Stereotactic Implantation Lab
Msc Biomedical Engineering - Neurotechnologies

1 Introduction

1.1 Experiment

The goal of this lab is the simulation of the Deep Brain Stimulation (DBS) electrode implantation surgery applying the stereotactic method. The patient will be simulated by a vegetable.

The procedure can be divided into 3 big steps, namely

1) the preoperative imaging and planning of the target point and trajectory,

2) the electrode implantation itself, and

3) the post-operative imaging and verification of the final electrode position.

These different steps will be performed using the stereotactic Leksell systems (Elekta, Sweden). For implantation, a biopsy needle will be used instead of a DBS electrode as the latter would be too expensive and too flexible and fragile to insert into a vegetable.

1.2 Preparation

Prepare yourself for the lab

- By checking again the slides from the lecture to be aware of the different surgical steps (pre, intra- and post-operative steps of the implantation procedure – intraoperative testing approaches cannot be performed in this experiment).
- by reading the present experiment description.
- by studying the different manuals uploaded in Moodle
- by trying to understand how the biopsy needle works
- by trying to understand the setting of the different stereotactic coordinates on the two frame systems

2 Background

The most common approach for DBS implantation is the stereotactic approach, which uses a guiding device that is arc centered. It uses a 3D polar system to place the trajectory. The target point is the center of the two angles to allow for the highest precision and accuracy. A common example is the Leksell stereotactic system, the frame used in this lab session.

Two versions of the Leksell system are available with the G-frame (Figure 1) and the Vantage frame (Figure 2). They are composed of a frame which is fixed to the patient's head, a localiser box used for imaging and a stereotactic arc which is used during surgery for the implantation. The main difference between the two systems is the material (Vantage frame : MRI compatible – less artefacts) and the facility with which the frame can be mounted. The Leksell coordinate system is depicted in Figure 1C.

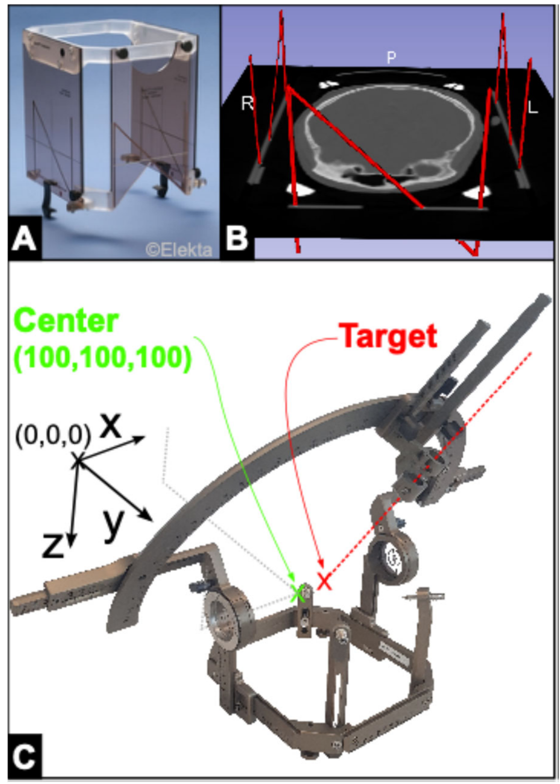

Figure 1: *Elekta stereotactic G-Frame system. A. CT localizer box; B. the CT localizer box results in hyperintensities in the CT image which have been segmented and are visualized as 3D surface; C. The G-frame with the arc mounted, the axes of the Lekselll coordinate system with the center of the frame corresponding to coordinate 100, 100, 100.*

2.1 Imaging and Planning

To localize the Leksell coordinate system in relation to the anatomy, localizer plates (image fiducials, Figure 1A) are placed on the frame during pre-operative CT or MR imaging. The fiducials result in hyper-intensities (Figure 1B, segmented in red) on the images. They define the coordinate system and allow computing Leksell coordinates for each position in the image.

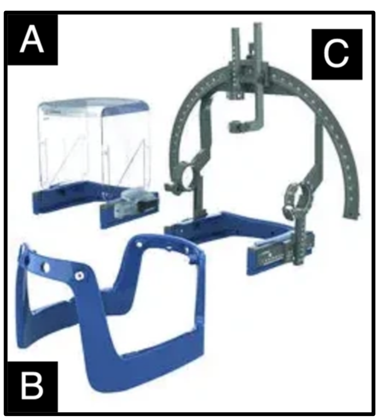

Figure 2: Elekta Vantage sterotactic system. A. CT localizer box; B. Frame; C. Arc

The main goal of the planning phase is to select a target and entry point on the images and convert the two points into a polar trajectory defined by the target point (X, Y, Z) and two angles (ring, arc). This all happens outside the surgery room between imaging and implantation.

The main steps consist in:

- imaging of patient with stereotactic frame
- frame identification in the images (= reference system)
- choice of target and trajectory to reach the target
- extraction of coordinates

2.2 Electrode implantation

The surgery usually takes place the same day as the pre-operative imaging, allowing the frame to stay attached to the patient's skull. In the operating room the localizer plates are replaced by the arc and the settings computed for the trajectory are set. A burr hole is drilled, the electrode is implanted and the frame is removed.

2.3 Imaging and verification

After suturing, post-operative imaging is acquired, and the position of the electrode is verified, compared to the planned one and the different contacts are identified.

3 Material

In this session of practical work, a stereotactic implantation will be simulated. This will involve the following material:

- Vegetable: simulating the head of the patient
- Medtronic O-arm: the O-arm can produce 3D X-ray tomographic images with sufficient field of view to include the Leksell systems (mobile CT)
- Leksell G-frame with 2 screw drivers
- CT localizer plates for Leksell G-frame
- Stereotactic Arc for Leksell G-frame
- Vantage frame with Vantage screwdriver
- CT localizer plates for Vantage
- Stereotactic arc for Vantage arc
- Multiple laptops with remote access to surgical planning station (Brainlab Elements)
- Biopsy needle
- Documents:
    - Leksell Coordinate System Quick Reference Guide
    - Leksell Multi-purpose Stereotactic Arc Quick Reference Guide
    - Vantage user manual
    - Disposable Biopsy Needle kit - Instructions for Use.
- USB stick
- Drill 2mm and rechargeable driller
- Mesurement device (e.g. ruler)

4 Method

4.1 Preoperative imaging

4.1.1 Frame installation

- Follow the quick reference sheet to assemble the frame assigned to your group.
- Install the frame on the vegetable assigned to your group. During the placement, keep in mind that you might have to reinstall the frame with precision if another group will work with the system in between (mark anatomical location, make clean holes with the screws, measure the protruding distance from the screws).

4.1.2 Positioning in O-arm

- Add the CT localizing plates on the frame
- Place the complete assembly approximately in the center of the O-arm
- Check that localiser plates are approximately parallel to the O-Arm. The planning system rejects angular deviations above 20°.

4.1.3 Imaging

- Create a patient named after your group on the O-arm station
- With the assistance of the lecturer, position the FOV of the O-arm to capture the CT localizer plates correctly and the upper part of the head completely.
- Proceed with imaging using the stereotexy acquisition mode; observe X-Ray safety
- After verification of the images on the O-arm station, disassemble the Leksell frame for the next group to use – if there is one.

4.1.4 DICOM export

- Export the data from your patient. This will always export all images into a DICOM folder.

4.1.5 Connection to planning station

- Connect to the planning station using the remote desktop software Connection settings:
    - Host: mu15ns33060.edu.ds.fhnw.ch
    - User: studentX (with X your group number)
    - Password: iamstudentX

You might need to change the user if another user has started the laptop session.

- In the connection settings, enable automatic redirection of removable drives (Figure 3):

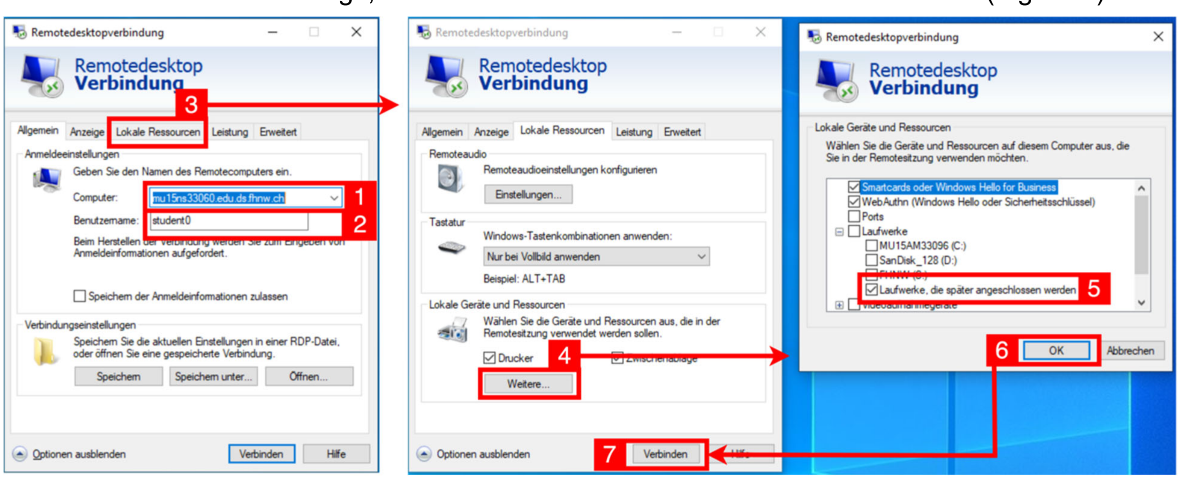

Figure 3: Connection over RDP to the planning station.

- FIRST open the RDP connection, THEN connect your USB stick to the laptop and check that the drives is redirected on the remote host (Figure 4).

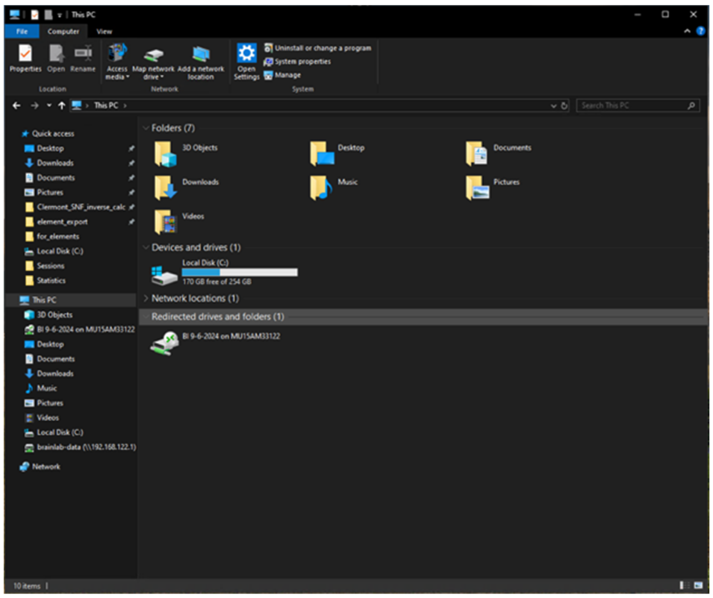

Figure 4: Removable drive automatic redictection over RDP

4.1.6 DICOM import

- Start Brainlab Elements (Figure 5)

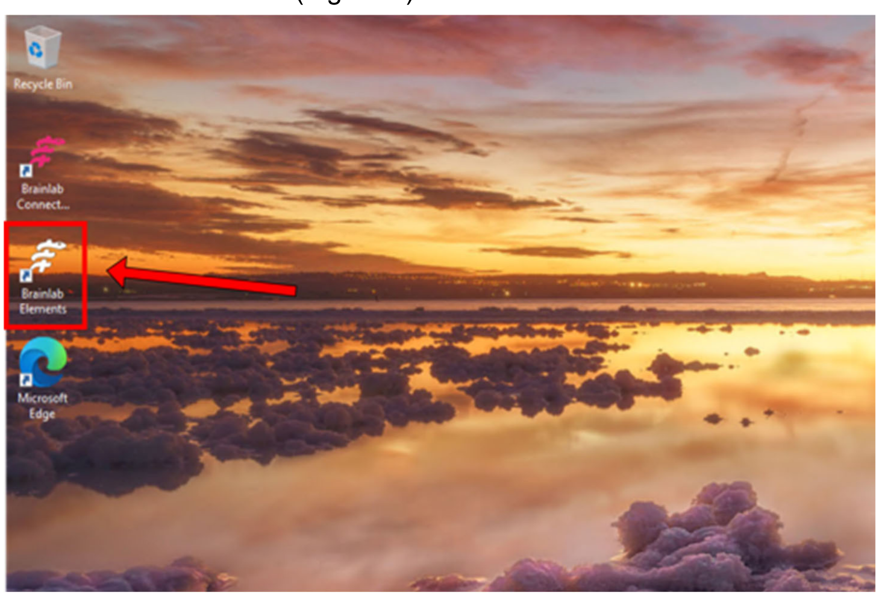

Figure 5: Brainlab Elements shortcut.

- Within the patient selector, click browse and select the shared DICOM folder (Figure 6)

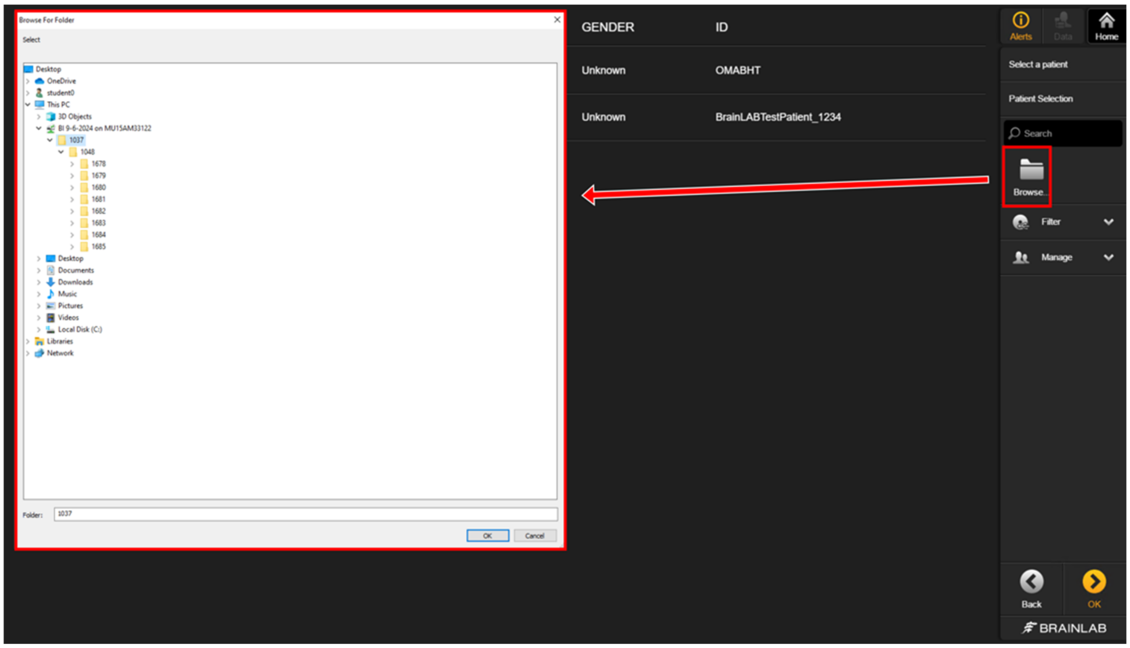

Figure 6: DICOM folder import.

4.1.7 Visualization

- Enter the "Stereotaxy" workflow and use the viewer to verify the images (Figure 7).

Figure 7: Selection of the Stereotaxy - Viewer tool.

4.2 Preoperative planning

- Click the “Home” button in the upper-right corner of the screen to go back to the “stereotaxy” workflow and select “planning -- stereotaxy” ((Figure 8):

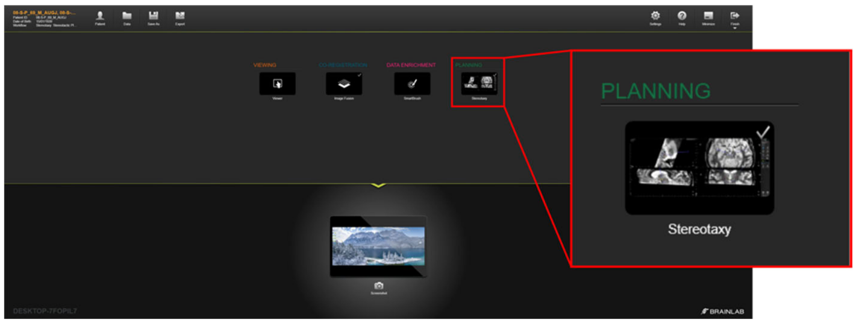

Figure 8: Selection of the Stereotaxy - Planning tool.

4.2.1 Frame localization

- Start the frame localization by deploying the “Frame” menu in the right panel (Figure 9).

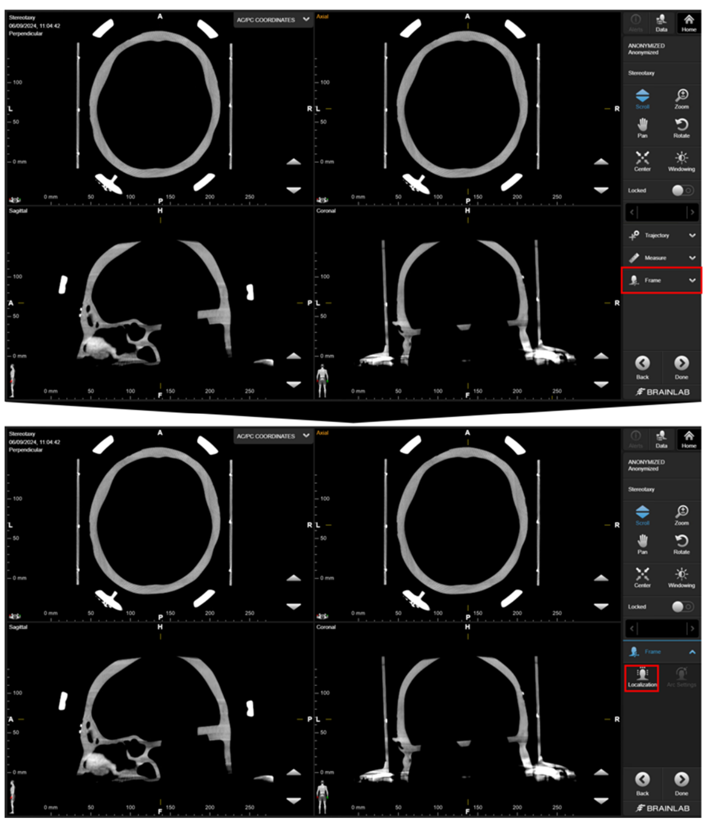

Figure 9: Start of frame localization wizard

- Select the appropriate indicator box to trigger the automatic recognition of the rods (Figure 10):

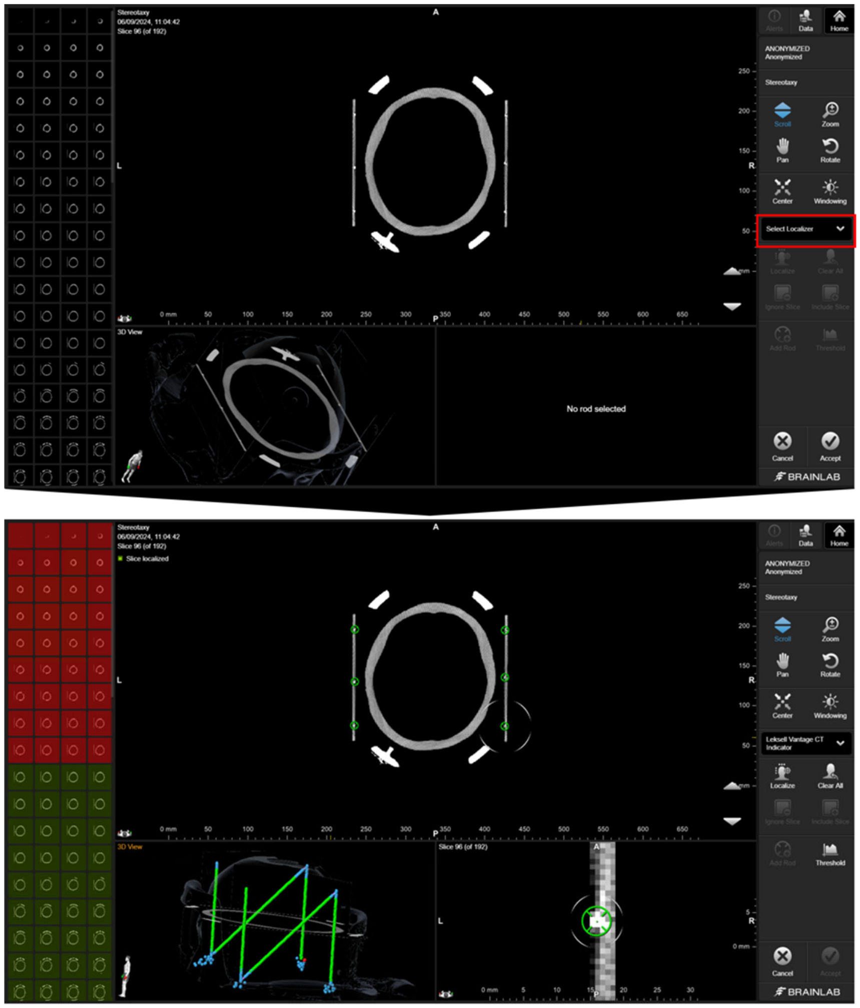

Figure 10: Parametrization and verification of frame recognition.

- Add rods where detection failed or ignore the slices where rods are not visible with the corresponding buttons in the right panel.
- Accept the localization. This will close the localization wizard and return to the main planning interface.

4.2.2 Target selection

- Collapse the “frame” menu and expand the “trajectory” menu (Figure 11).
- Create a new trajectory and place the target point.
- Discuss accessibility with the lecturer.

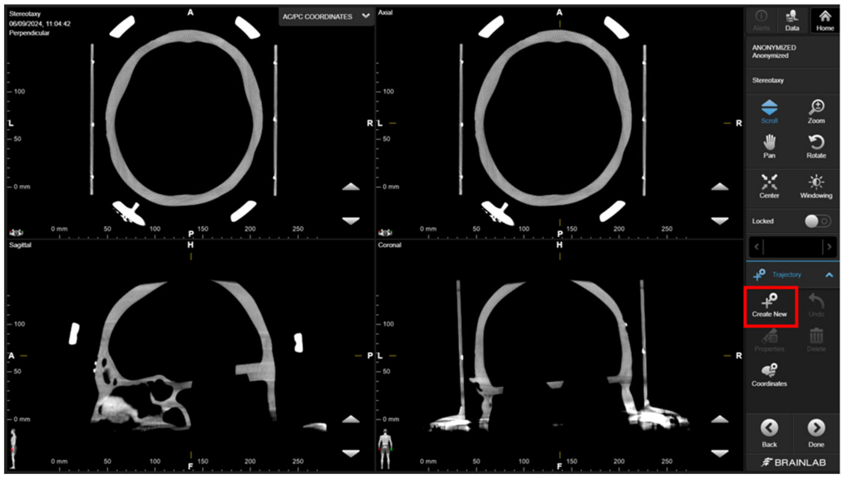

Figure 11: Creation of new trajectory.

4.2.3 Entry point selection

- Place the entry point of the trajectory at the surface of the vegetable and check the trajectory angle. The entry point should be on the same hemisphere as the target point. Discuss trajectory orientation with your lecturer before going to the frame settings export.

4.2.4 Frame settings export

- In the frame menu, select “Arc Settings” to obtain the arc settings. Take care to the “arc mounting” and match it to the assembly of the frame (Figure 12).

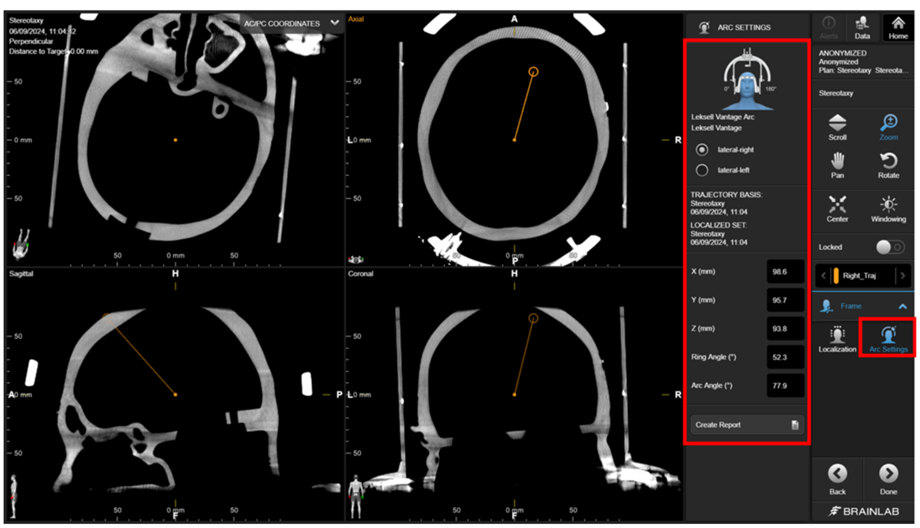

Figure 12: Leksell arc settings read-out.

- Produce the PDF report (“create report”) and save the PDF to your USB stick.
- Disconnect from the RDP session and insert the USB stick to your personal or the lecturer’s laptop to print the report.

4.3 Implantation

- Mount the arc to the frame following the user manual, but in the presence of your lecturer.
- Apply the arc settings (see manual)
  Preparation: You should know where on which plate and arc you find which coordinate and how to change it!
- Introduce the biopsy needle (still with the inner cannula) into the stereotactic holder upto the surface and mark the position of the entry point on the surface.
- Drill a hole with a 2mm drill approximately in the direction of the trajectory. Don't go deep, it is just to cross the very hard surface of the vegetable.
- Implant the biopsy needle (still with the caunla as it is more rigid): Push it down **carefully** until its alignment marks
- Take out the inner canula for the imaging (the biopsy window will be better visible on the images).
- Take off the arc very carefully

4.4 Post-operative imaging and verification

4.4.1 Imaging

Repeat the imaging procedure as discribed above.

- Position the patient in the O-Arm with the frame but without the localiser box this time (in clinical practise surgery is terminated before the postoperative imaging if the center has no intraopertaive CT)
- Perform the imaging in the same way as before, export the DICOM images (this will re-export all images for the patient.
- connect to the planning station and the patient DICOM folder again, the new images will be added (if the patient name matches).
- Make sure both pre- and post- operative images are selected in the data selection screen.

4.4.2 Pre- and post-op image co-registration

- Go back to the "stereotaxy" workflow and select the "image fusion" tool (Figure 13)

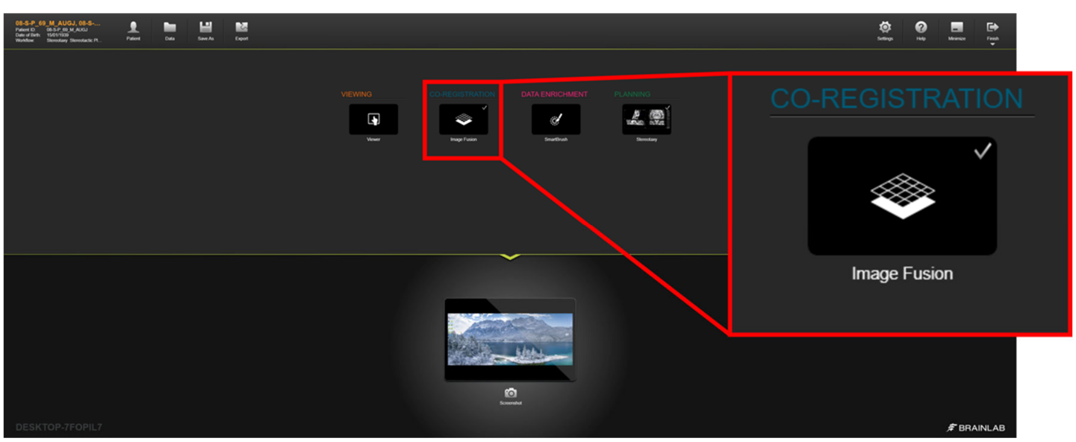

Figure 13: Start of image fusion tool.

- Fusion between pre- and post-operative images should begin automatically. Inspect the result with the spy glass and accept or reject the fusion result.
- Go back to the “planning - stereotaxy” tool and generate a new trajectory for the implanted biopsy needle based on the artifact in the image.

4.4.3 Error quantification

Determine the euclidian distance between the pairs of target and entry points (pre- and post-op) of trajectories using the stereotactic coordinates (Figure 14).

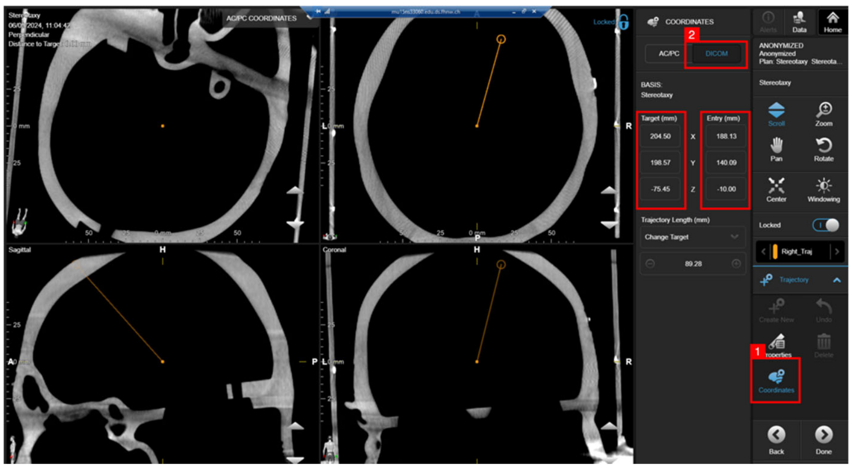

Figure 14: DICOM coordinate read-out.

Muttenz 24.9.2024 Dorian Vogel, Simone Hemm