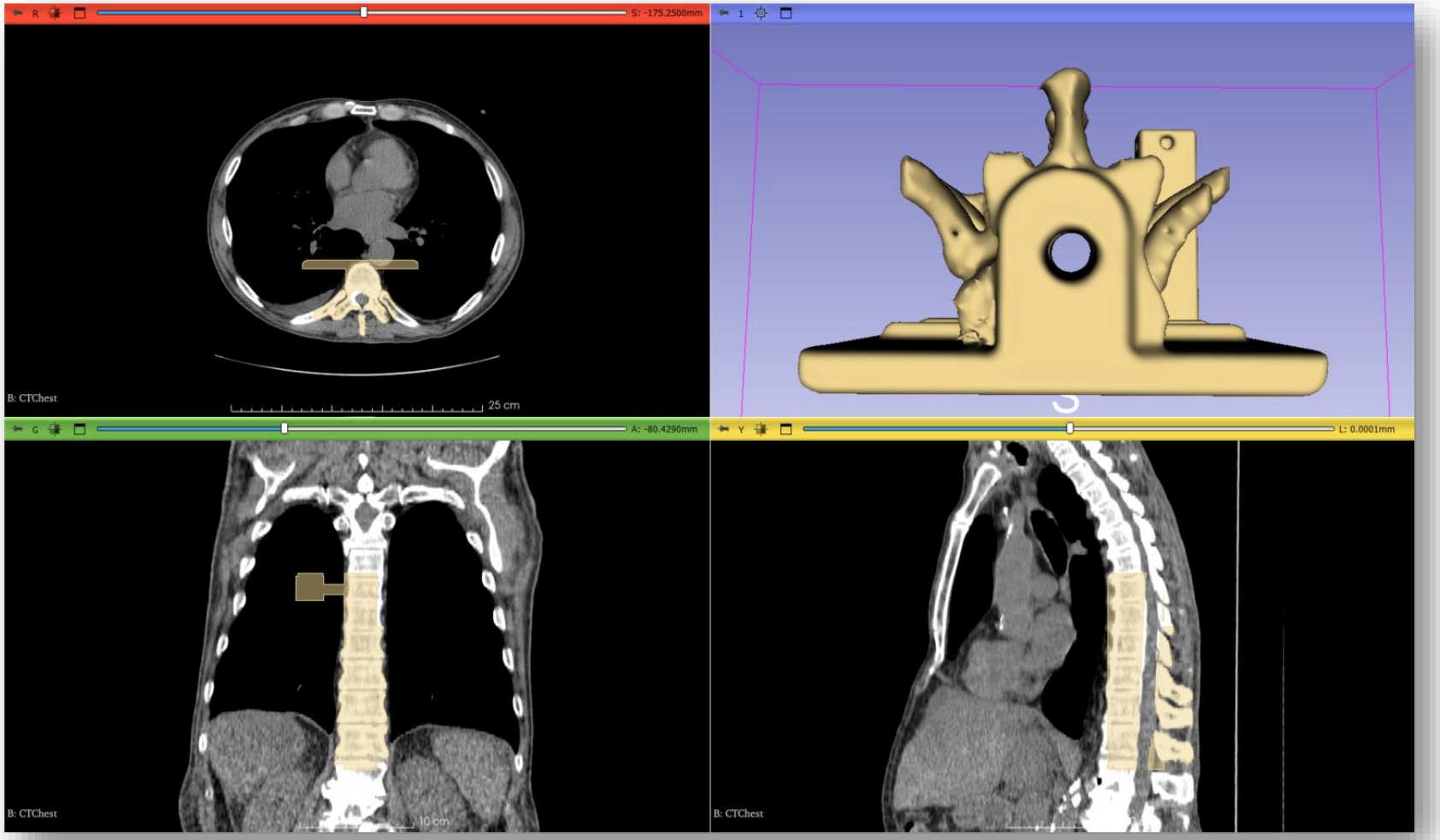
Learning Objective

This tutorial demonstrates image segmentation in the Segment Editor module of 3D Slicer for the purpose of 3D printing.



Clinical utility of the created spine phantom

- Training phantom for needle insertion
- Electromagnetic marker holder
- Filled with gel (~soft-tissue)
- Covered with sheet (~skin)
- Tube with water in the center

[Moult et al. 2013]

Material

This tutorial requires the installation of a recent 3D Slicer stable release (at least 5.6.1), which is available at the

Slicer download page:

http://download.slicer.org/

Tutorial dataset: Phantom base STL model

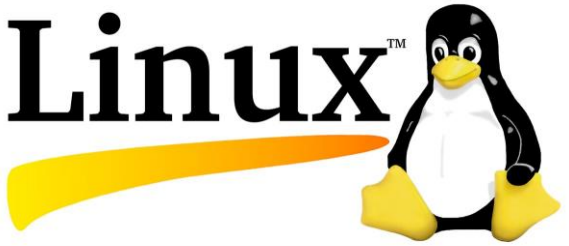
https://raw.githubusercontent.com/Slicer/SlicerSegmentationFor3DPrintingTutorial/main/BasePiece.stl
(source: PerkLab Model Catalog)

User documentation pages:

https://slicer.readthedocs.io/en/latest/user_guide/modules/segmentations.html
https://slicer.readthedocs.io/en/latest/user_guide/modules/segmenteditor.html

Platforms

- Developed and maintained on Windows 64bit, macOS, and Linux 64bit & 32bit



- Slicer requires
  - Minimum 4GB RAM (more is recommended)
  - Dedicated GPU for fast rendering (OpenGL 3.2+)

A quick guide on how to use this tutorial

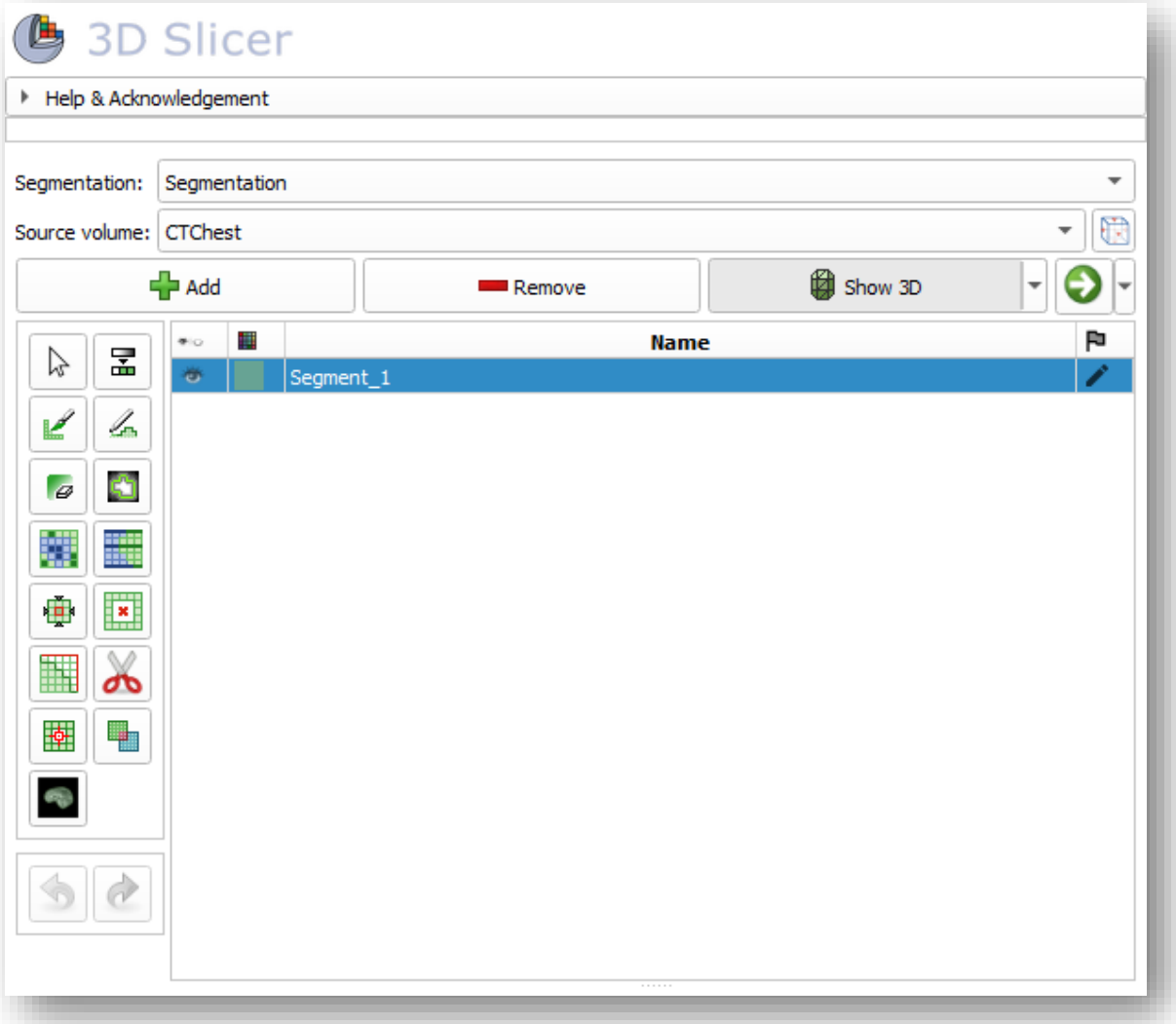
Slicer is a comprehensive platform. Hence, there's usually more than one ways to work with your data and achieve the same result.

During the course of this tutorial, we sometimes show more than one possibility, so you will see three kinds of slides:

- Slides that are **common** to both approaches, have a **white background**.
- If you are interested in somewhat **more details**, then simply follow all the slides. Slides with a **light green tint** show different ways to achieve the same results.
- If you want a **quicker** solution, without going too much into the details, in addition to the white ones, follow the slides marked with a clock (shown in the corner), and a slighty **red-tinted** background.

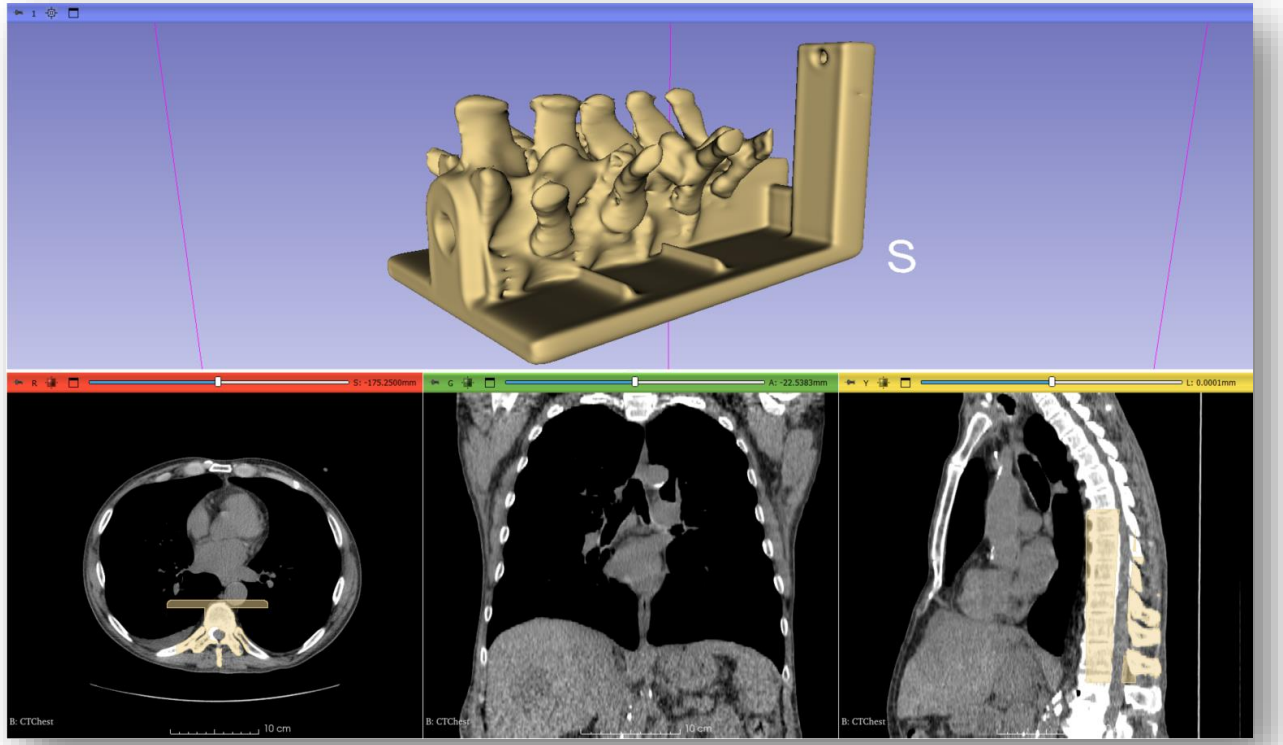
Segment Editor module

- Real-time 3D surface update
- Editing on oblique slices
- Overlapping segments
- Intuitive tools
- Manual
- Semi-automatic
- Advanced settings



Overview

1. Load CT image
2. Segment vertebrae to be 3D printed
3. Add phantom base to segmentation
4. Merge and finalize phantom
5. Save phantom segment to STL file for 3D printing



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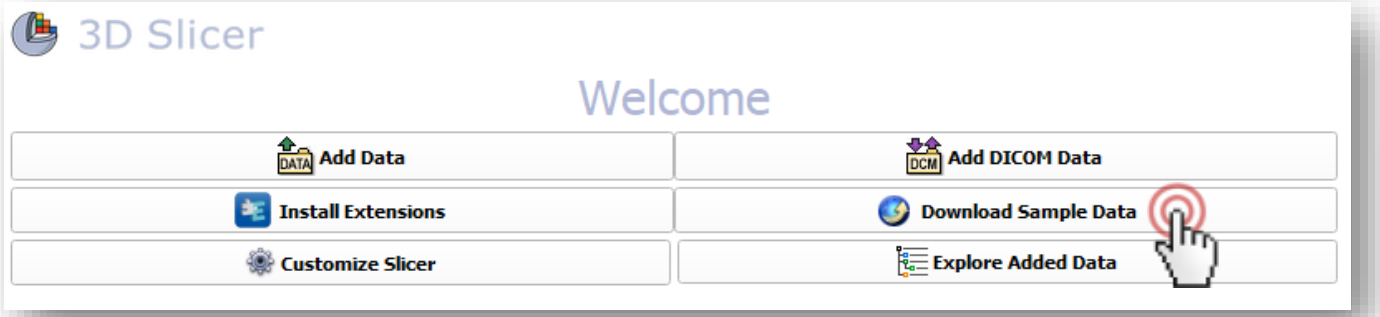
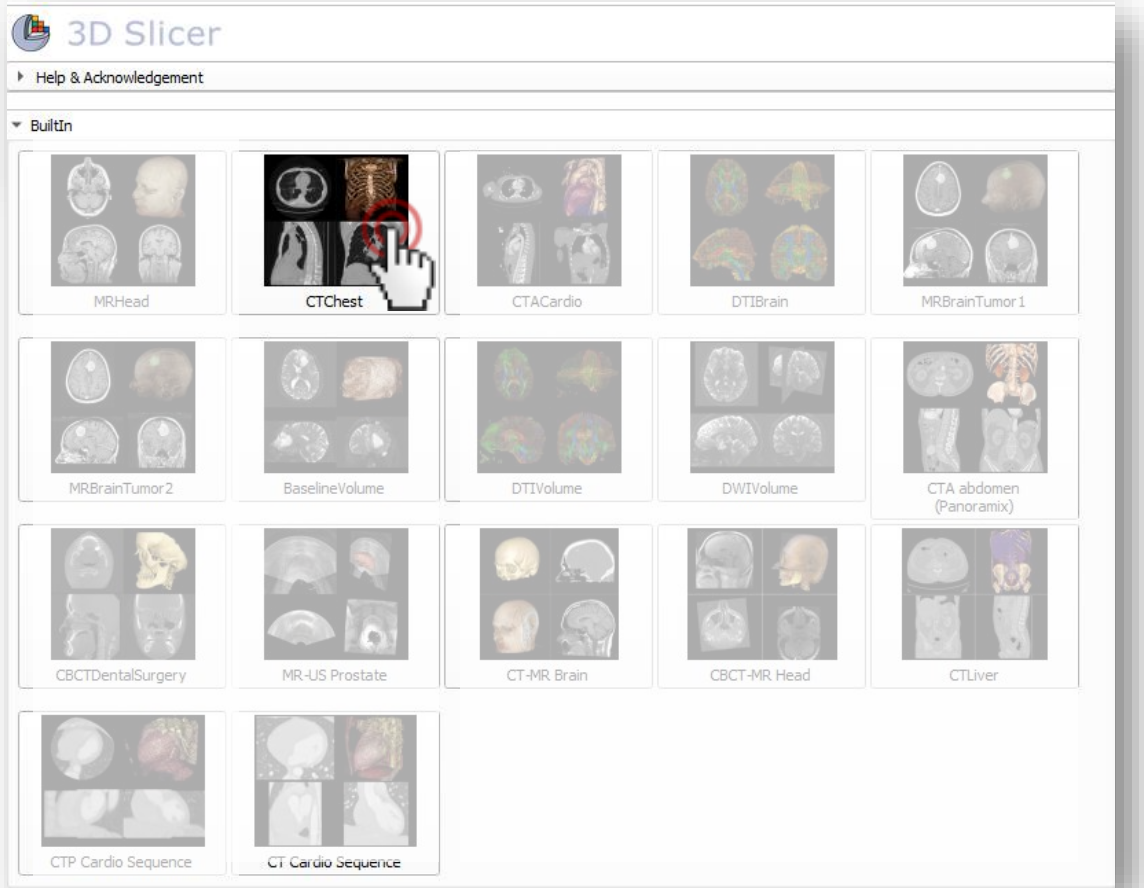
Part 1: Load CT image

Overview:

- Load sample “CTChest” dataset
- Set image contrast for better visibility

1/1: Load CTChest dataset





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1/2: Sample CT loaded

Requesting download *CT-chest.nrrd* from https://github.com/Slicer/SlicerTestingData/releases/download/SHA256/4507b664690840abb6cb9af2d919377ffc4ef75b167cb6fd0f747befdb12e38e ...

Downloaded 4.0 MB (10% of 40.2 MB)...

.
.
.

Downloaded 40.2 MB (100% of 40.2 MB)...

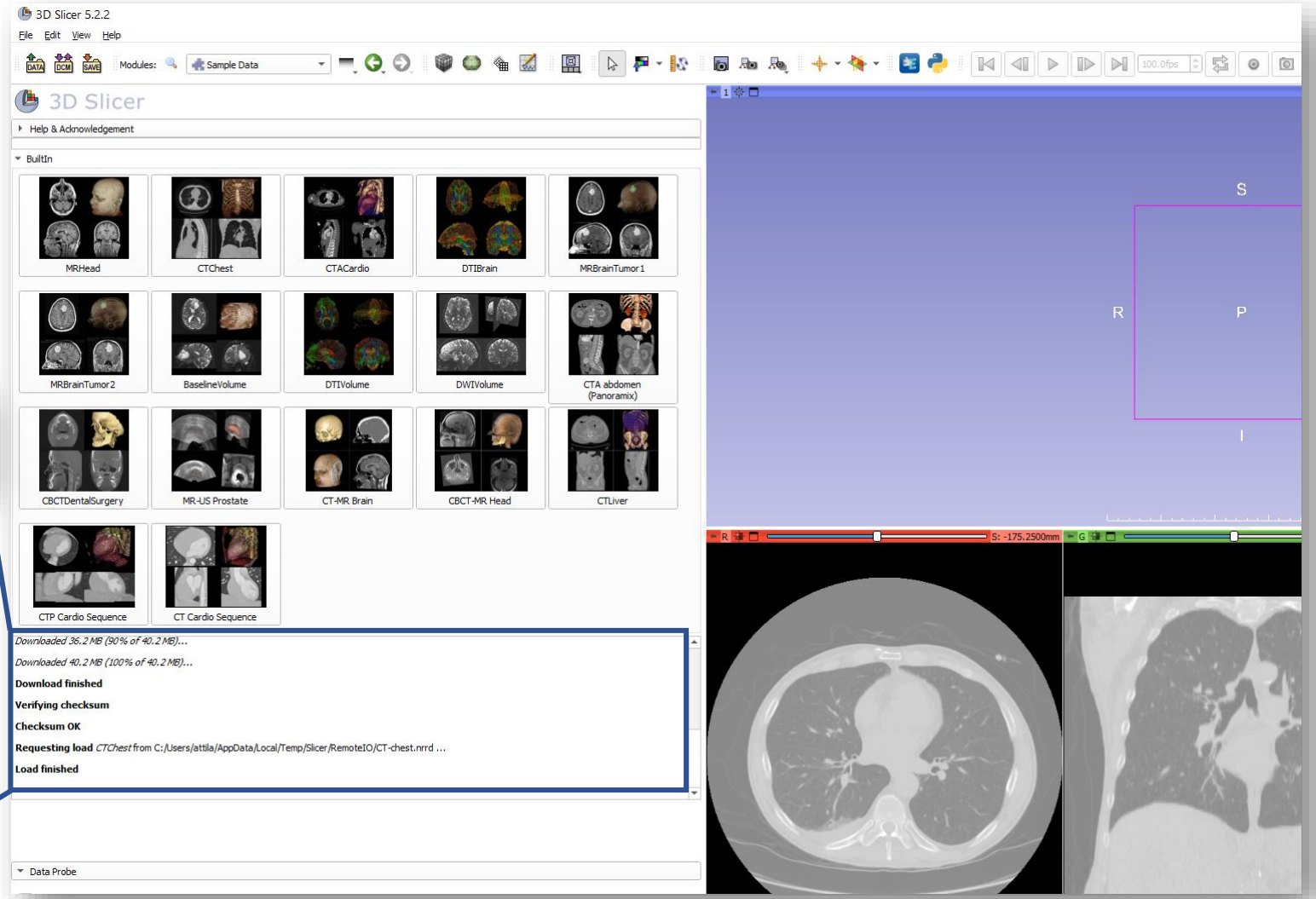
Download finished

Verifying checksum

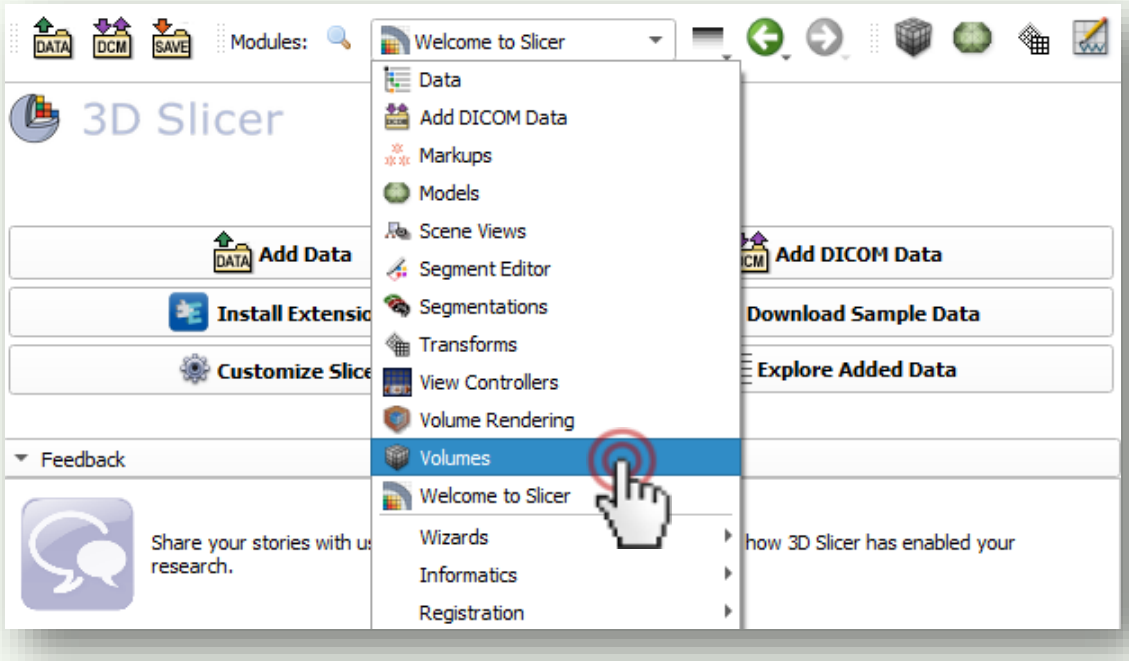
Checksum OK

Requesting load *CTChest* from C:/Users/attila/AppData/Local/Temp/Slicer/RemoteIO/CT-chest.nrrd ...

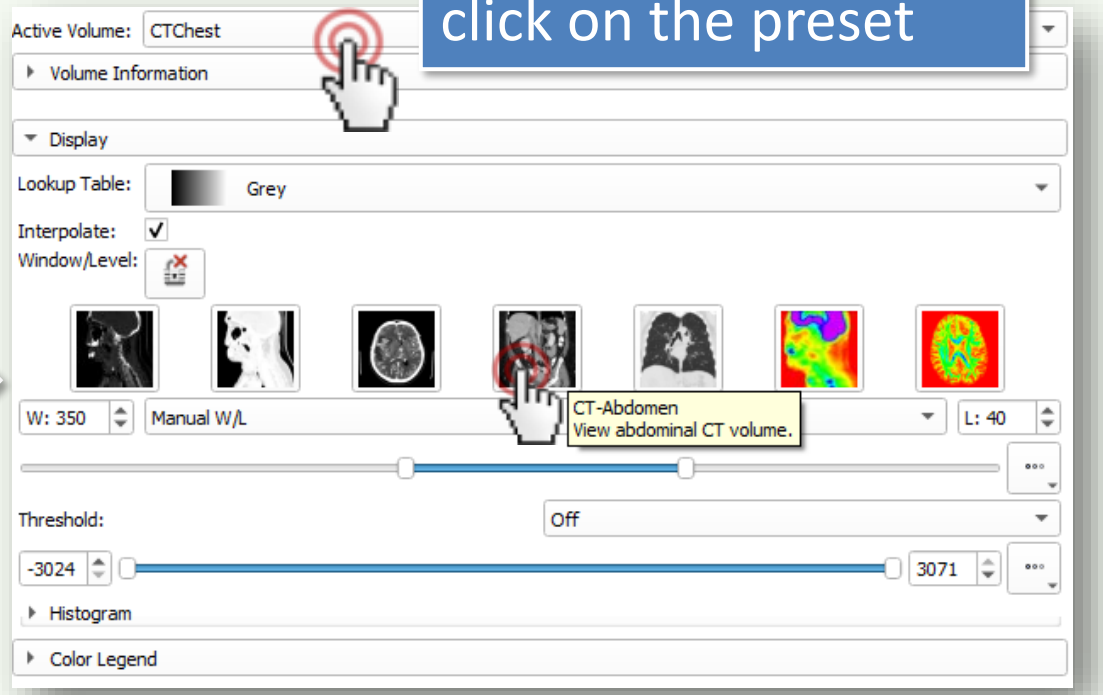
Load finished



1/3/A: Change contrast

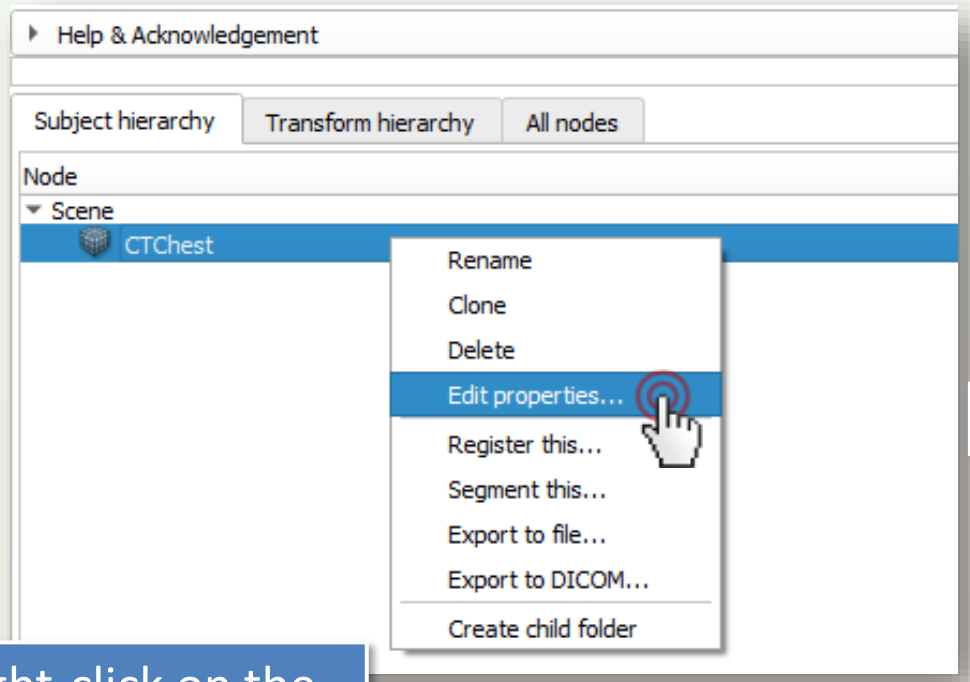


Select *CTChest* as active volume and click on the preset



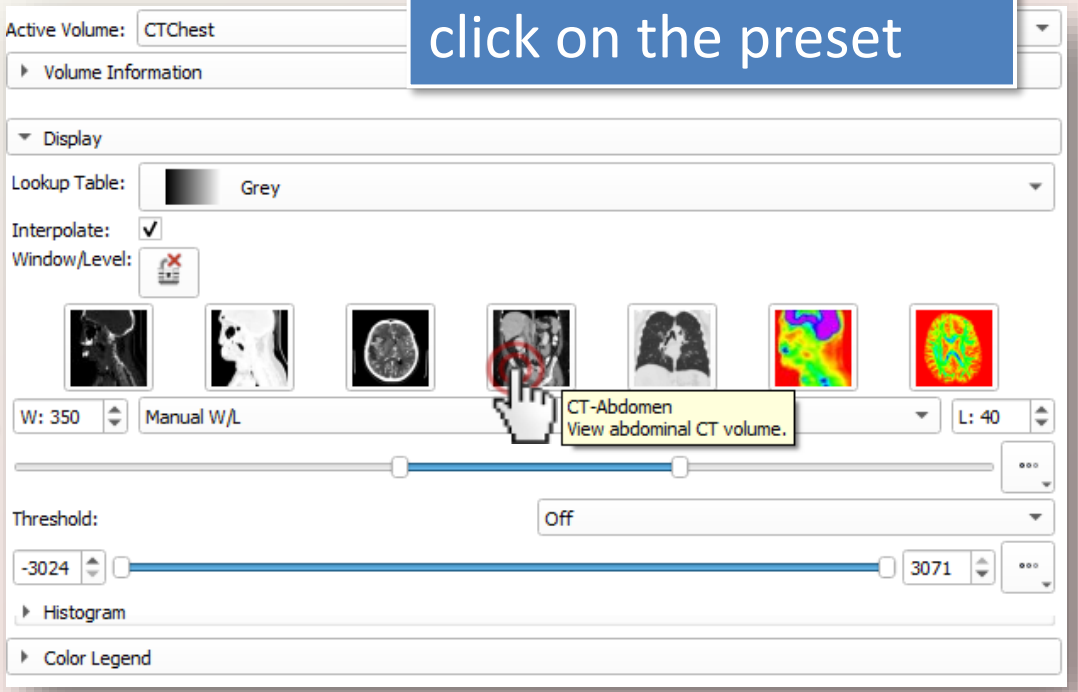
1/3/B: Change contrast

Switch to the *Data* module



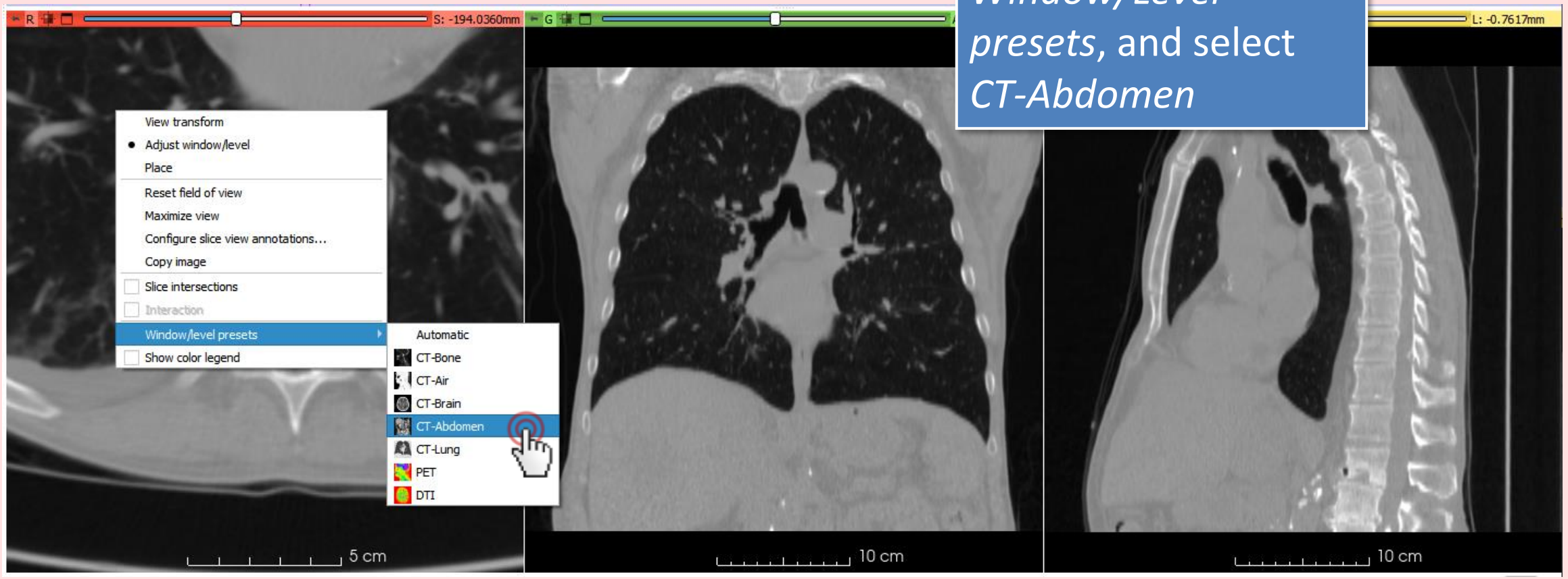
Right-click on the data and click *Edit properties…*

Select *CTChest* as active volume and click on the preset



1/3/C: Change contrast

Right-click on any of the slice views, select *Window/Level presets*, and select *CT-Abdomen*

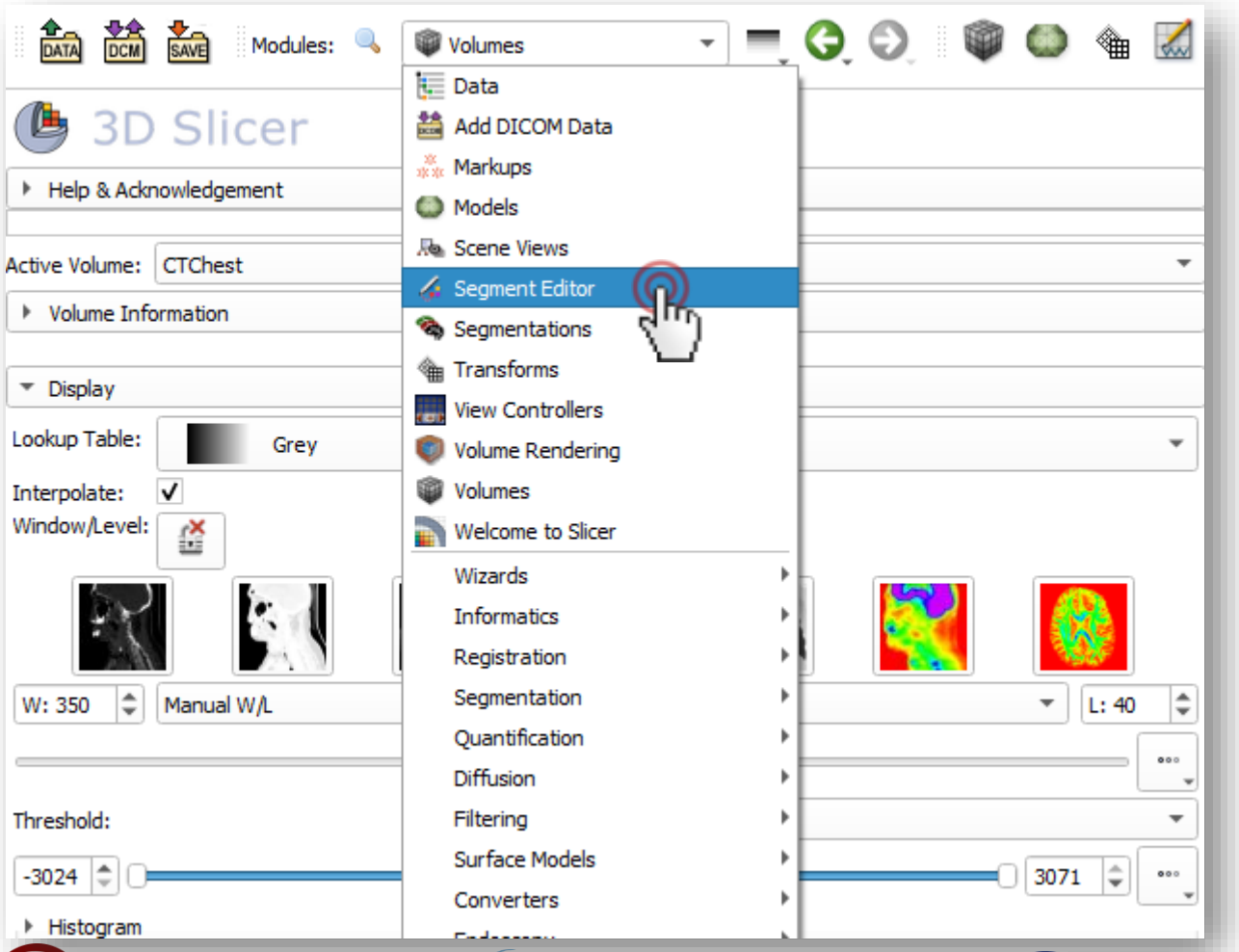


Part 2: Segment vertebrae

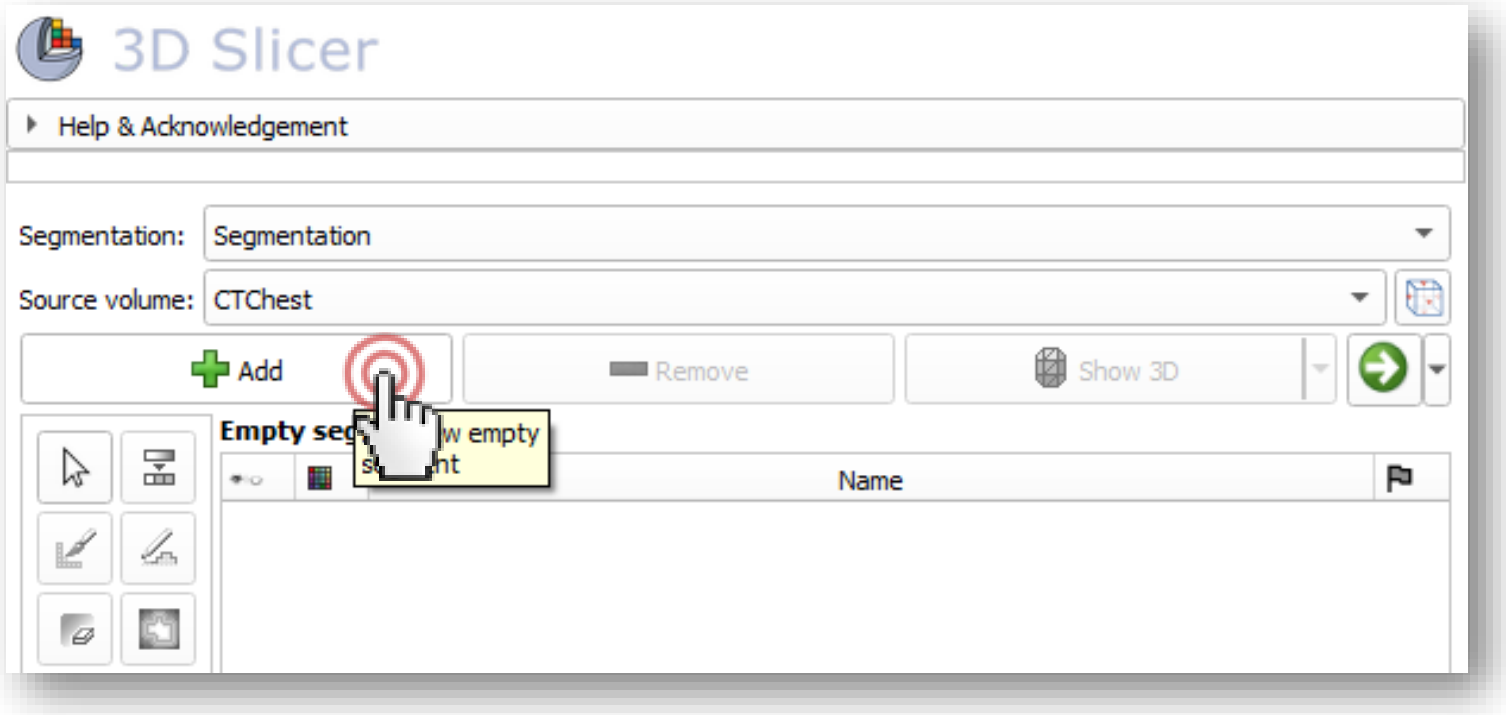
Overview:

- Add new segment
- Threshold bone
- Remove speckles with Islands
- Cut out vertebrae with Scissors

2/1: Switch to Segment Editor module



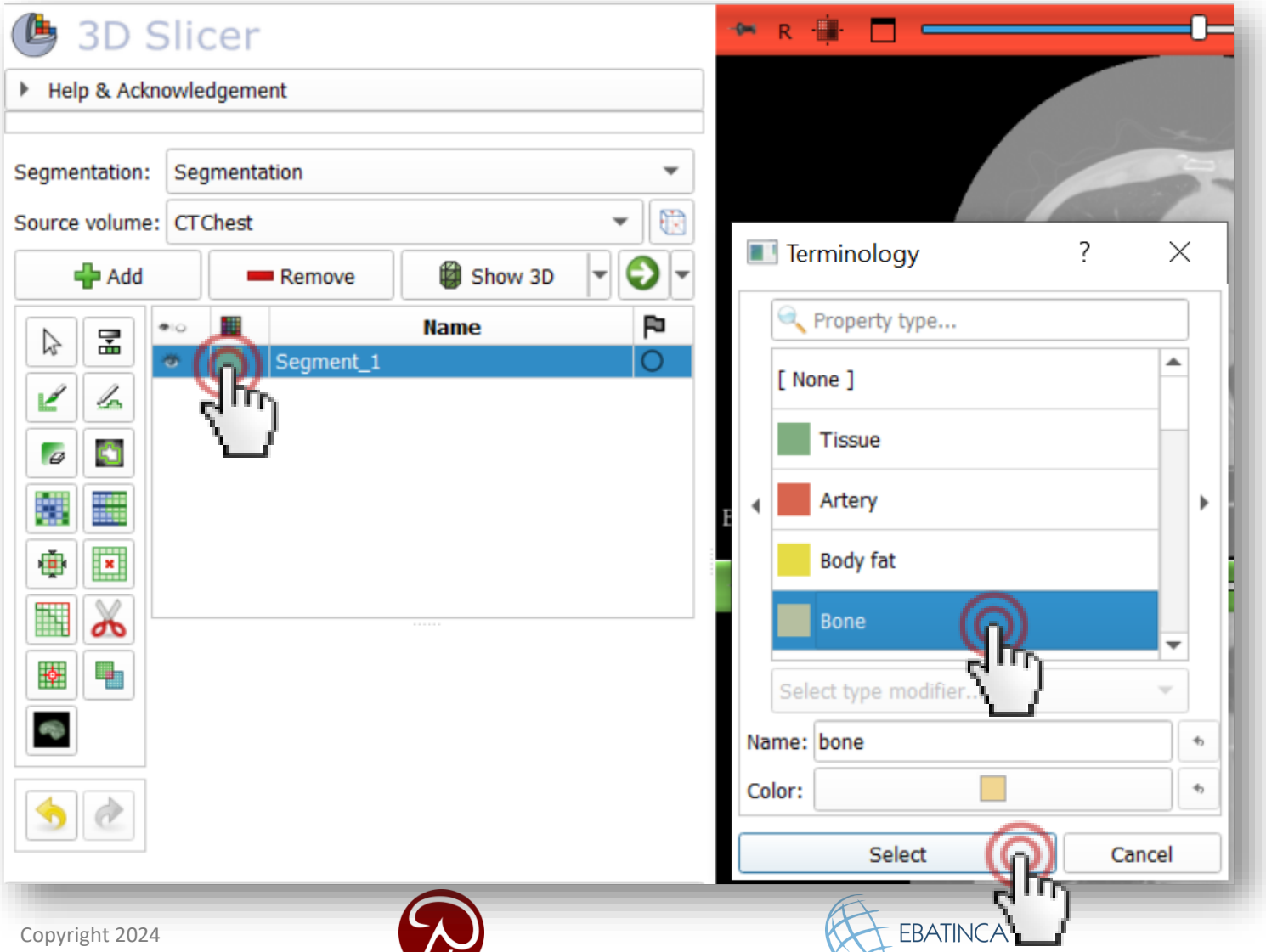
2/2: Add new segment



- Segmentation automatically created
- CT volume automatically selected as source

(Source volume is the segmented volume that defines the resolution of the segments)

2/3: Set terminology

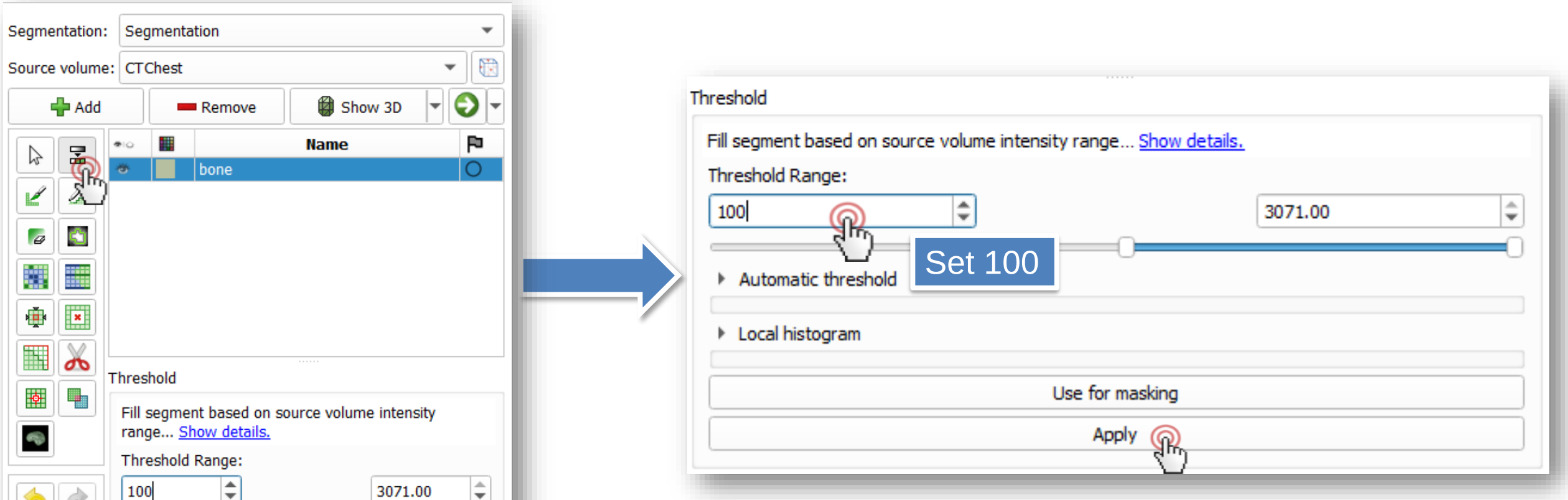


1. Double-click on the segment's color
2. Pick a Terminology for the given segment (A name and a color for the segment.)

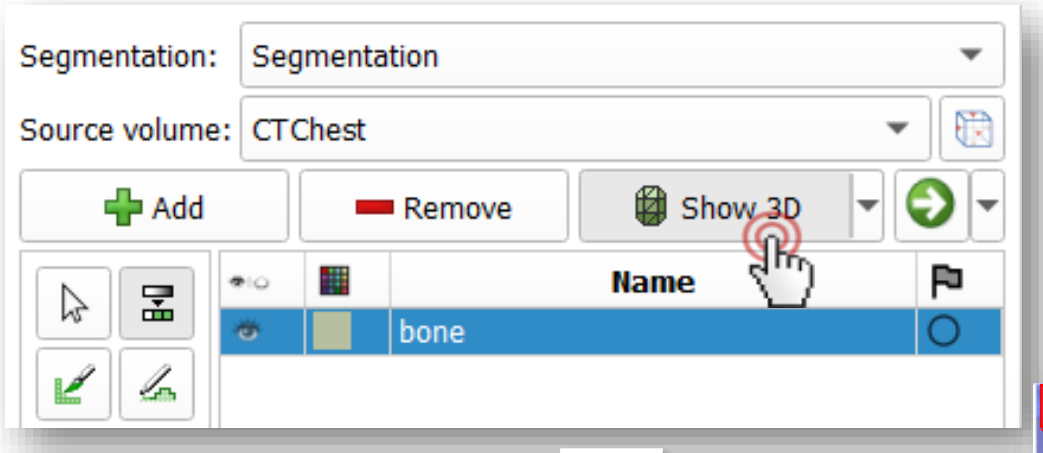
You can also set a different name and color if needed.

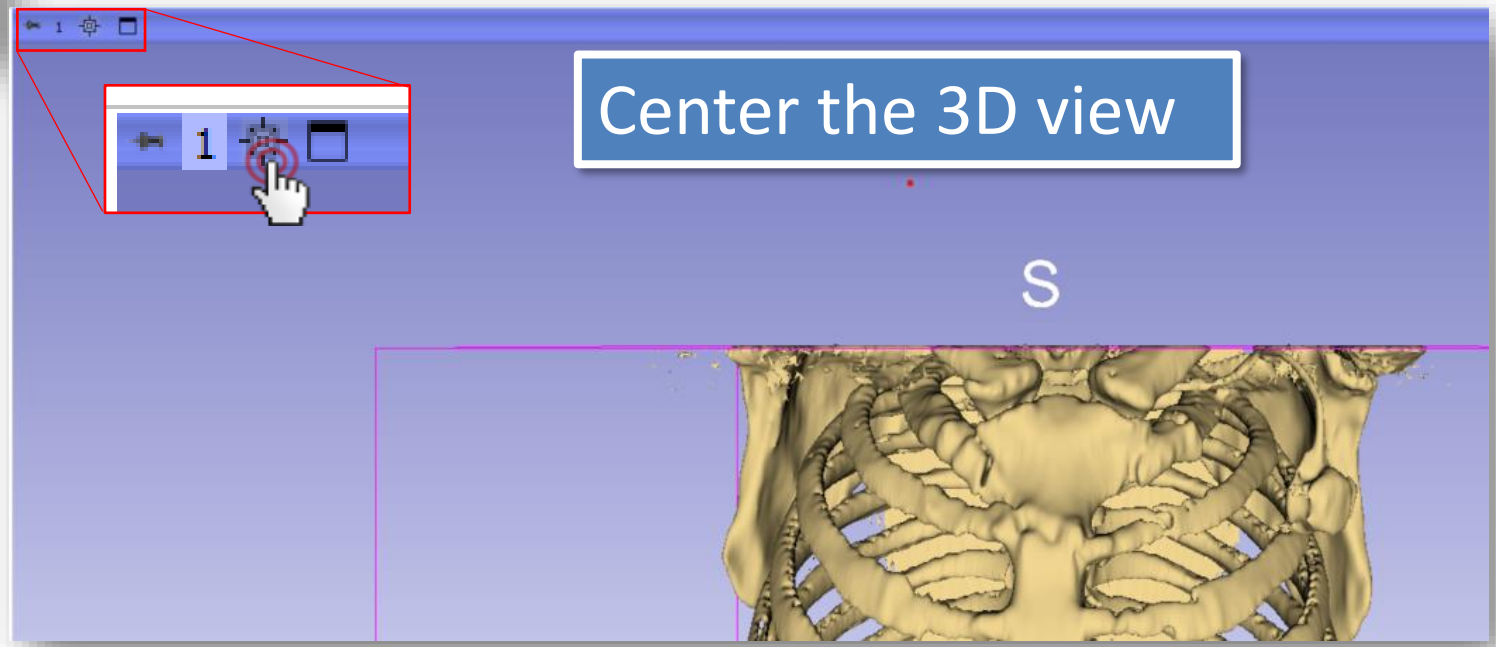
It is not required, but makes your workflow more robust.

2/4: Set threshold to get bone

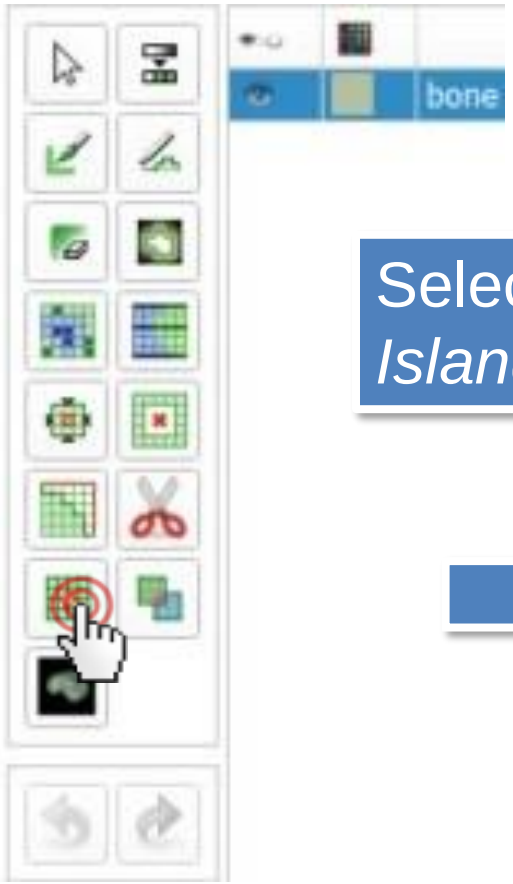


See it in 3D!

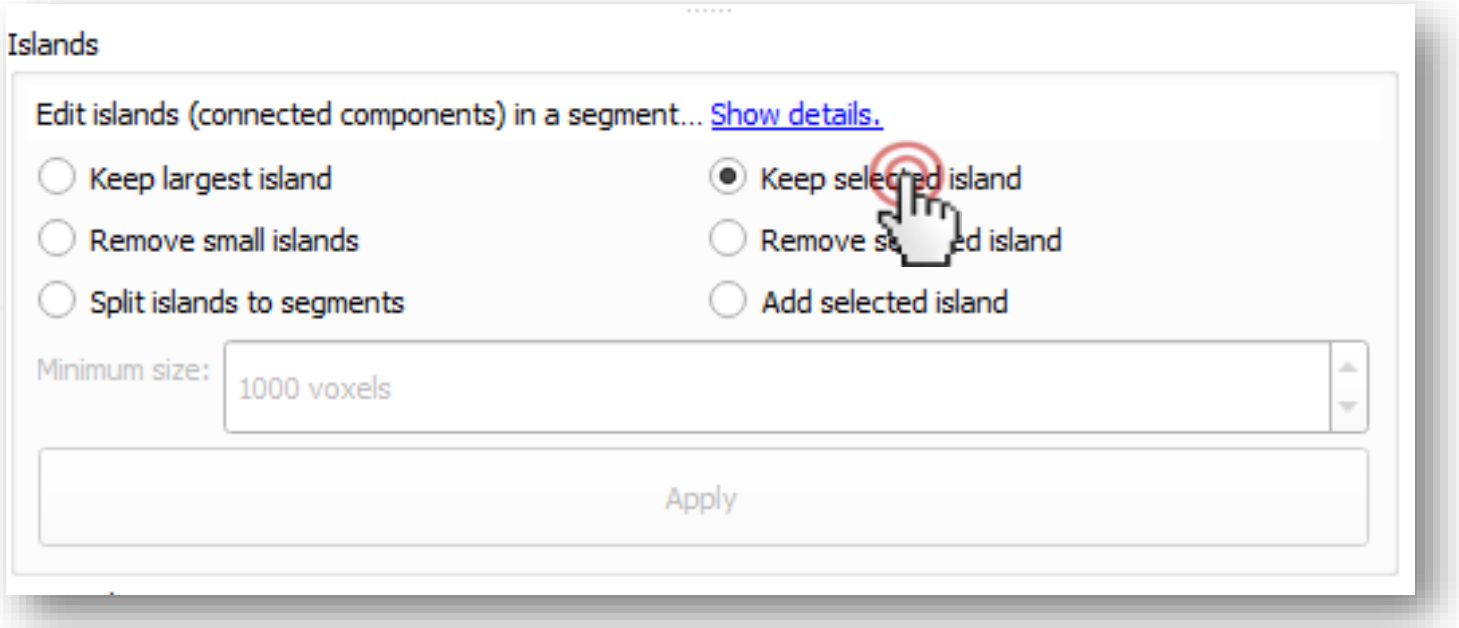




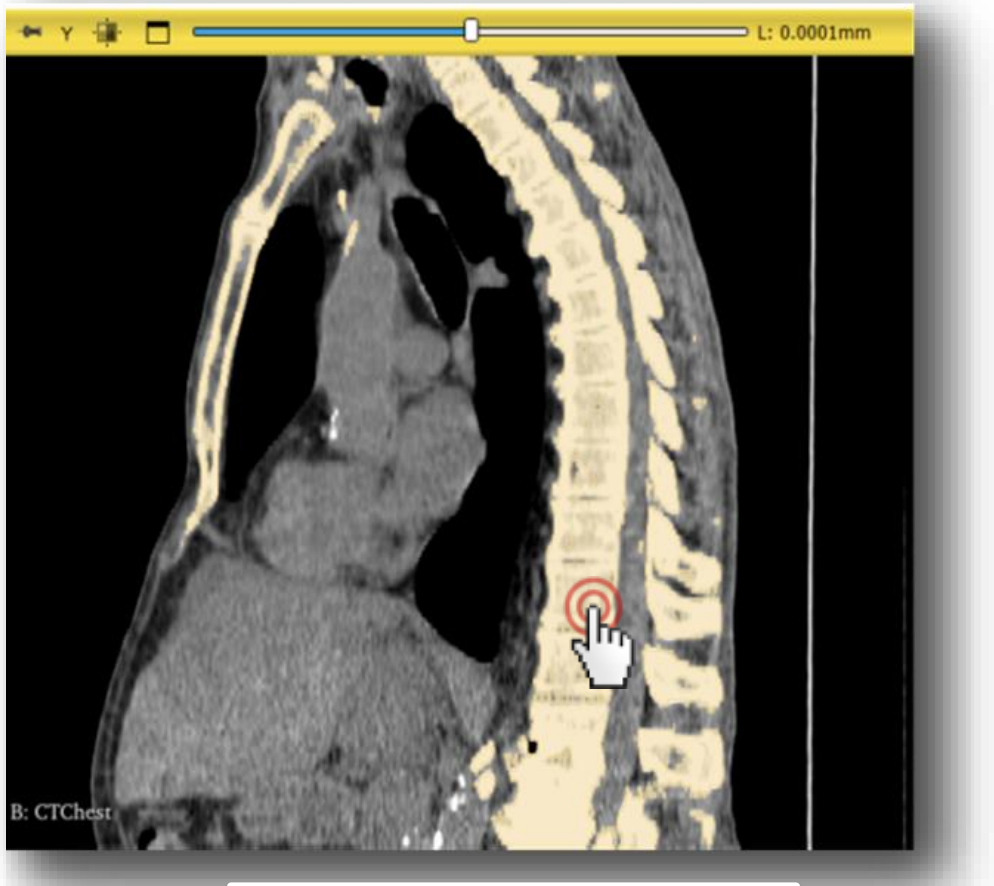
2/5: Remove speckle with the Islands effect



Select the *Islands* effect

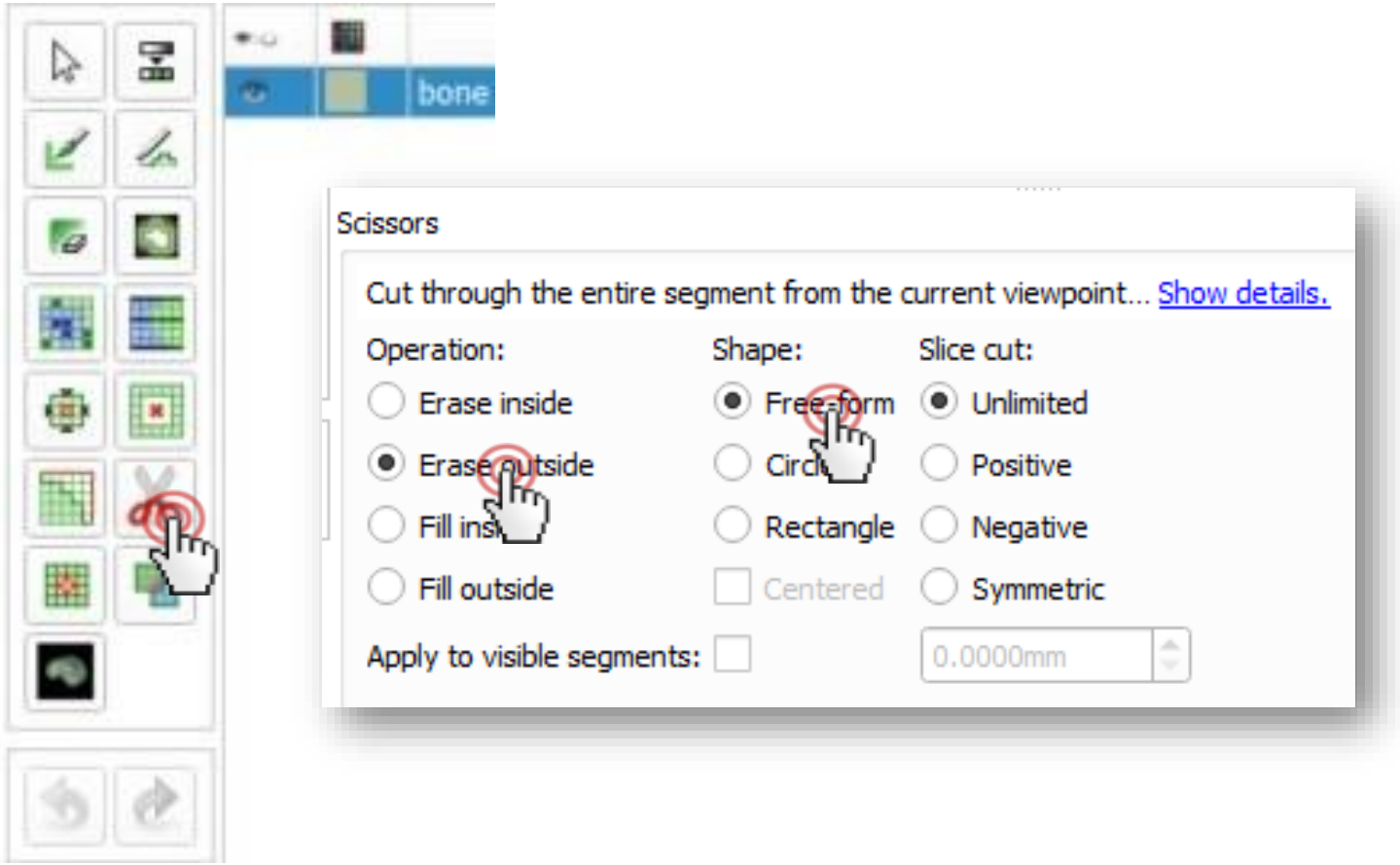


2/5: Remove speckle with the Islands effect



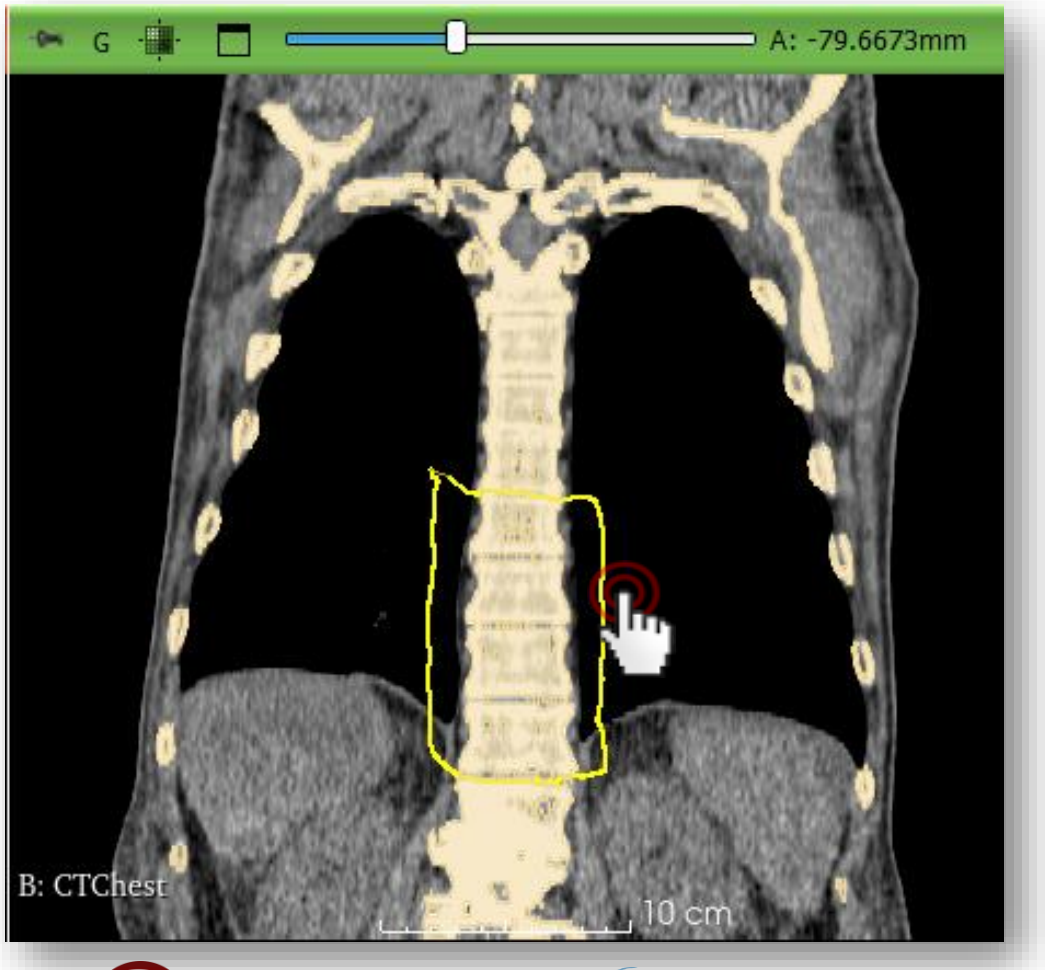
Click on the spine

2/6: Cut out vertebrae with Scissors



1. Select the *Scissors* effect
2. Choose *Erase outside* as operation
3. Choose *Free-form* shape

2/7: Cut out vertebrae with Scissors



Trace around the desired vertebrae with the scissor on the coronal view (green slice)

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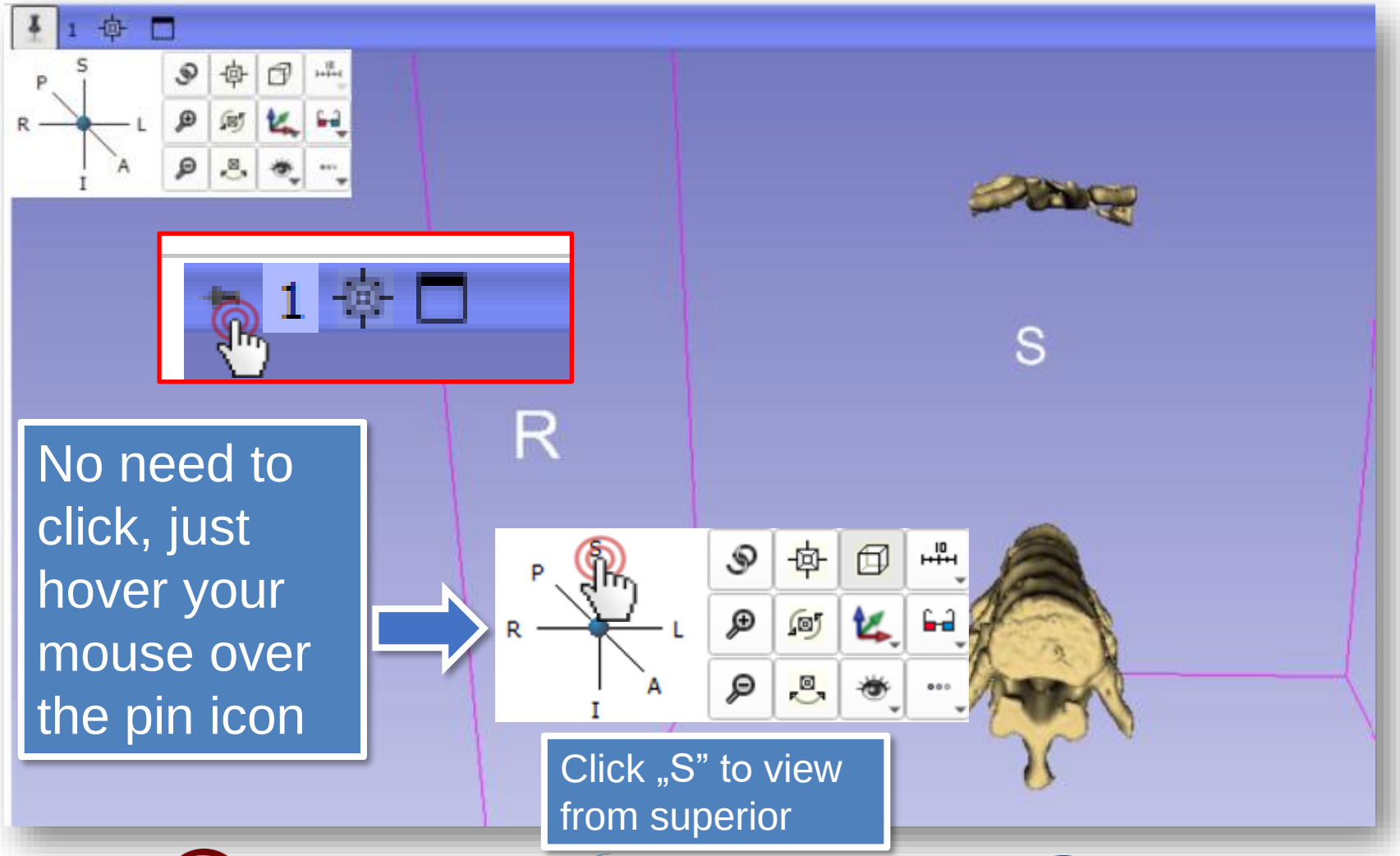
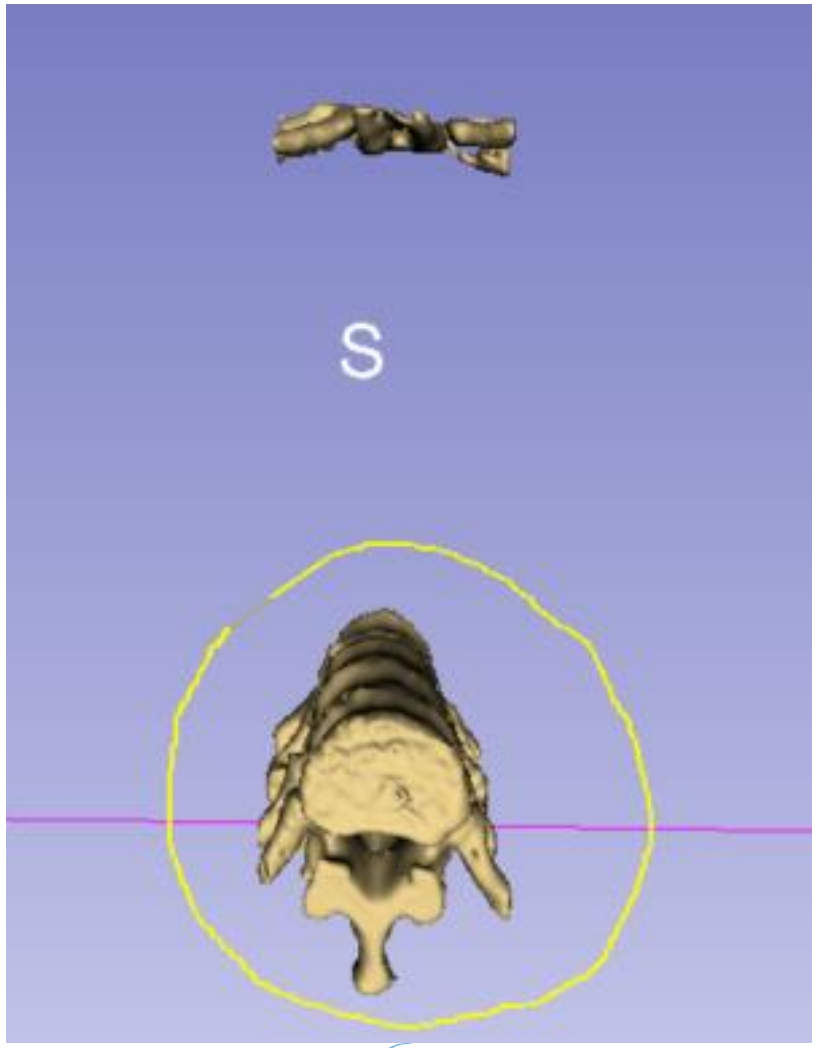
Orient the 3D view

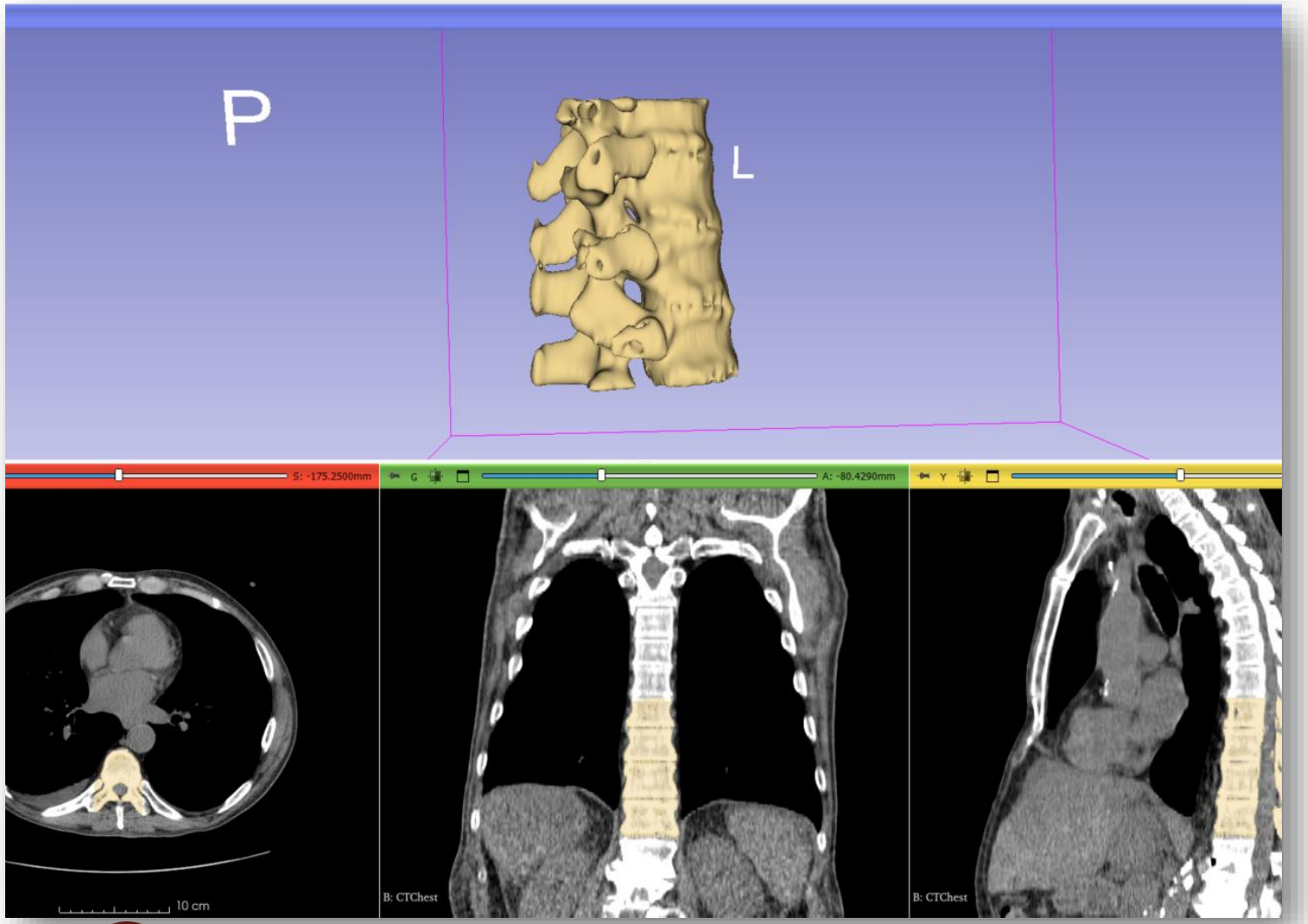


2/8: Remove remaining parts with Scissors



Select the vertebrae in the 3D view to erase the unnecessary parts (ribs on the anterior side in this case)

2/9: Vertebrae are segmented



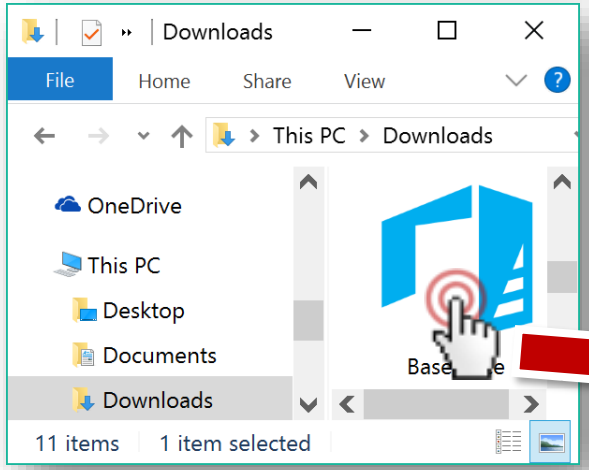
Part 3: Add phantom base

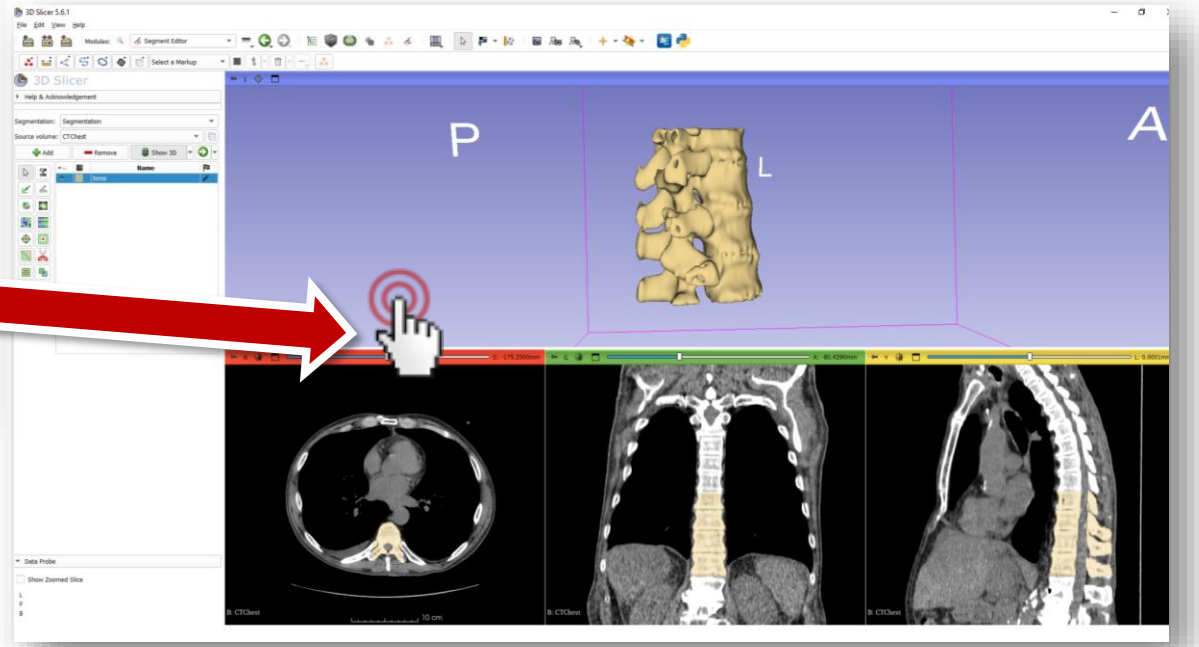
Overview:

- Load phantom base STL file
- Transform model to desired position and orientation
- Import model to segmentation node
- Cut hole through middle of the spine

3/1: Load phantom base as model node

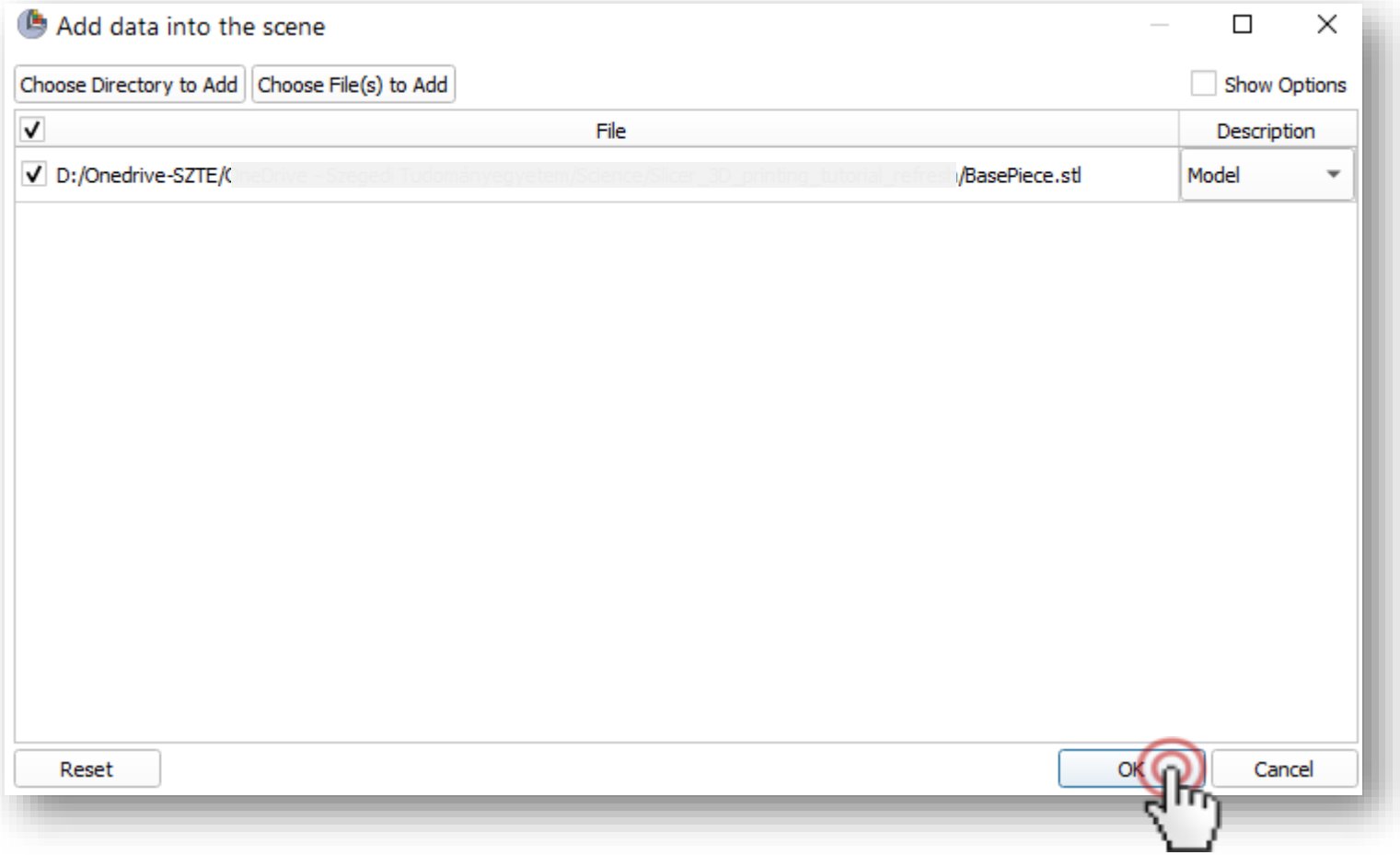
Download phantom base STL file from
https://www.slicer.org/wiki/File:BasePiece.zip



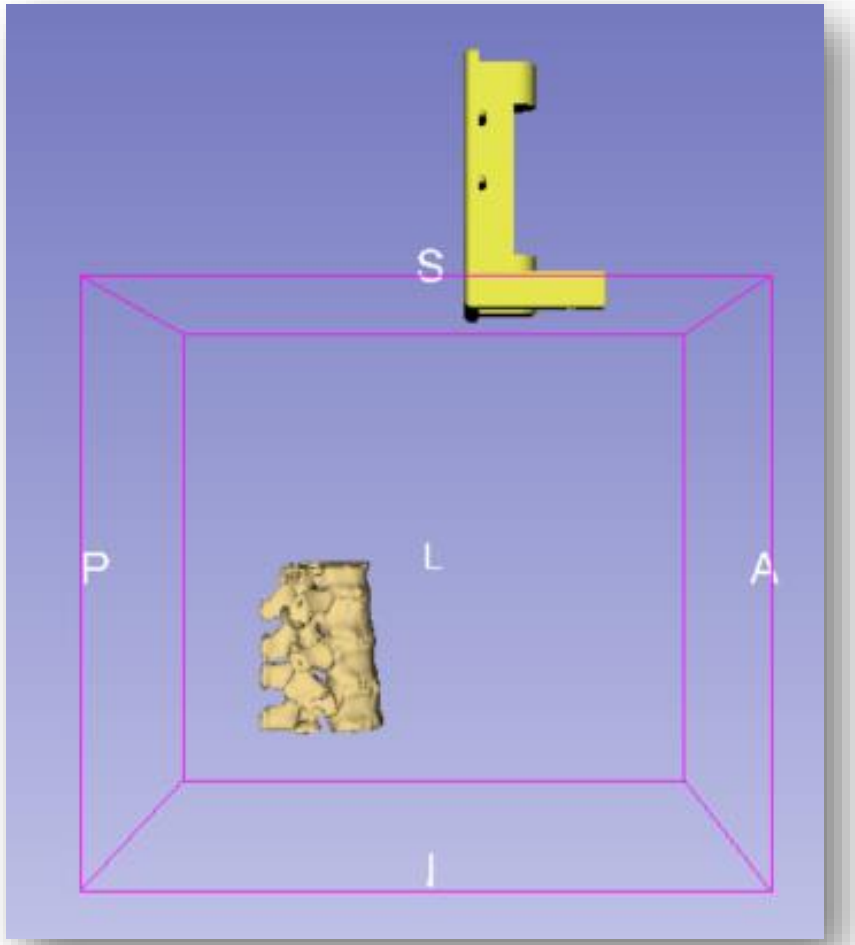


Extract the contents of the zip file and drag&drop *BasePiece.stl* onto the Slicer window

3/2: Load phantom base as model node



3/2: Load phantom base as model node



Phantom base is loaded

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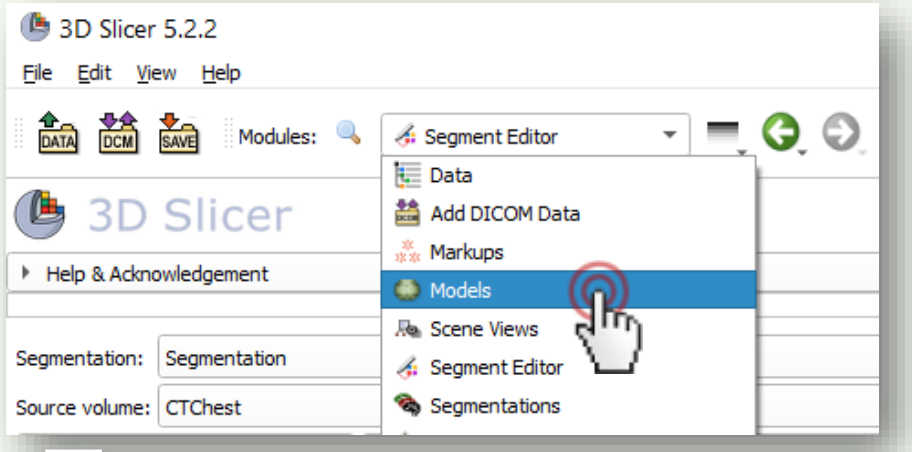
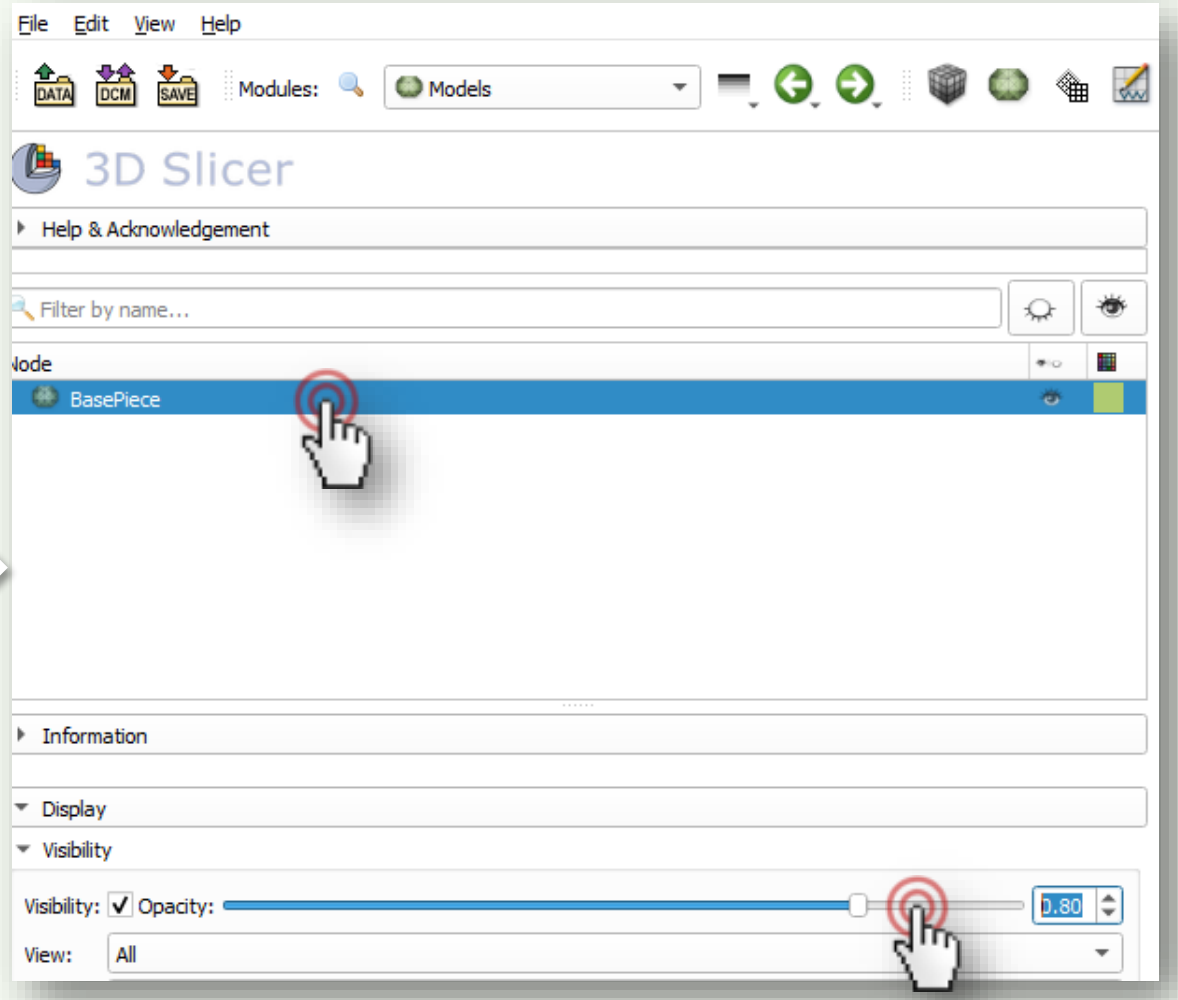
3/1: Make base semi-transparent in Models



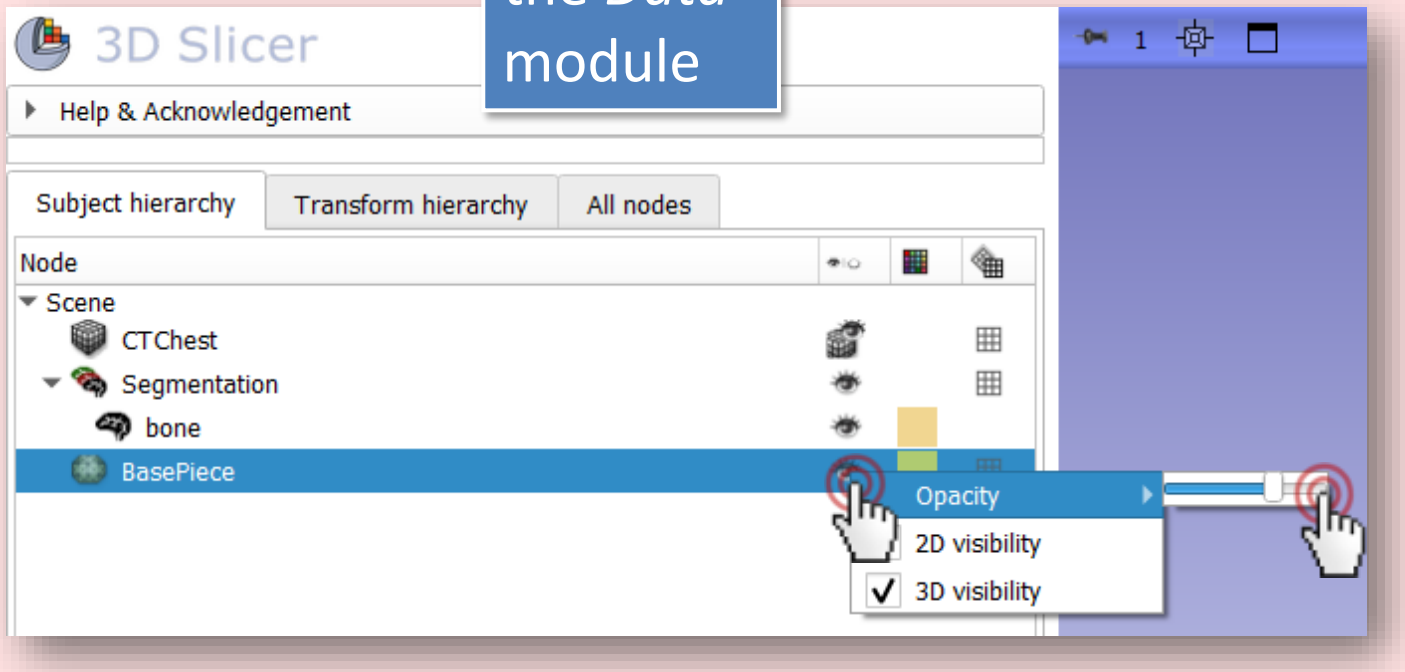
1. Switch to *Models* module
2. Decrease opacity to 0.8



When both the segmentation and the model are opaque, it is hard to see when they are in a good relative position

3/1: Make base semi-transparent

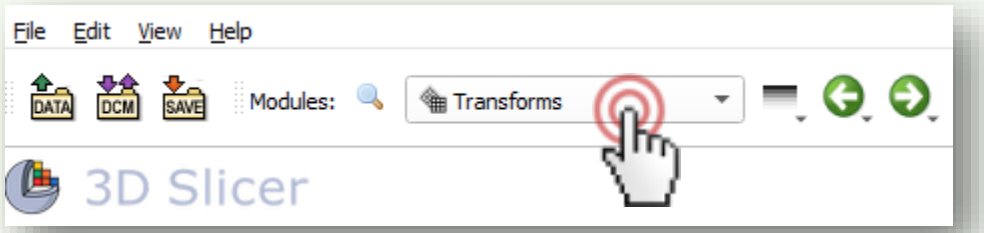
Switch to the *Data* module



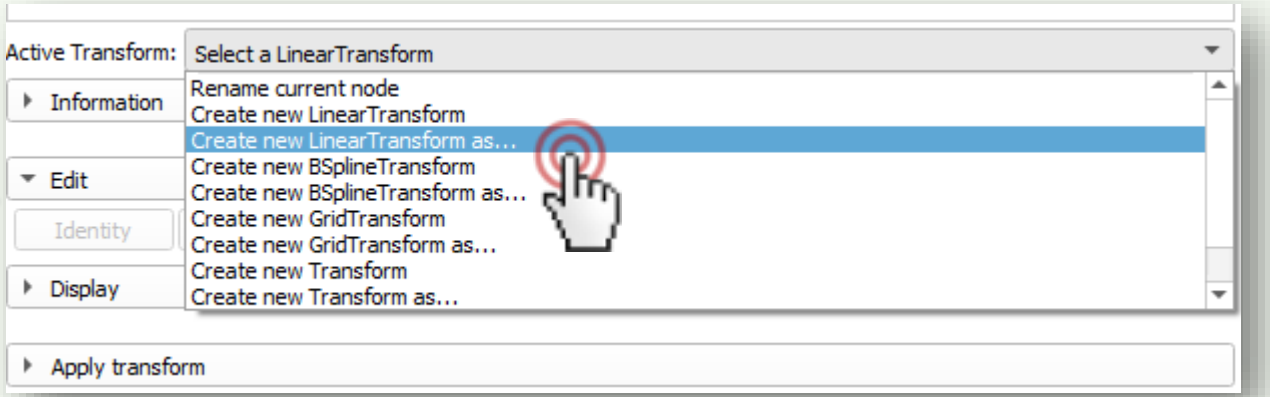
Right-click on the eye icon next to *BasePiece*, and hover your pointer over the *Opacity* option. Set it to about 3/4.

When both the segmentation and the model are opaque, it is hard to see when they are in a good relative position

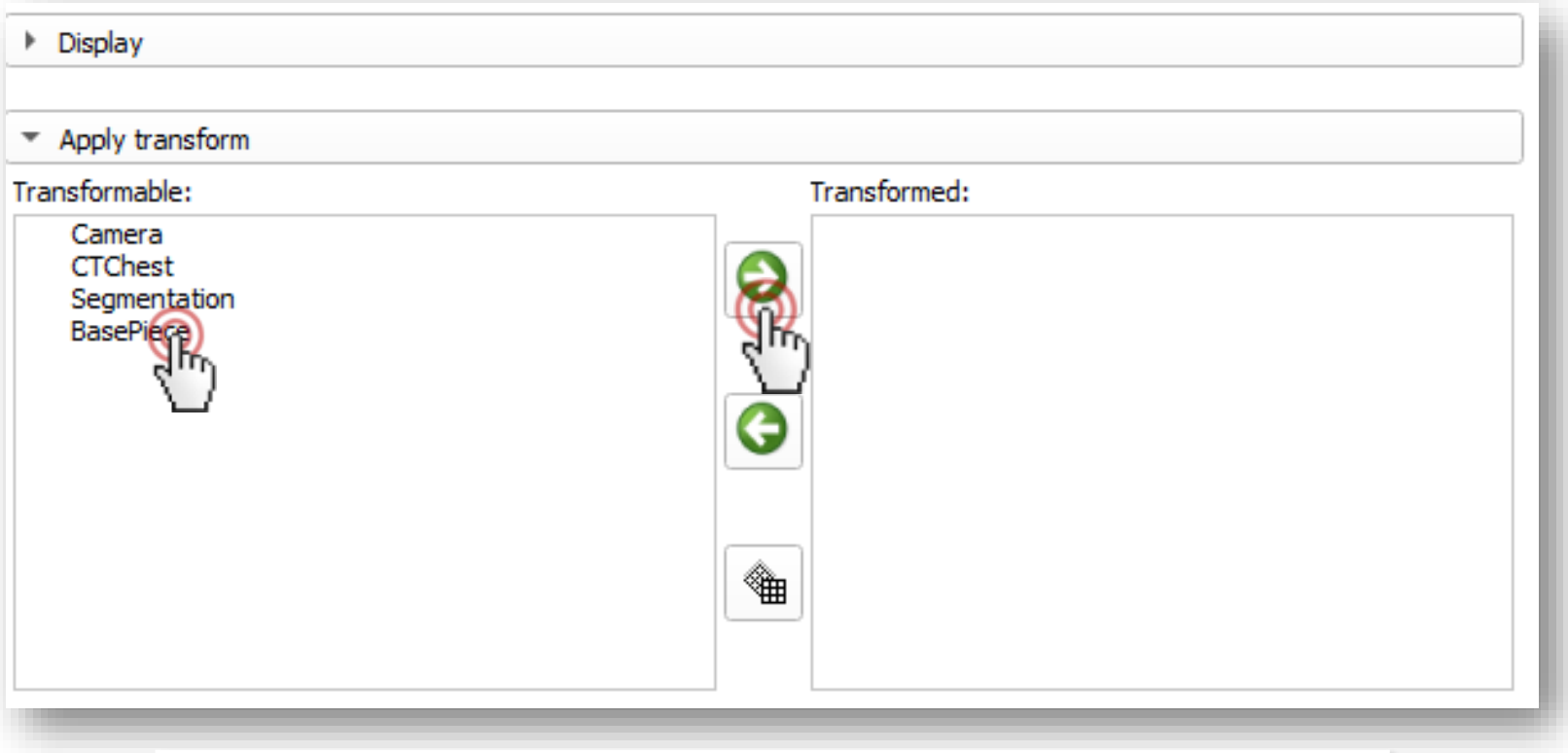
3/2/A: Create transform



1. Switch to the *Transforms* module
2. Create linear transform
3. Name it '*BaseToSpineTransform*'

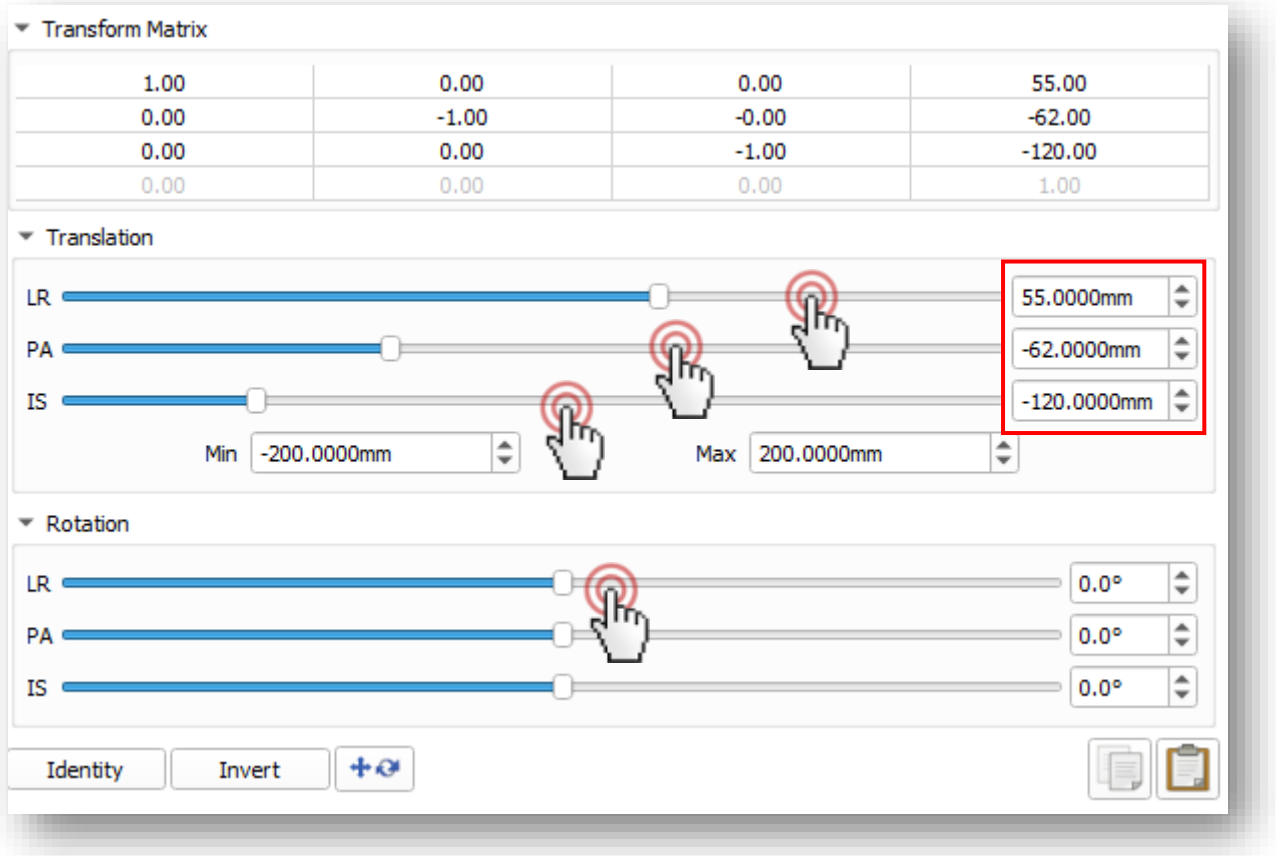


3/3/A: Apply transform to base



1. Select base piece
2. Move it under the transform

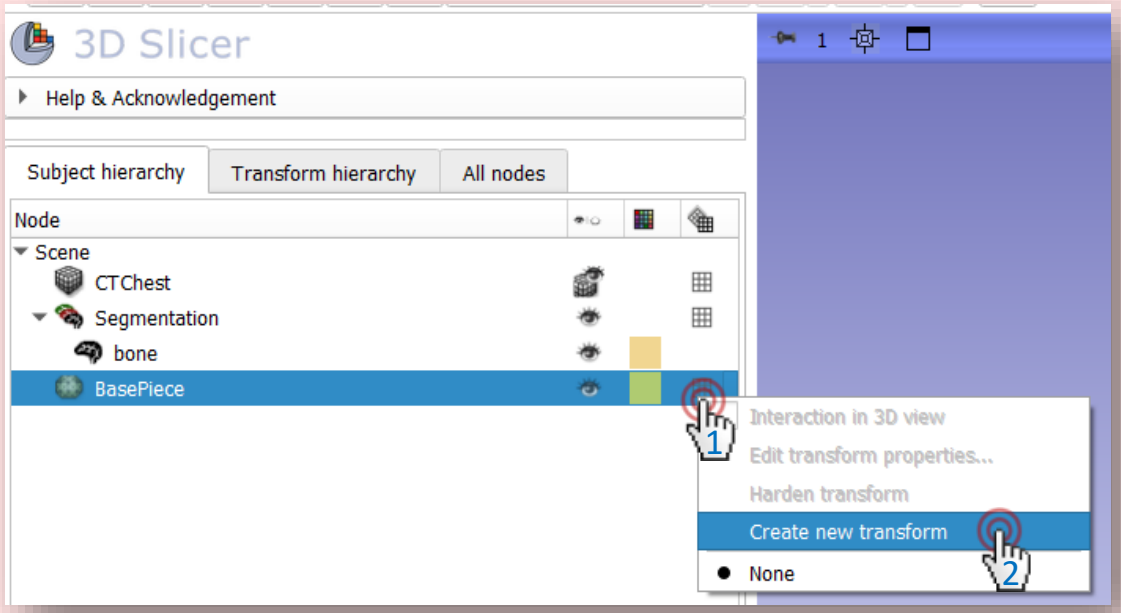
3/4/A: Move base into place

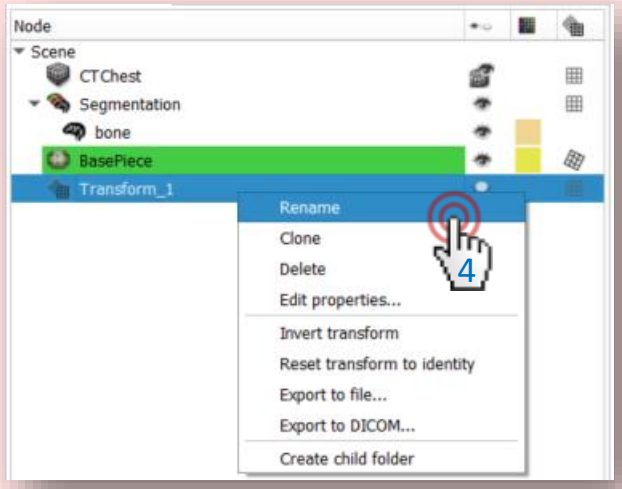


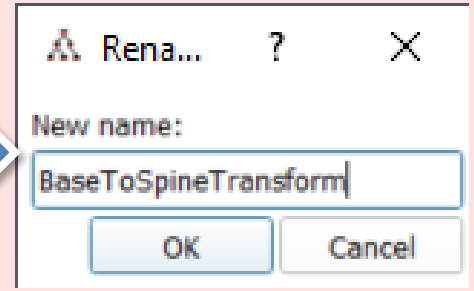
1. First rotate the model 180 degrees Left-Right by dragging the „*LR*” slider to the left
2. Move sliders until the base is in the correct position (values in picture are the final ones)

3/2/B: Create transform

1. Right-click on the grid (the last icon)
2. Create linear transform
3. The transform will appear in the list
4. Right-click on it and rename it '*BaseToSpineTransform*'



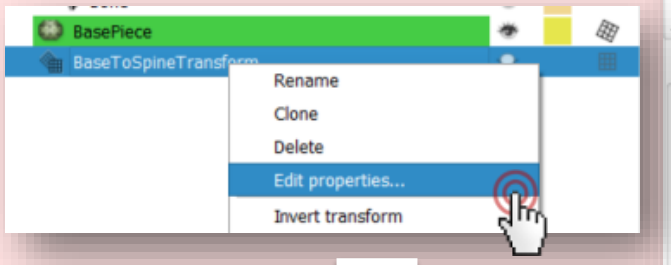


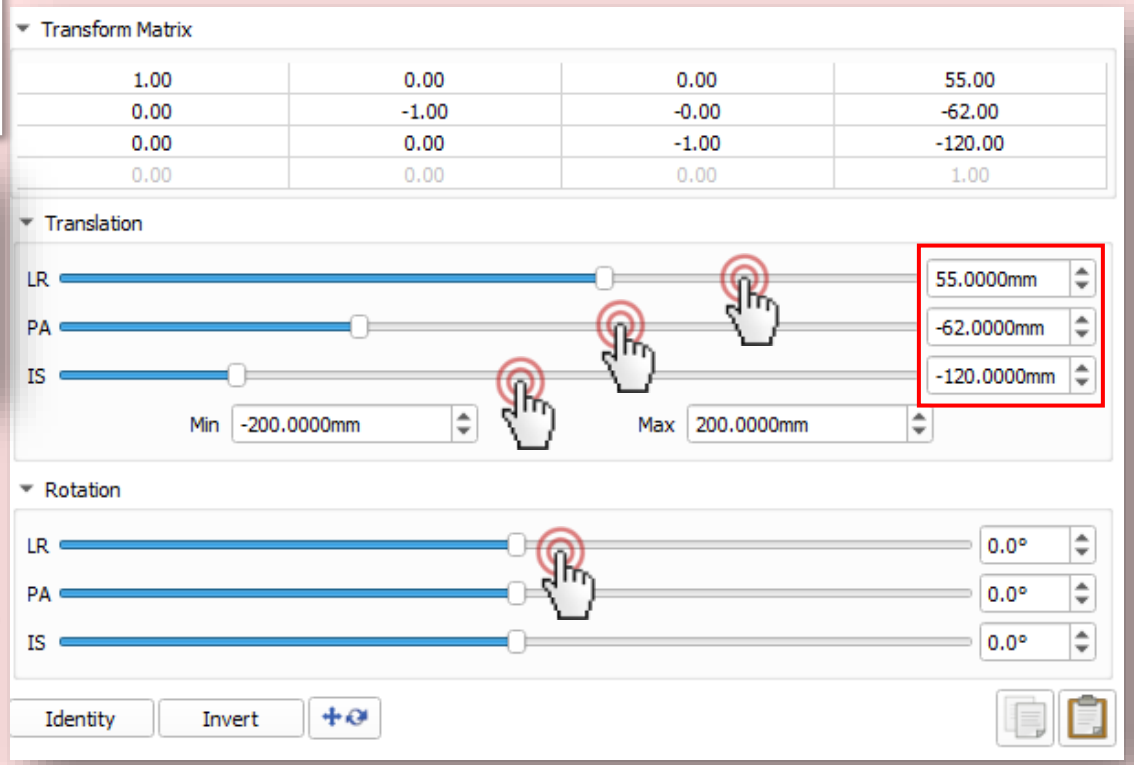


3/4/B: Move base into place

(We don't need 3/3 when we do it this way)

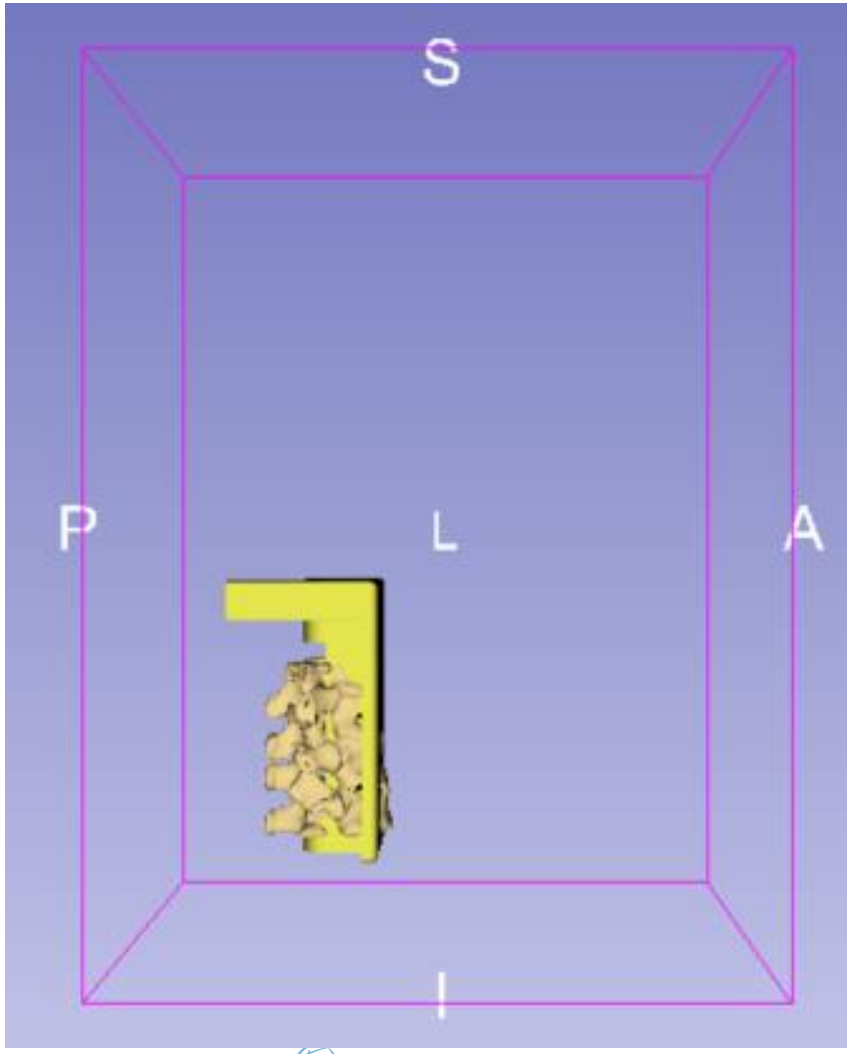
Right-click the transform again, and choose *Edit properties…*





1. First rotate the model 180 degrees Left-Right by dragging the „*LR*" slider to the left
2. Move sliders until the base is in the correct position
(values in picture are the final ones)

3/6/A: Base is in the correct position



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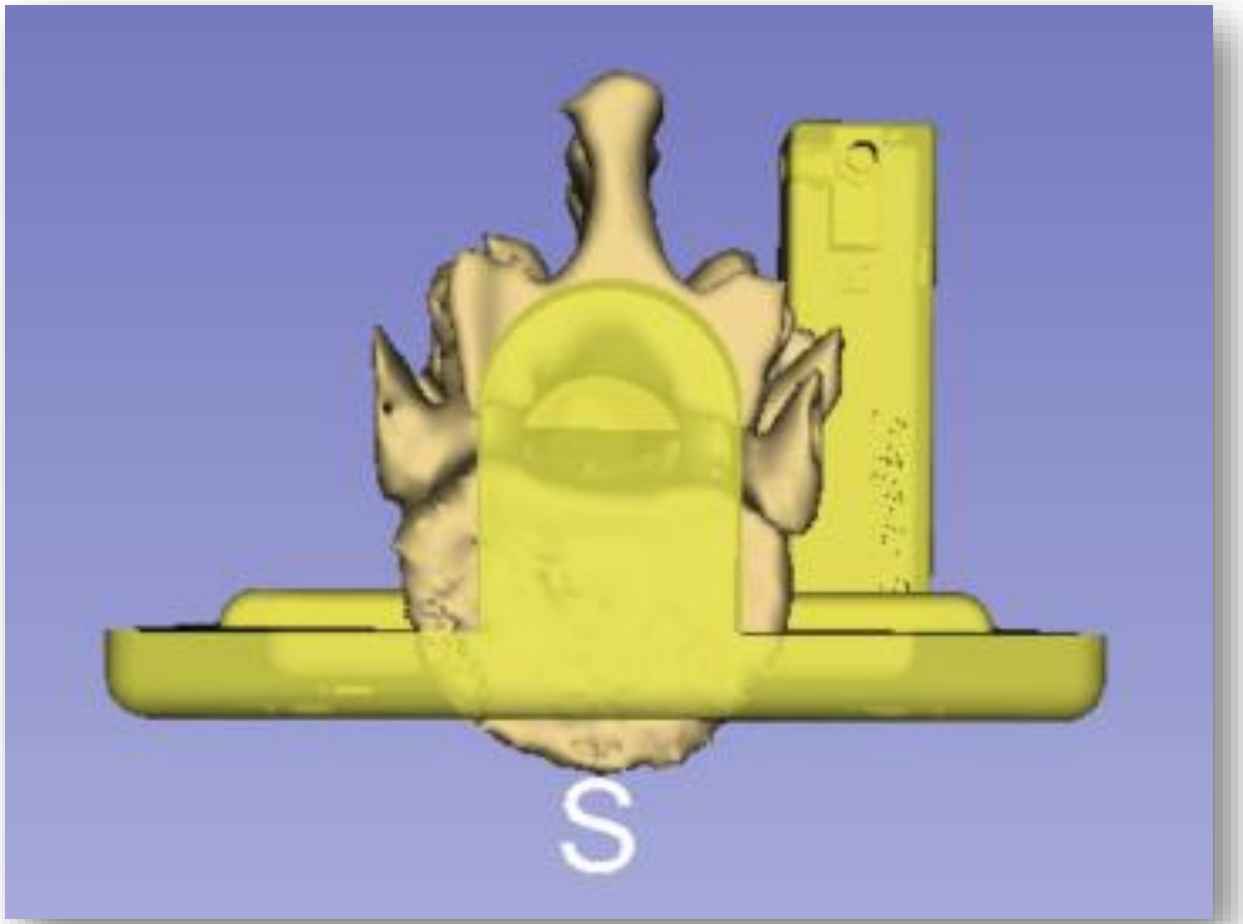
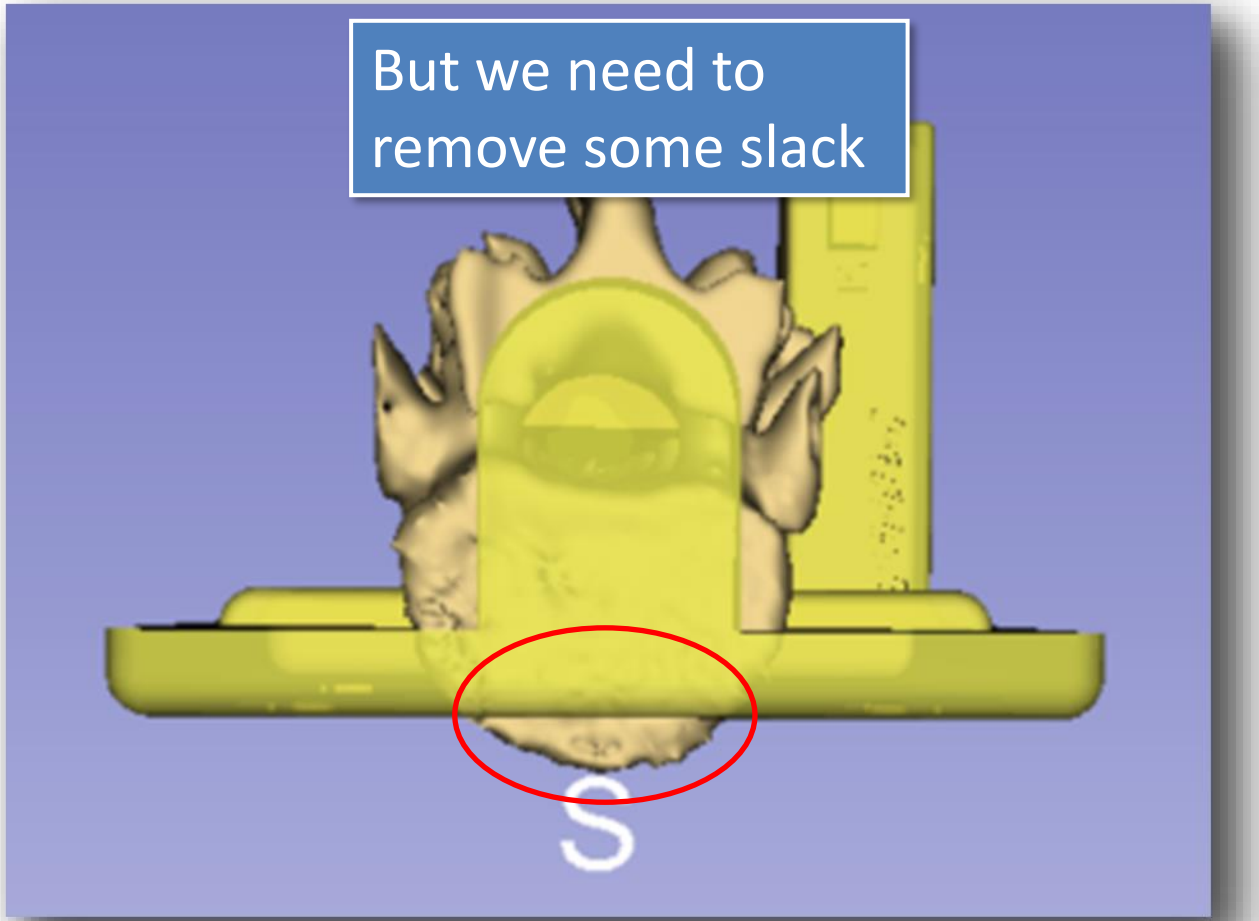
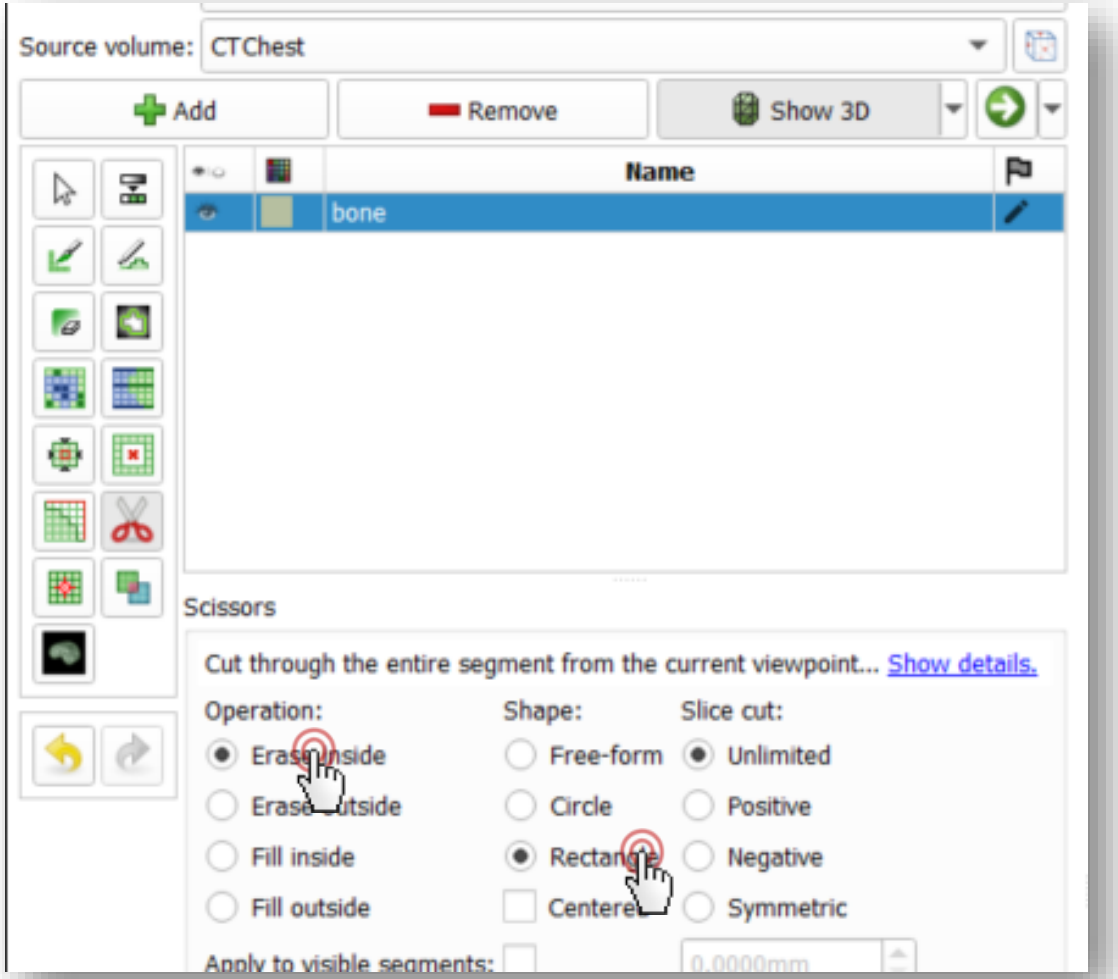
3/6/B: Base is in the correct position

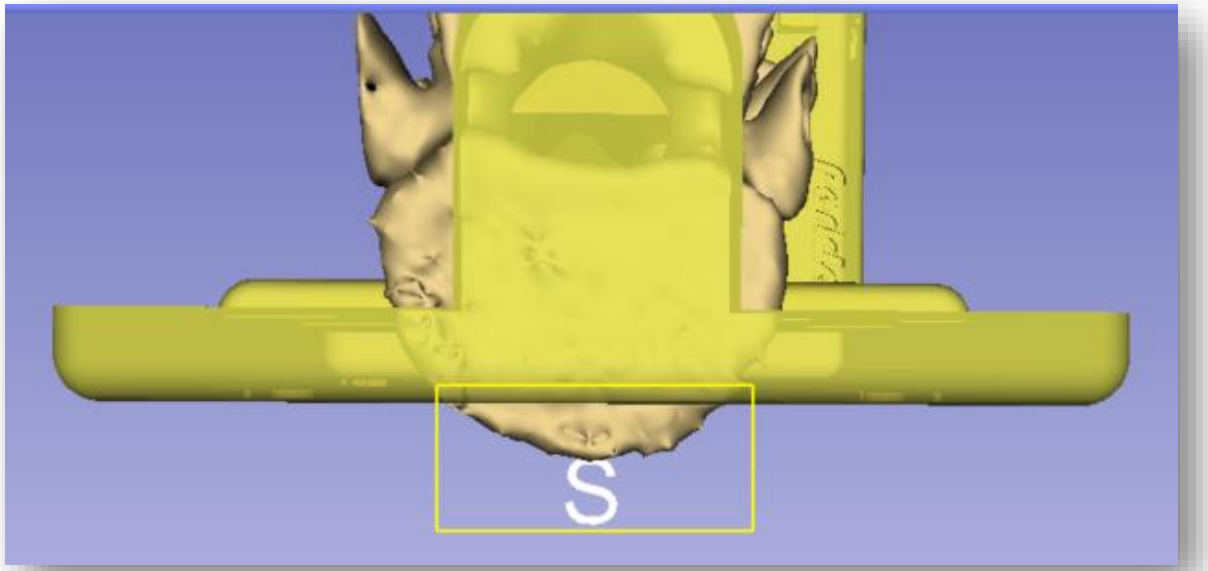




3/7: Use Scissors effect to remove slack



1. Switch back to *Segment Editor*
2. Erase slack

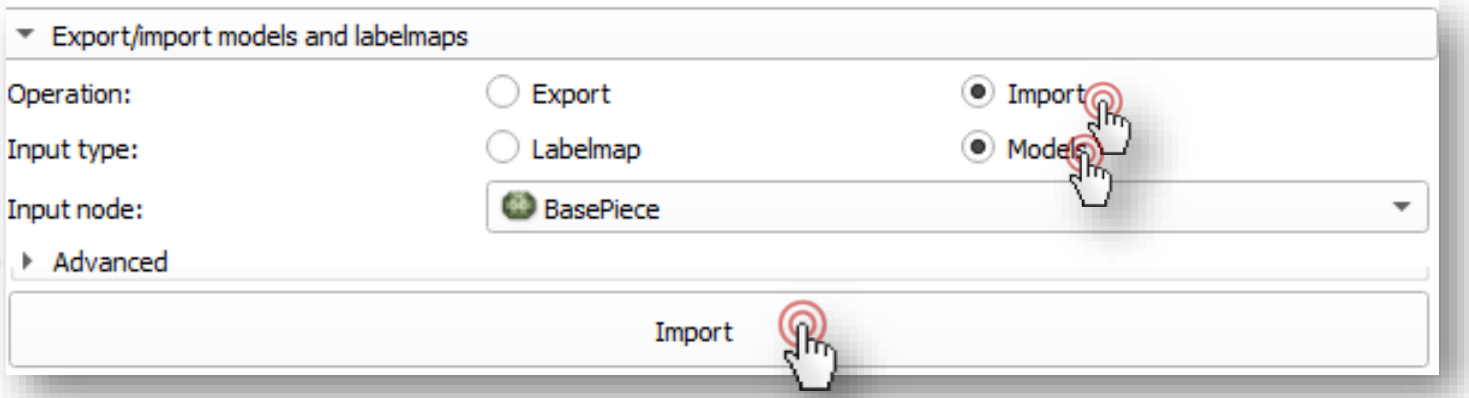


Part 4: Merge and finalize phantom

Overview:

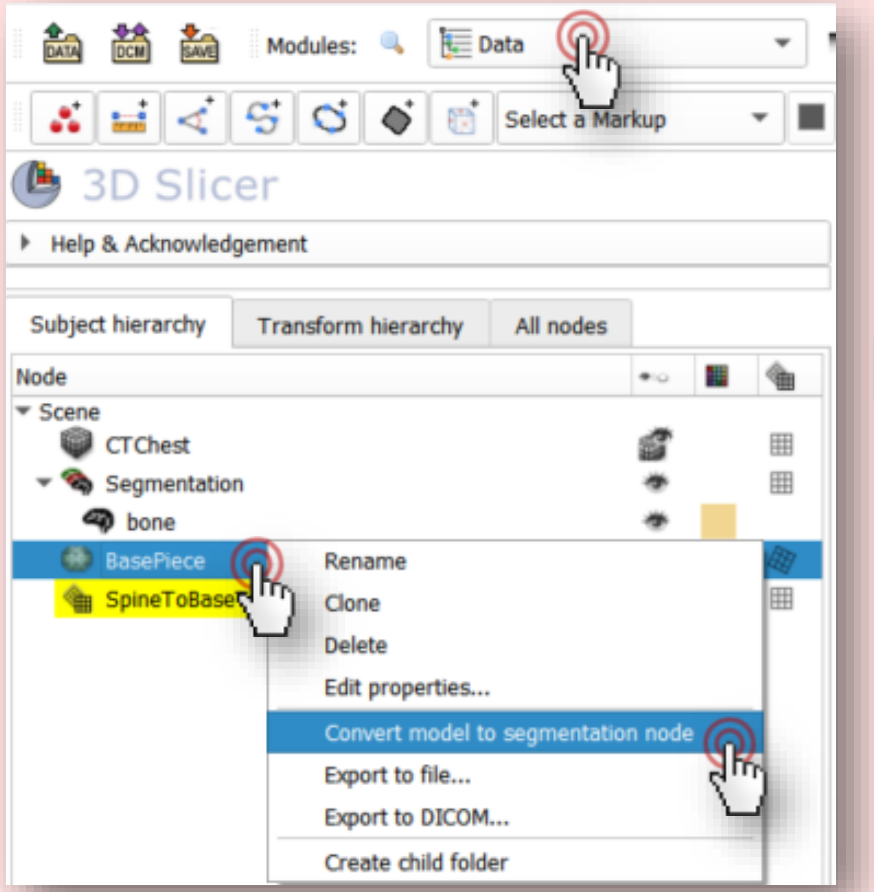
- Create segmentation from base piece
- Copy base piece segment into vertebrae segmentation
- Merge two segments
- Cut hole through phantom

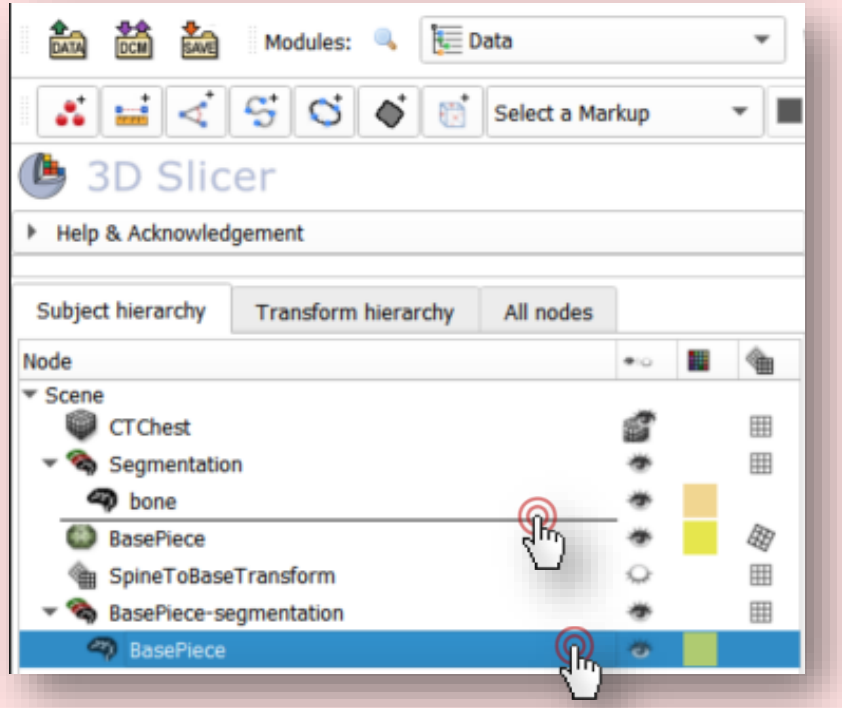
4/1: Import base into segmentation



4/1/A Import base into segmentation

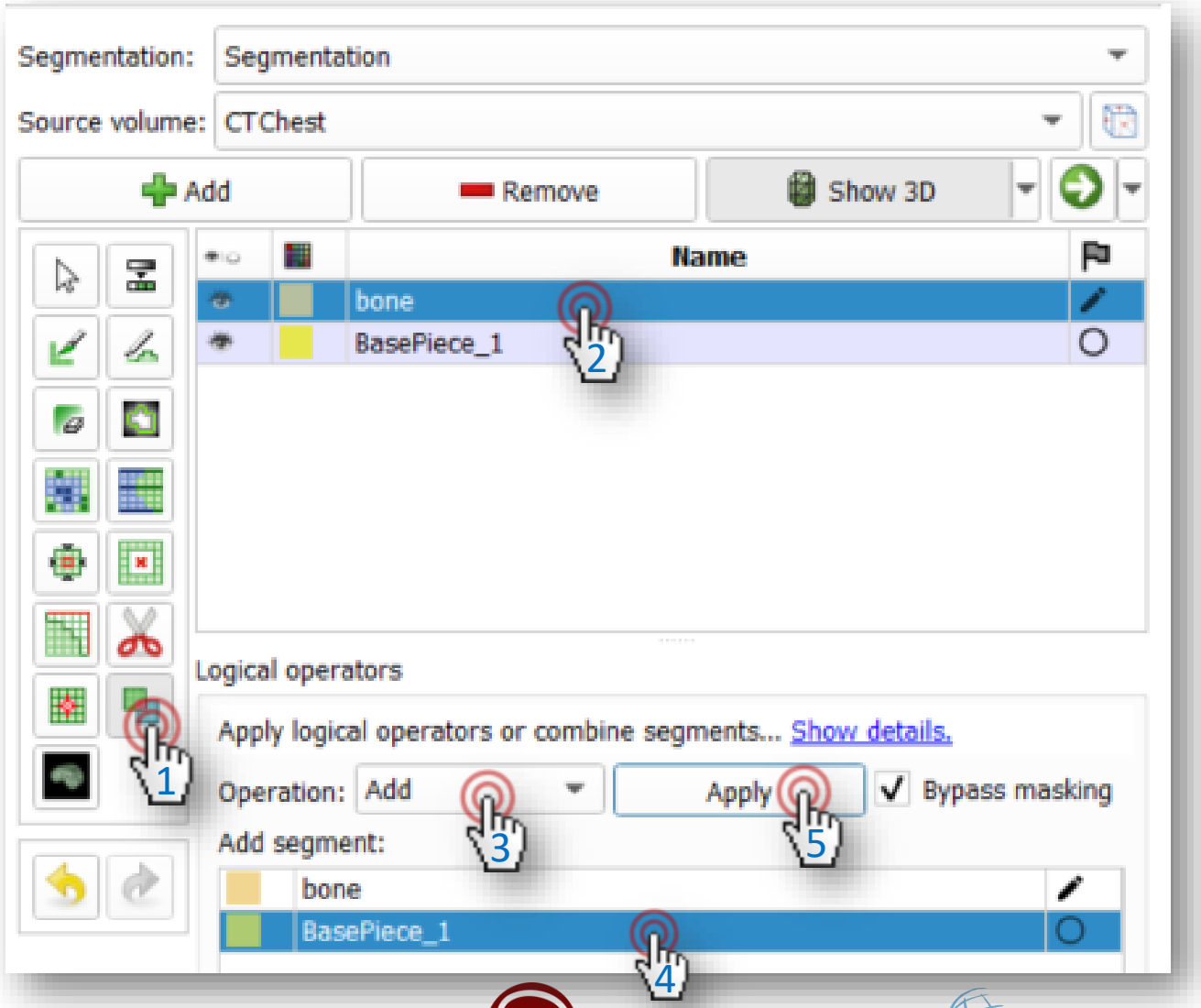
Switch to the Data module, right click on Basepiece, and select „Convert model to segmentation node”





Drag and drop „Basepiece” from the „Basepiece segmentation” to below the „ Bone” segment.

4/2: Merge the two in Segment Editor



Back to *Segment Editor*

1. Select *Logical operators*
2. Select spine (bone)
3. Choose *Add* operation
4. Select *BasePiece*
5. Click *Apply*

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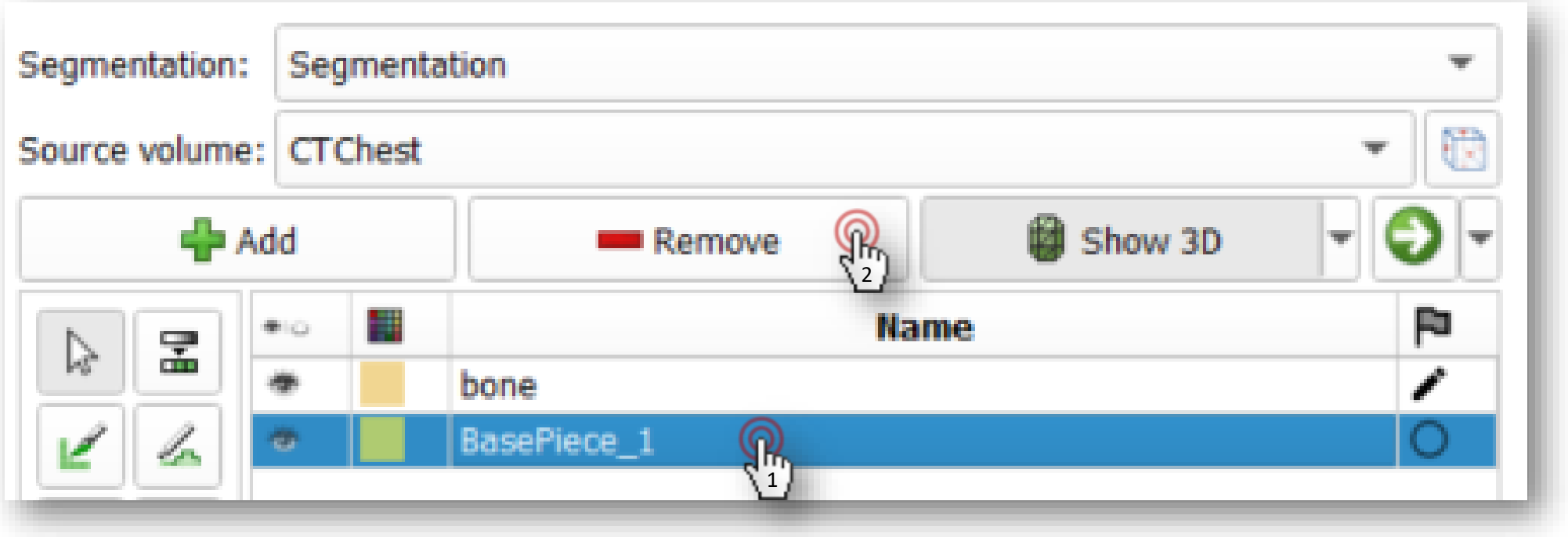
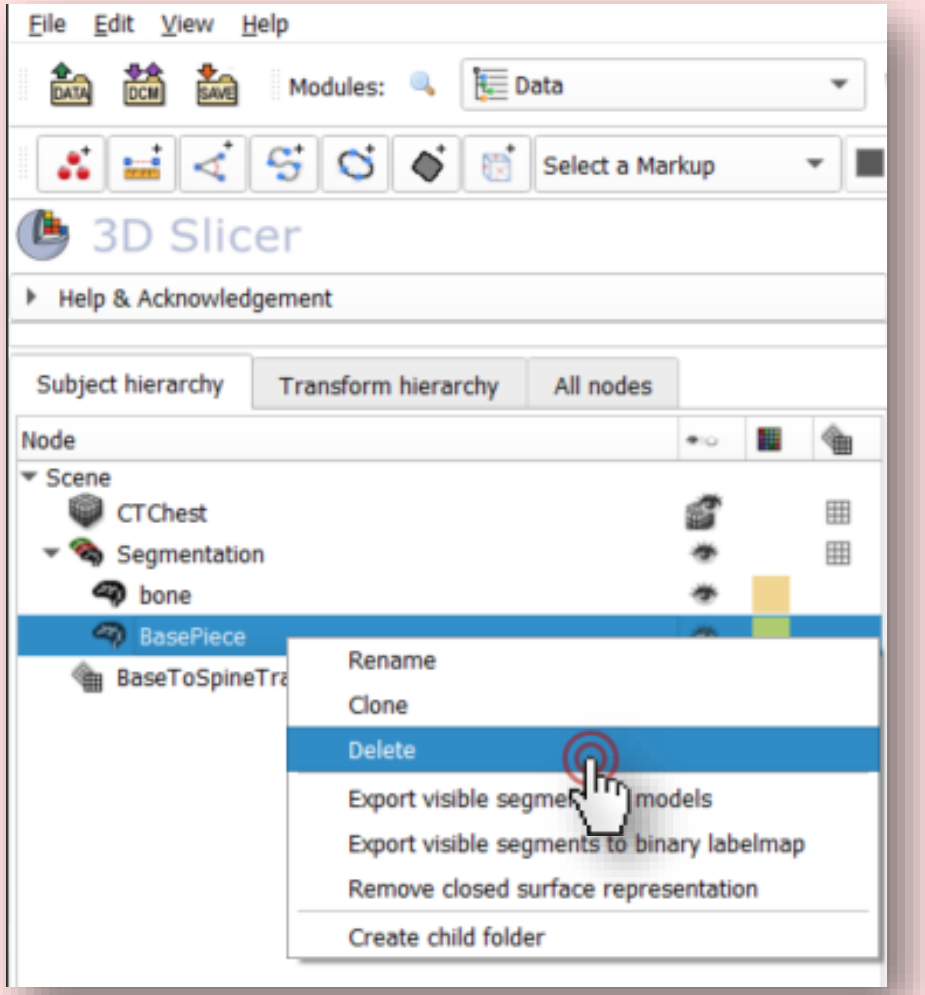
4/3: Remove base piece segment



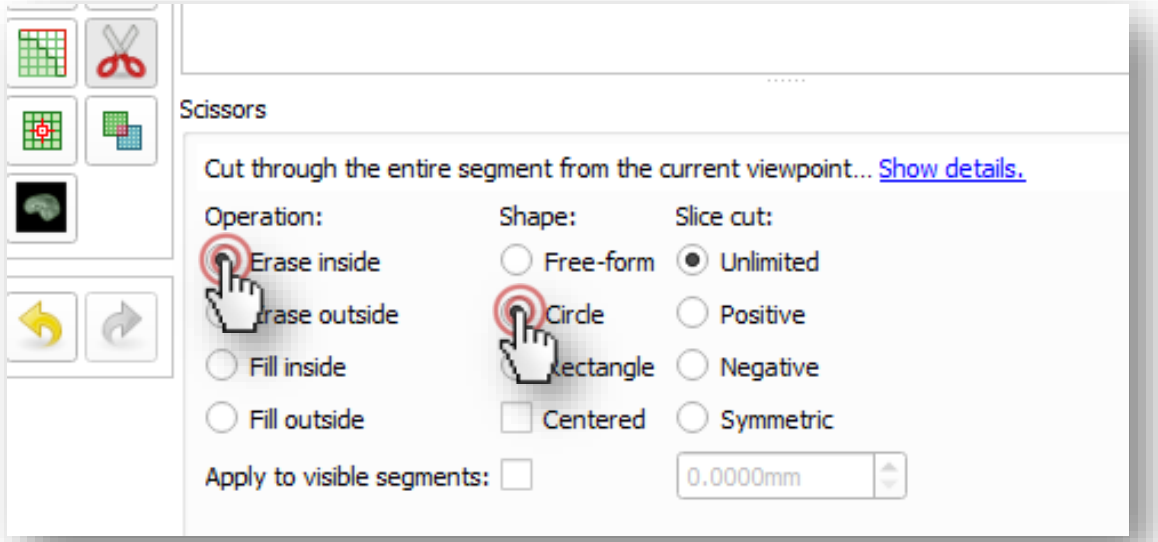
4/3: Remove base piece segment

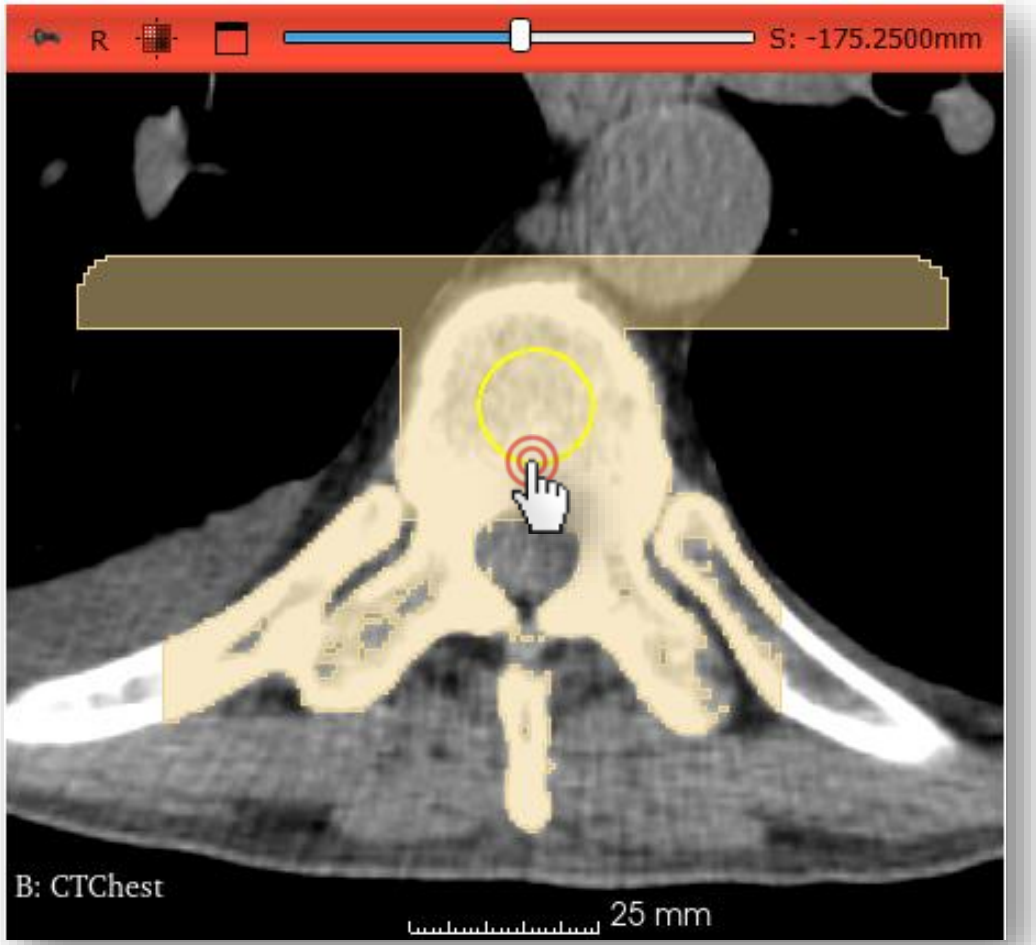
Switch to the *Data module*



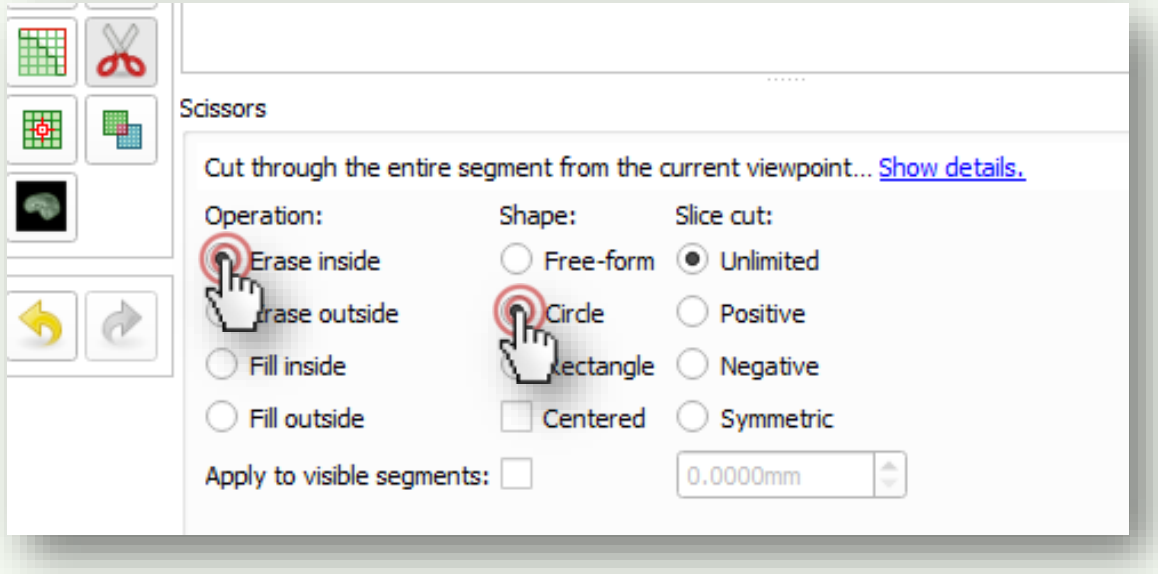
Right-click the *BasePiece* segment node and choose *Delete*

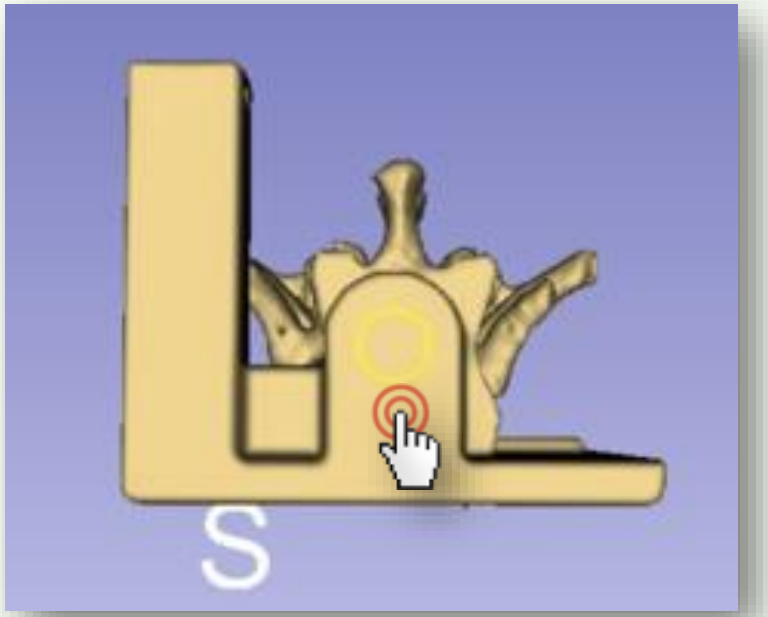
4/4: Cut hole through phantom using Scissors





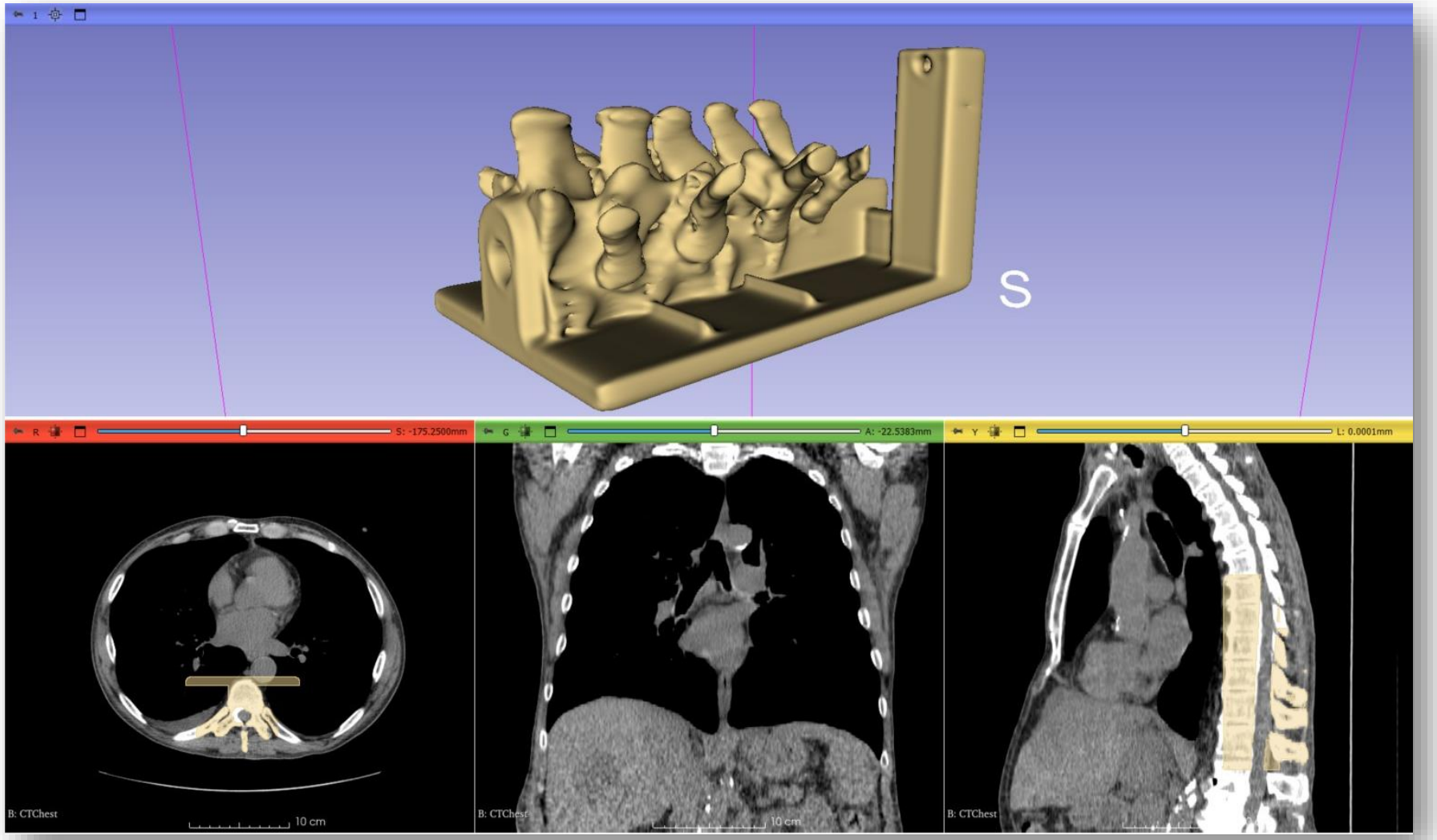
4/4: Cut hole through phantom using Scissors





You can also cut the hole from within the 3D view.

Phantom is ready!



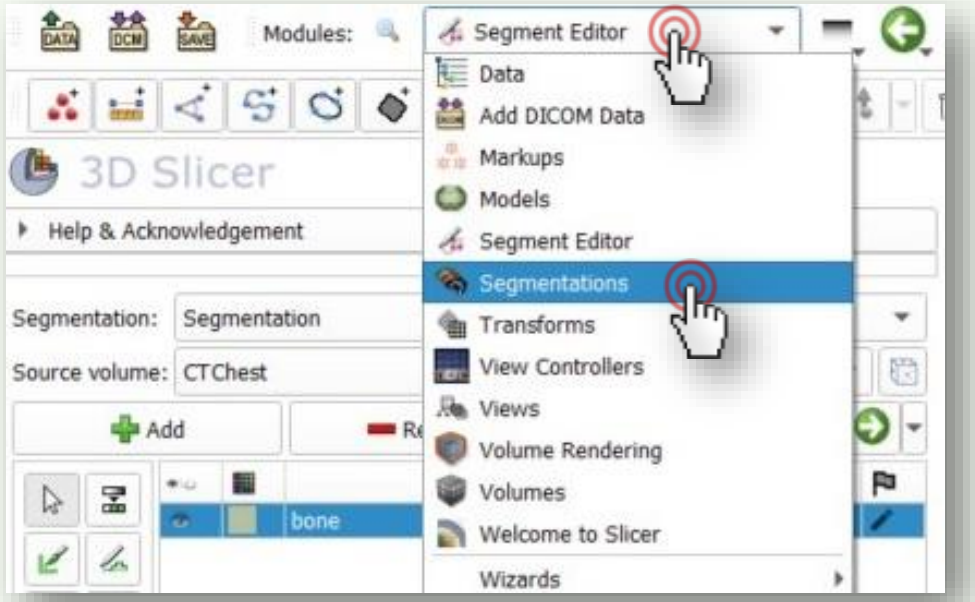
Part 5: Save phantom to STL

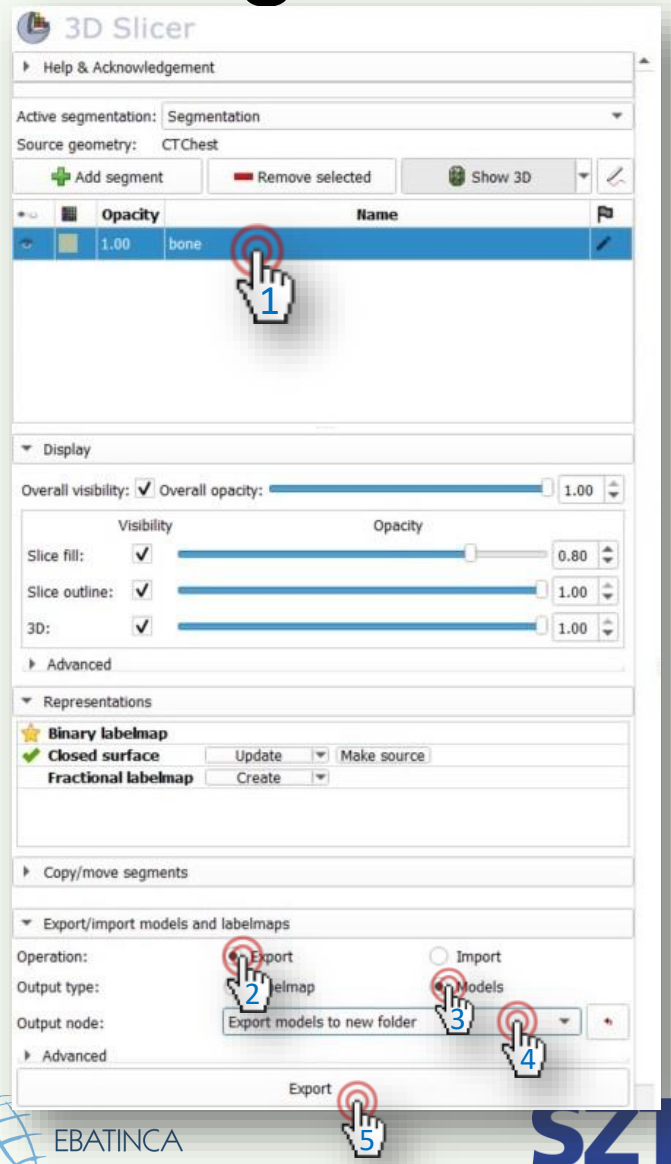
Overview:

- Export phantom segment to model node
- Save model to STL file

5/1: Export phantom segment into model

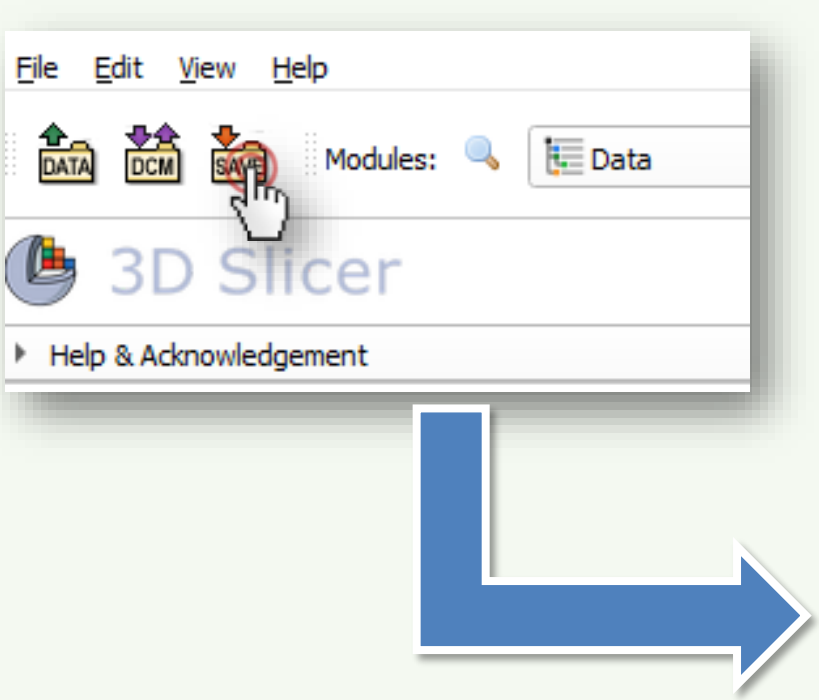
Switch to the *Segmentations* module

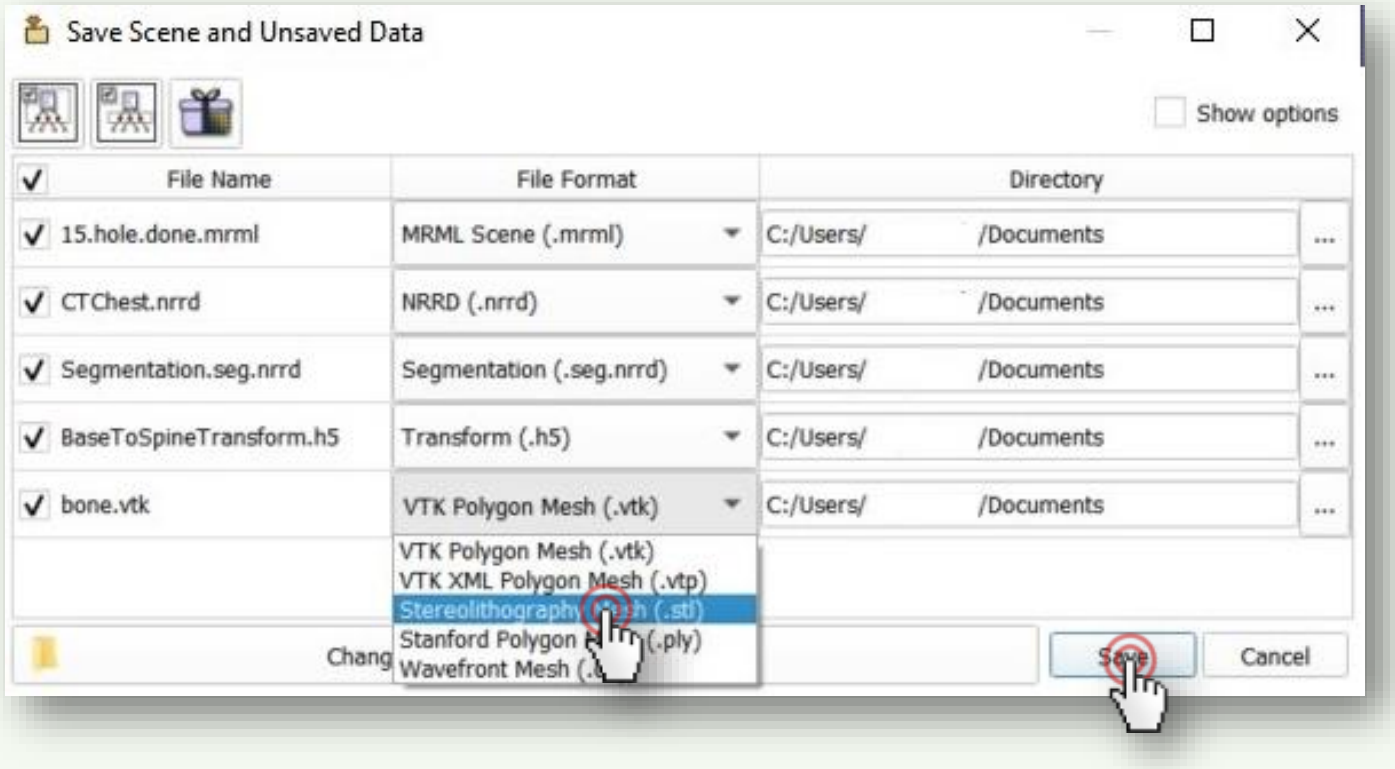




1. Select the segment
2. Select *Export*
3. Select *Models*
4. Choose *Export models to new folder*
5. Click *Export*

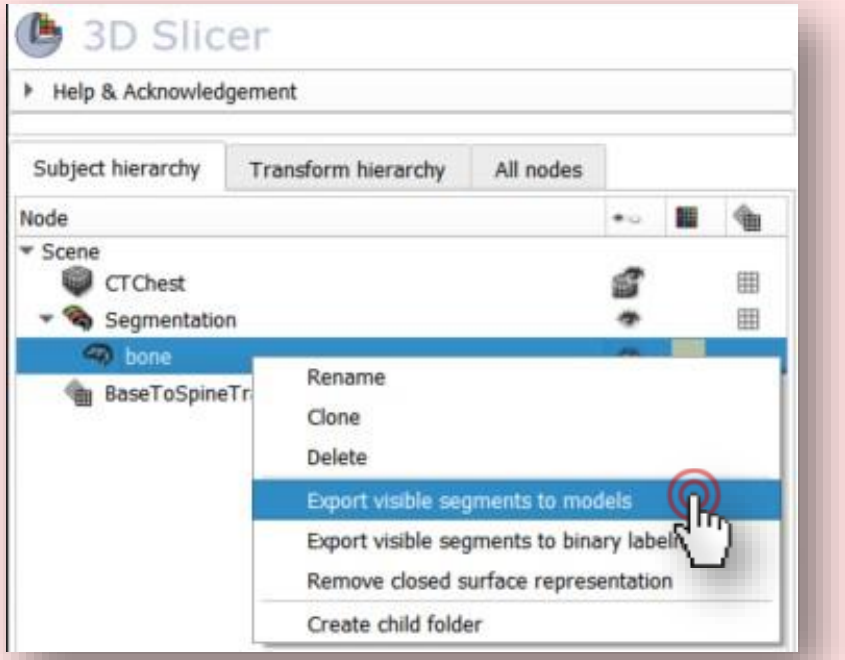
5/2: Save model into STL





5/1: Export phantom segment into model

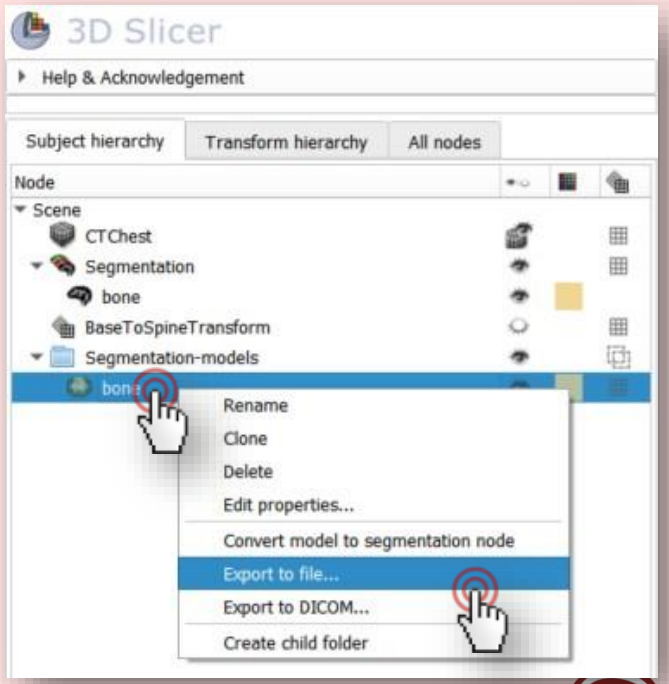
Switch to the *Data* module, right-click on the segment, and click *Export visible segments to models*

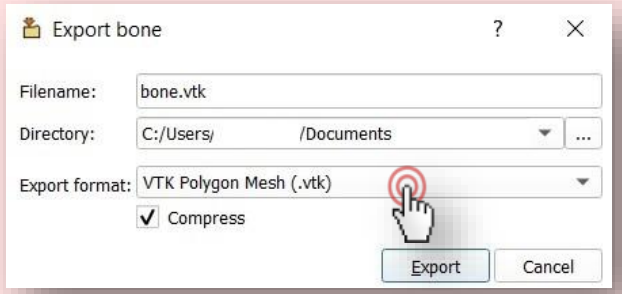


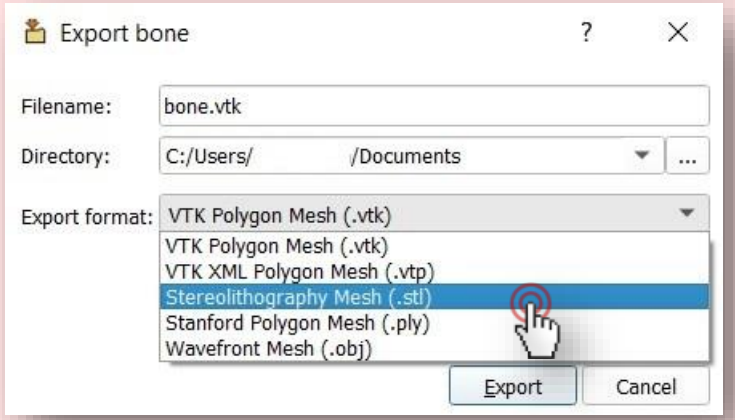
You can set the visibility of a segment by clicking the eye icon

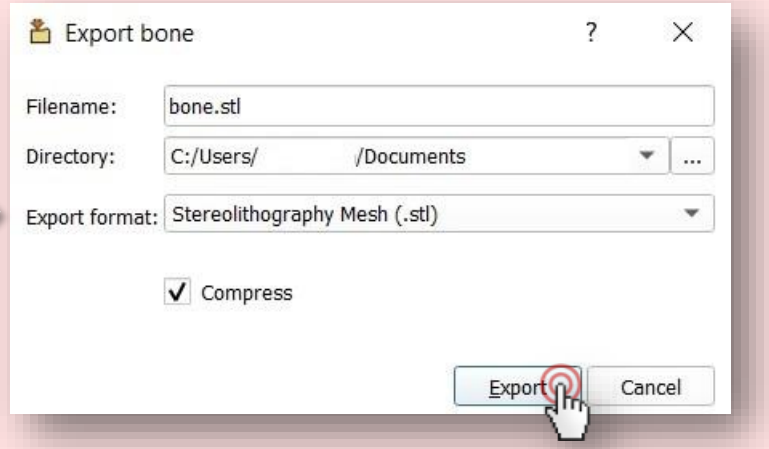
5/2: Save model into STL

Still in the *Data* module, right-click on the segment, and choose *Export to file*





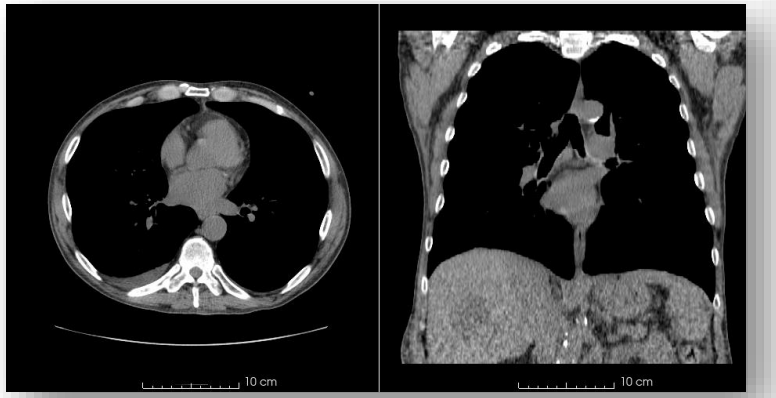


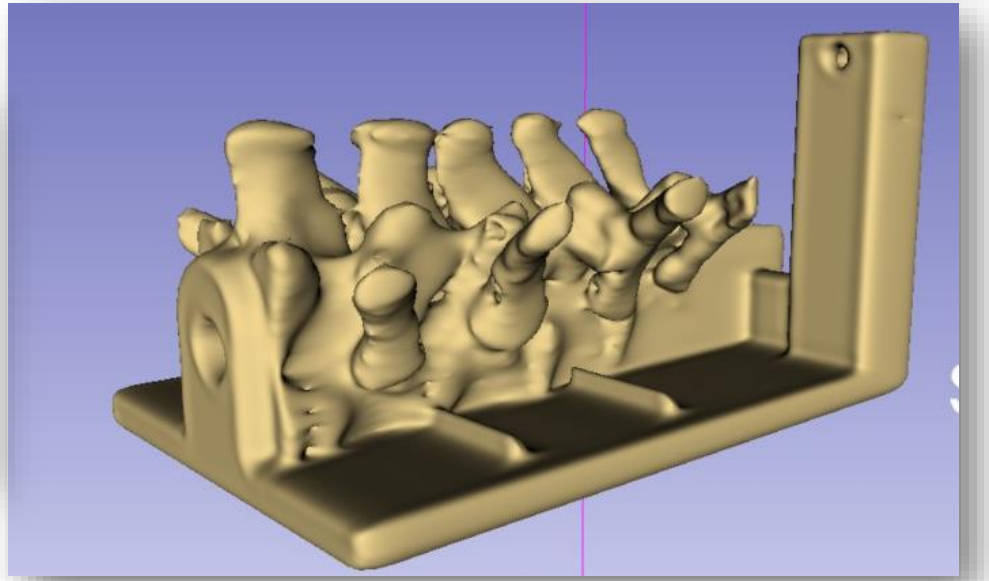


1. Set the output directory by clicking on the 3 dots.
2. Click Export format drop-down and select '.stl'
3. Click *Export*

Conclusion

In the tutorial we summarized through an example, how we can load, and segment an anatomical region in 3D Slicer, and also, what steps it takes to prepare the created model for 3D printing.





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