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White Paper

Posterior approach for stereotactic neurosurgery using the Leksell® Vantage Stereotactic System

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Introduction

In stereotactic neurosurgery, posterior approaches are used to access regions of the hindbrain, such as the pons, lower brainstem or cerebellum. Although posterior approaches can be technically challenging[1], they often provide a shorter and safer trajectory to targets in these regions of the brain.

The Leksell® Vantage Stereotactic System (Figure 1) can be used for posterior trajectories. In this paper Dr Marie Krüger provides guidance on how to plan and carry out a surgical intervention with a posterior approach using the Leksell® Vantage Stereotactic System. Specifically, the paper describes how to identify the required position of the Vantage head frame on the patient's head and how to secure it accordingly to allow posterior trajectories. For additional information on this method see Krüger et al. (2022).

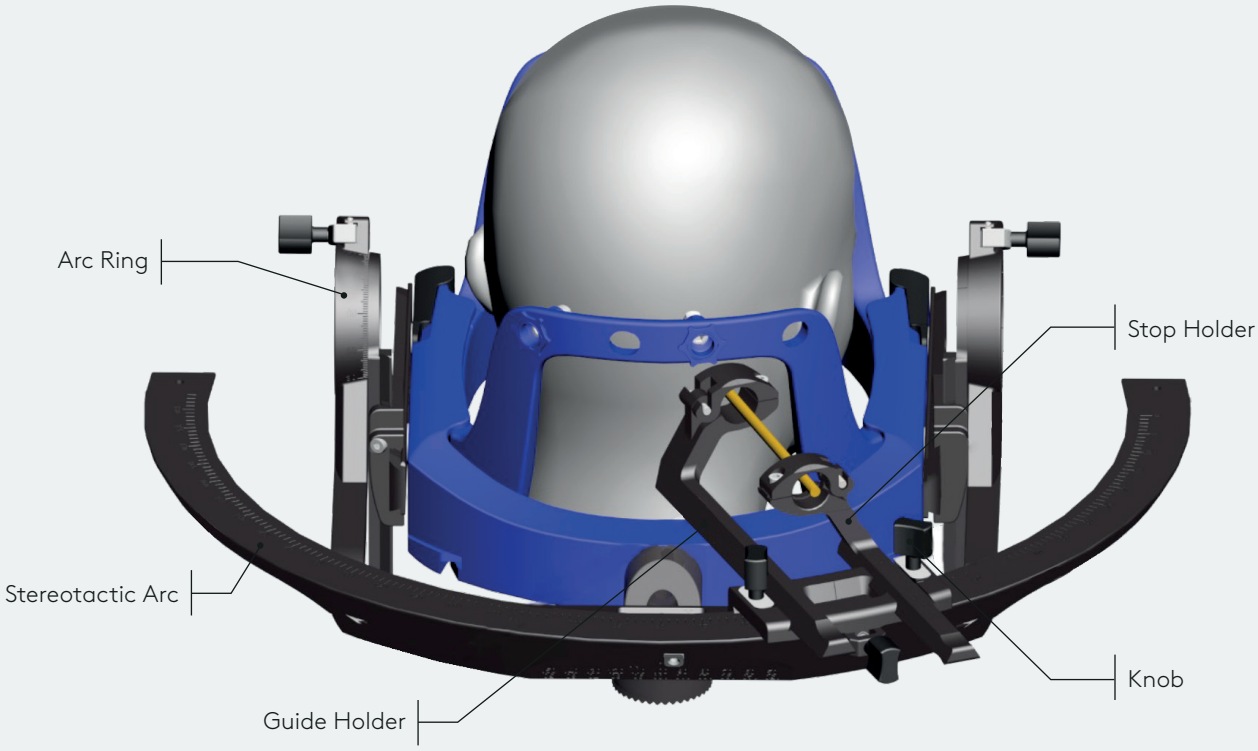

Figure 1. Illustration of the the Leksell Vantage Stereotactic System used for posterior approaches. Yellow cylinder illustrates a trajectory towards a typical target in the cerebellum.

Posterior window

In its current design, the Vantage head frame and Frame Holder allows a limited, fixed window of approximately 10 cm x 7 cm for posterior approaches. Since the design of the frame cannot be changed, frame placement needs to be tailored to each entry, target and trajectory. The entry point must be located within the posterior window and the trajectory must allow sufficient room to avoid hitting the head frame or frame holder during the procedure.

When securing the head frame on the patient's head there are three important aspects of the trajectory to consider, its axial rotation, sagittal angle, and inferior-superior position (Figure 2). The head frame is then secured to position the trajectory within the posterior window.

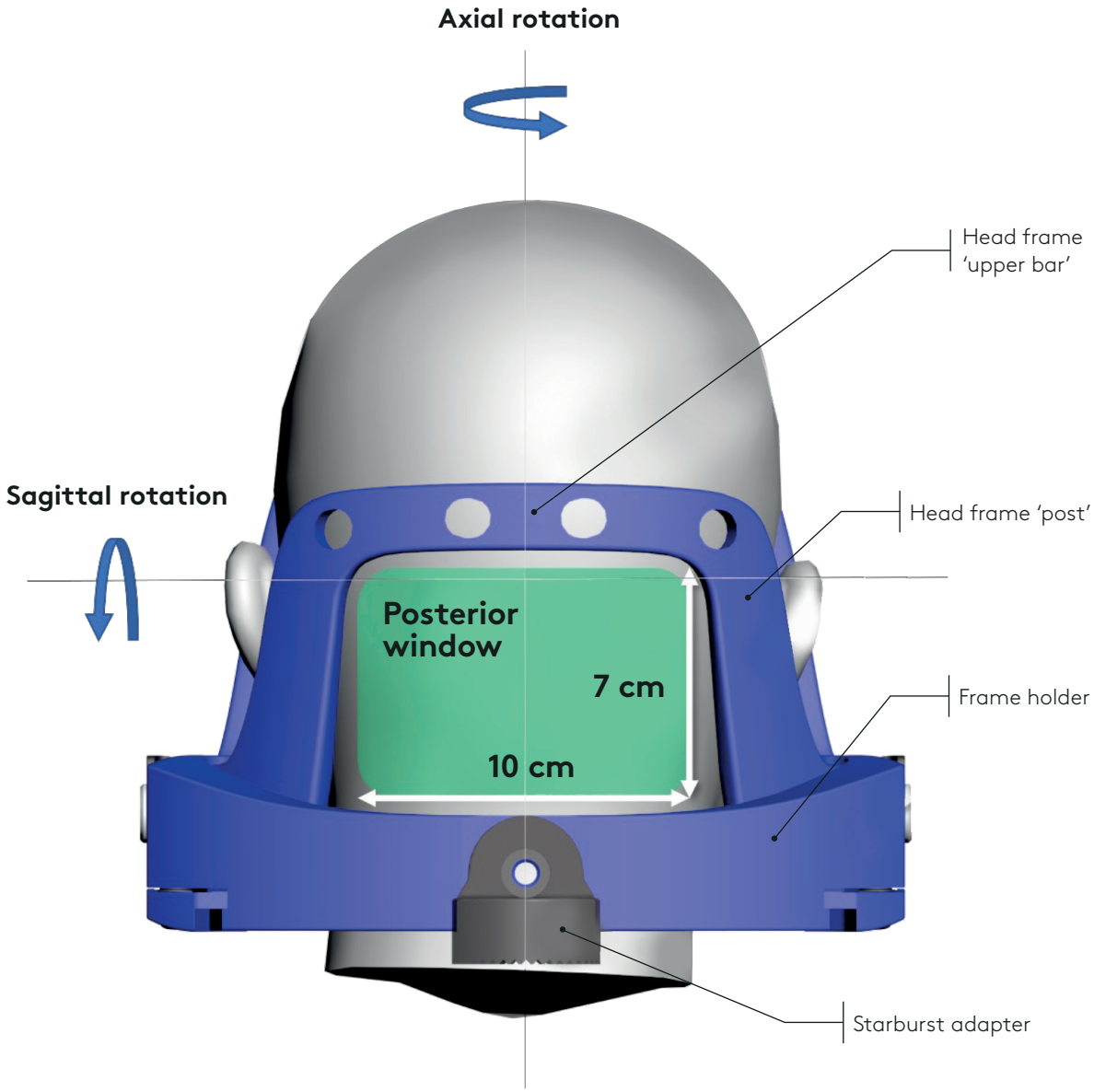

Figure 2. The Vantage head frame allows a 10 cm x 7 cm posterior window for posterior approaches. Certain entry points and trajectory angles will lead to collision of the arc systems with the frame or the frame holder. This can be avoided by tailored frame placement.

Trajectory planning

Before a suitable position of the frame can be defined, it is recommended to define a target, entry point, and trajectory in a planning software tool compatible with Leksell Vantage Stereotactic System, e.g. Brainlab Elements for Stereotaxy 2.5., or Medtronic StealthStation S8 1.3. Such a plan should be defined on images acquired prior to frame placement and surgery. Information from the plan can then be used to mark points on the patient's skin to facilitate proper head frame attachment that allows the planned trajectory. This can be done in the planning software by deriving the location of the entry point, the target point, and the trajectory angle in relation to extra-cerebral landmarks.

Defining the axial orientation of the trajectory

The horizontal/axial rotation of the entry point can be derived in the planning software by measuring the distance from the entry point to the midsagittal plane at the level of the skull. In the example below a distance of ~50 mm was measured between the entry point and the midsagittal plane (Figure 3).

When the entry point is located ~50 mm lateral from the midsagittal plane, there is a risk that the trajectory will be blocked by the 'post' of the head frame if mounted in a standard position (Figure 4). To allow the planned trajectory the head frame must be rotated along the axial plane before securing it to the patient's head.

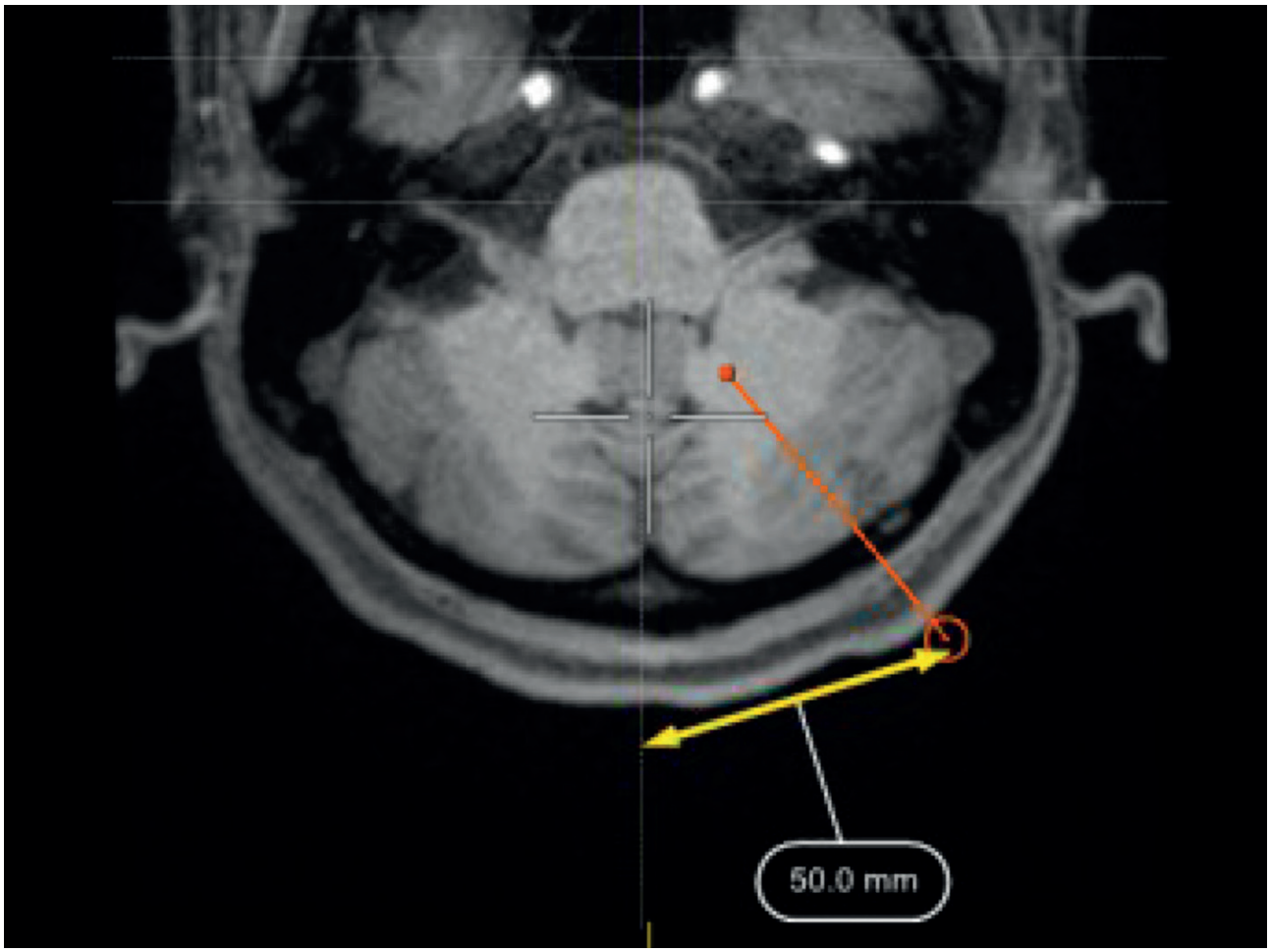

Figure 3. Axial view of the planned trajectory at the level of the entry point. A distance of ~50 mm was measured between the midsagittal plane and the planned trajectory.

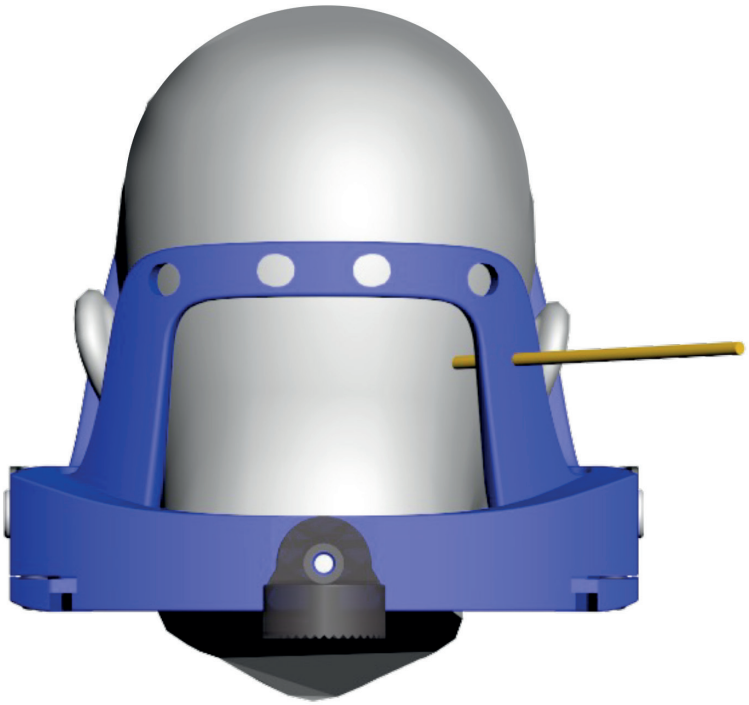

Figure 4. Posterior view of a regularly mounted head frame and frame holder together with a trajectory illustrated with a yellow cylinder. In this case the trajectory is blocked by the right 'post' of the head frame.

Defining the sagittal orientation of the trajectory

The posterior window is limited not only by the 'posts' of the head frame, but also by the 'upper bar' of the head frame as well as the frame holder. Therefore, the sagittal angle of the trajectory must also be considered when orienting the head frame.

The sagittal angle of the planned trajectory can be derived in relation to the AC-PC plane. This may be done in a planning software by studying the sagittal slices where both the AC-PC plane and the planned trajectory are visible (Figure 5).

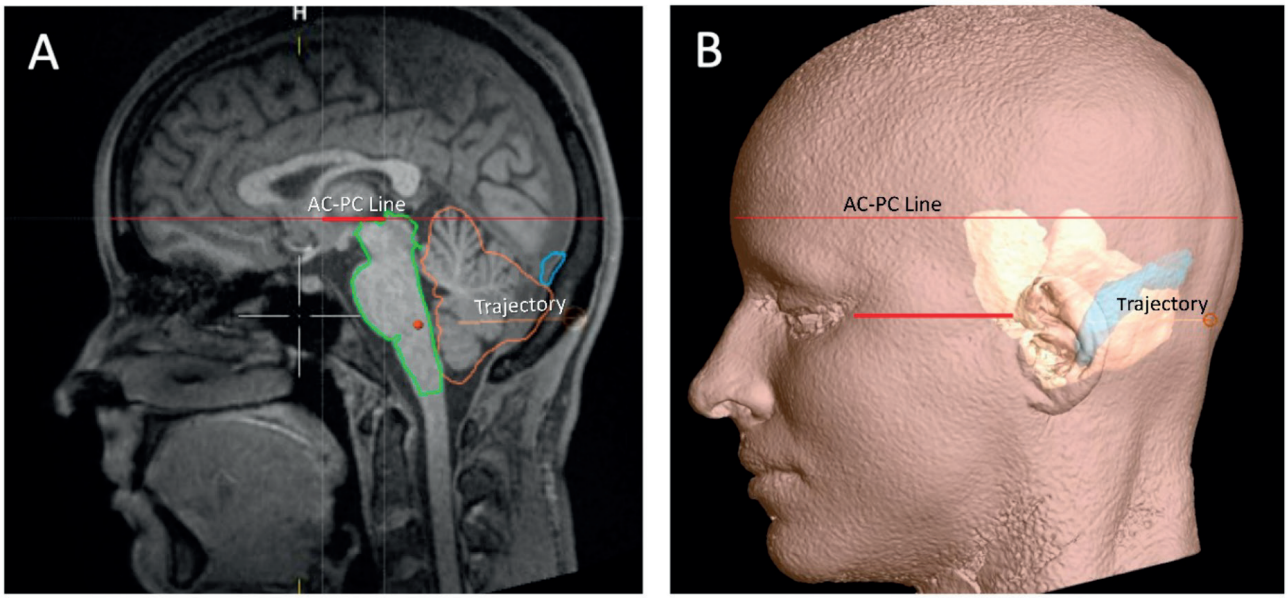

Figure 5. Target, entry point, and trajectory in relation to important anatomical structures like brain stem (light green), cerebellum (orange) and sinus (blue). AC-PC overlaid on A) sagittal MRI and B) 3D image. In this case the trajectory is angled similar to the AC-PC plane

Defining the inferior-superior position of the trajectory

In addition to the horizontal and sagittal rotation, the inferior-superior position of the planned entry point may be derived. This is done in the planning software by comparing the location of the entry point in relation to extra-cerebral landmarks. Ear lobes and the ear-canal are suitable landmarks (Figure 6).

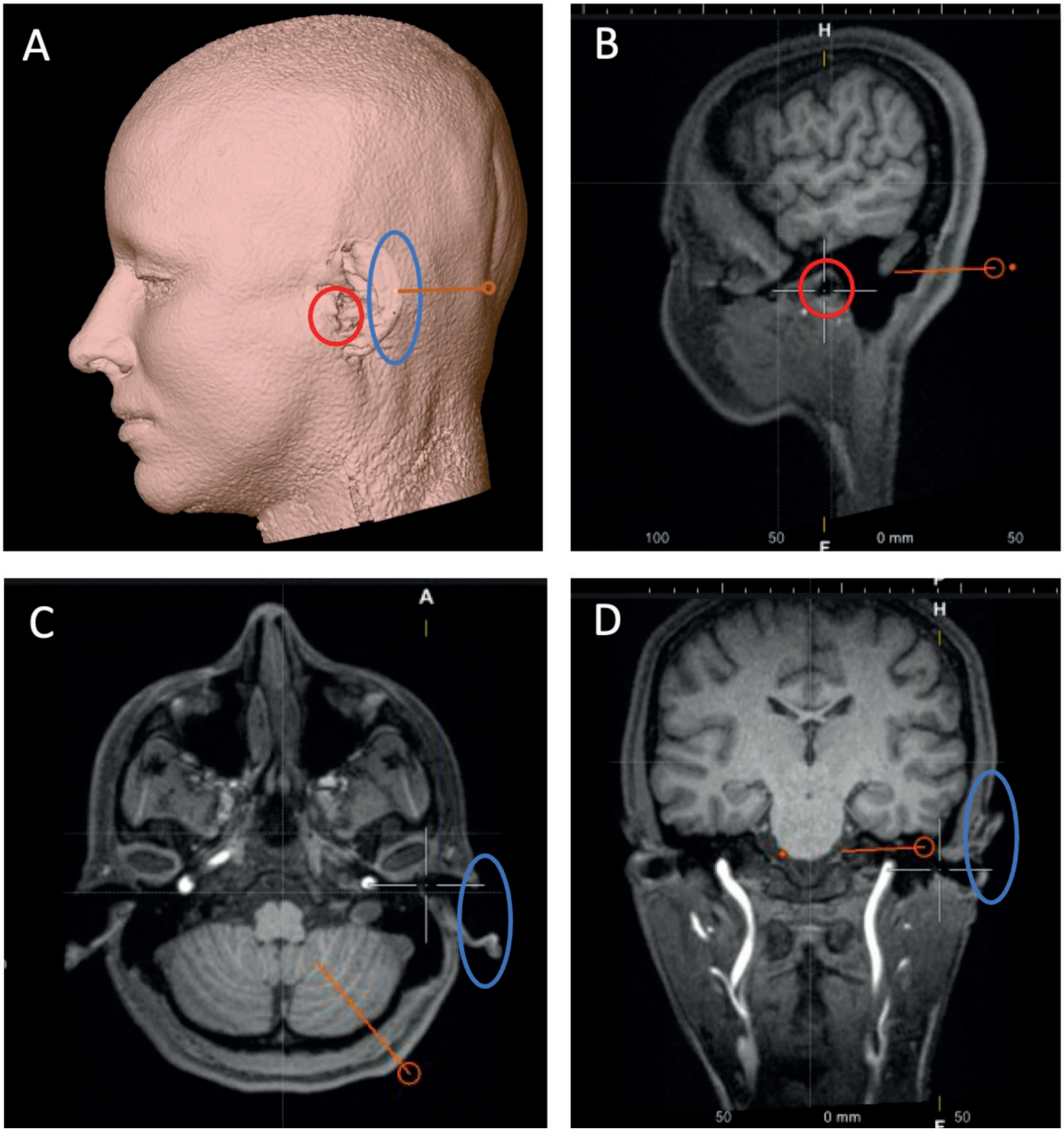

Figure 6. A) Trajectory (orange) and landmarks (ear canal (red) and ear lobe (blue)) on 3D model. B) sagittal, C axial, D) coronal slides on MRI images on which the location of the entry point can be defined in relation to extra-cerebral landmarks.

Patient preparations

As an aid during head frame placement, the entry point and sagittal angle may be marked on the patient's skin, based on information from the surgical plan.

The axial angle of the entry point is marked in two steps. First, mark the midsagittal line on the back of the head. Second, draw a line at a distance corresponding to the measured distance between the mid-sagittal plane and the entry point.

The inferior-superior position of the entry point is marked on the patient's skin based on the relationship between the extra-cerebral landmarks and the entry point derived during the planning. In the current example, the inferior-superior position of the entry point is located at the level of the ear canal in the AC-PC plane (Figure 7).

The sagittal angle of the planned trajectory is marked in two steps. First, mark a reference of the AC-PC plane. It may be approximated by the Nose-Ear-Line (NEL) which has been shown to correspond well with the orientation of the AC-PC plane (Otake et al., 2018). Second, mark the sagittal angle below the NEL at the angle derived from the planned trajectory (Figure 8).

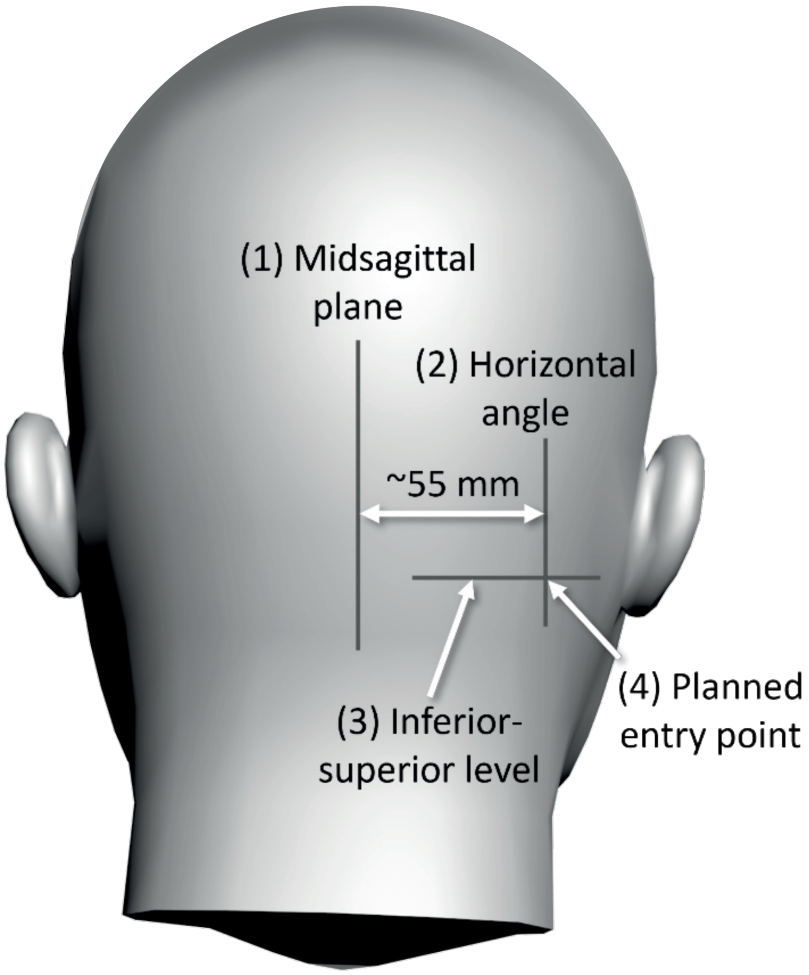

Figure 7. Markings of the horizontal angle and the inferior-superior level of the entry point. Due to the curvature of the head, the horizontal angle was marked at 55 mm (instead of the measured 50 mm) from the midsagittal plane.

Head frame attachment

After marking the entry and target point as well as the sagittal angle of the trajectory, the head frame may be fixed on the patient's head. It is now important that the posterior window of the head frame is positioned to allow for the planned trajectory. A suitable head frame position allows a margin of 30–40 mm between the head frame and the marked entry point. FirmFix screws may be placed 30–40 mm superior to the marked entry point, and the 'post' of the head frame may be located 30–40 mm lateral to the marked entry point (Figure 9, upper left). The frontal FirmFix screw on the surgery side will normally end up vertically in line with the eye (Figure 9, upper right). Depending on the shape of the head in relation to the rotated head frame, it may be decided to apply FirmFix screws in the more medial holes of the head frame (Figure 9, lower left). More than four FirmFix screws may be applied to increase stability in cases of extreme angles.

The sagittal rotation of the head frame should be 5–10 degrees larger angle than the sagittal trajectory angle. This is to avoid having stereotactic Arc ring angles >180 degrees which may result in the Arc being blocked by the frame holder (Figure 9, lower right).

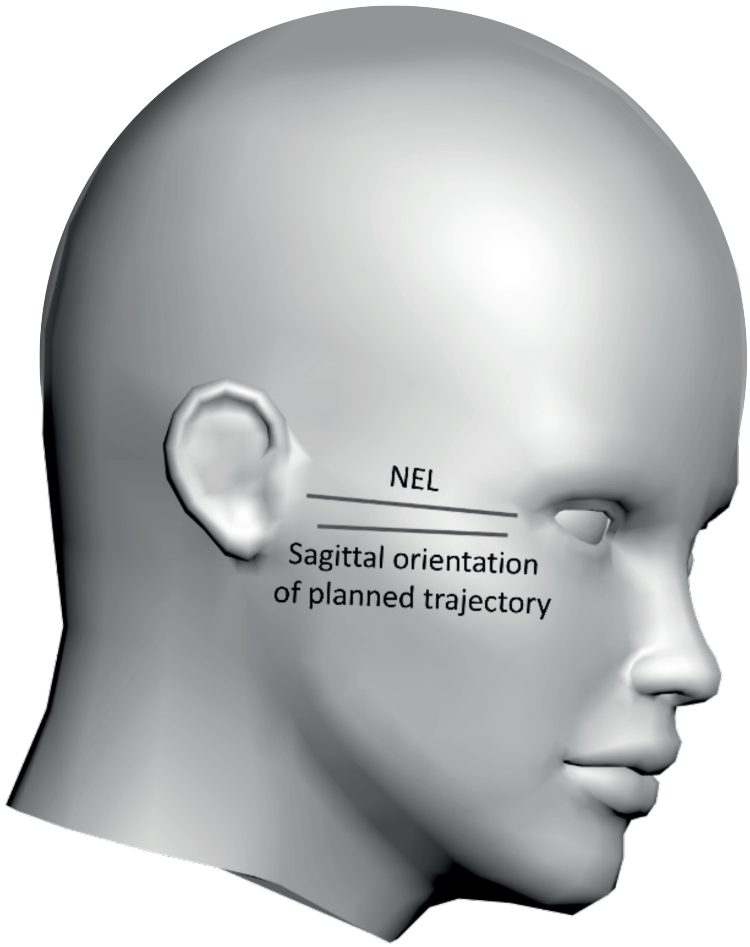

Figure 8. Markings of the Nose-Eye-Line (NEL) and sagittal angle of the planned trajectory.

Stereotactic coordinates

When the head frame has been attached to the patient's head, stereotactic images can be acquired. Given the sometimes extreme angles, it is recommended to perform a stereotactic CT where the frame can be fixated rigidly and the scan only takes a few seconds. After registration of the stereotactic image with the pre-planned MRI (with the planned entry, target and trajectory) the stereotactic coordinates (x, y, z) and angles (ring, arc) can be calculated, but first the lateral orientation of the arc must be decided. The Leksell Stereotactic Arc can be positioned in either lateral left or lateral right orientation. The laterality of the arc is defined by which side the 0 degrees arc angle is located on. For lateral right the 0 degrees arc angle is located on the right side of the patient. Each orientation has its pros and cons when applied during posterior approaches.

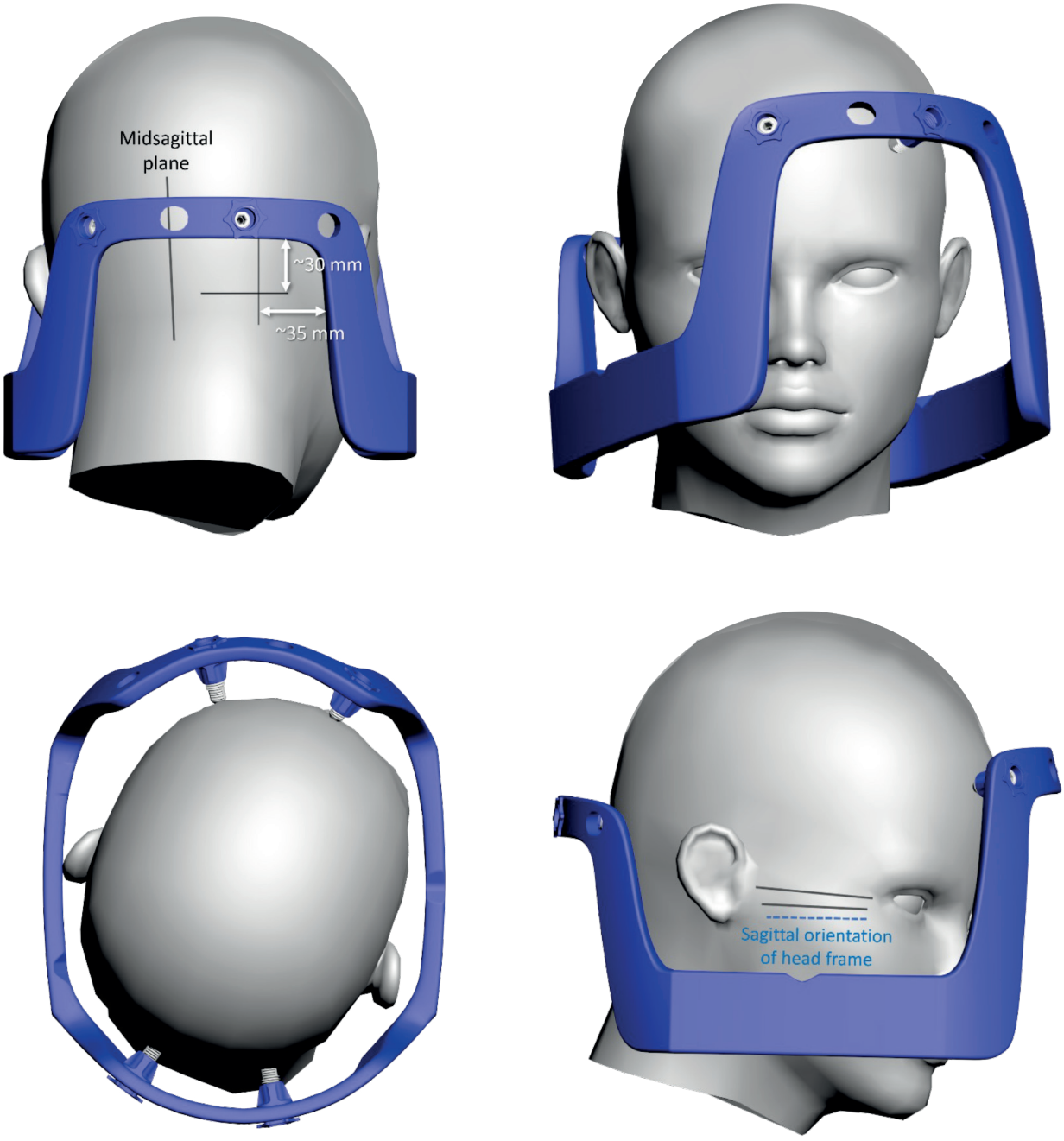

Figure 9. Illustration of head frame positioned according to markings. The frame is mounted with ~25 degrees horizontal rotation and with a few degrees larger sagittal angle than the planned trajectory. The trajectory is located within the posterior window and will be accessible for the stereotactic procedure. Upper left: Posterior view, upper right: frontal view, lower left: superior view, and lower right: lateral view.

In the lateral-right orientation, the arc is positioned inferior to the trajectory and the risk of the arc getting blocked by the Frame holder is increased. Lateral right orientation is, however, convenient from a user's perspective when changing the depth of the stop and guide holders which will be facing the user (Figure 10).

Figure 10. Vantage arc in lateral right orientation. Left) posterior view, and Right) lateral view.

In the lateral-left orientation, the arc is positioned superior to the trajectory and the risk of the arc getting blocked by the frame holder is reduced. Lateral left orientation is, however, less convenient from a user's perspective when changing the depth of the stop and guide holders since these will be facing down towards the frame holder and can make it difficult to open the knobs.

Figure 11. Vantage arc in lateral right orientation. Left) posterior view, and Right) lateral view.

When the laterality of the arc has been defined, stereotactic coordinates and angles can be derived from the planning software. As a final step before carrying out the surgical procedure the feasibility of the actual stereotactic coordinates and angles can be tested. In the publication by Krüger et al. (2022), there is a feasability matrix with coordinates and related angles.

If the trajectory is not feasible there are a few actions that can be taken. First, the laterality of the stereotactic arc can be changed. If the trajectory is still not feasible, alternative targets and trajectories may be considered. In the instance where the trajectory is still blocked, the head frame will need to be repositioned to allow for the trajectory. In this case, new stereotactic images must be acquired.

Tips and examples

Tip 1

To facilitate frame placement, it is best to respect the following aspects if the lesion and surrounding structures allow:

- The entry point should be as close to the midline as possible to avoid extreme axial rotations (Figure 12 and 13).
- The trajectory should be as flat (similar to the AC-PC line) as possible to avoid extreme ring angles (Figure 12 and 13).

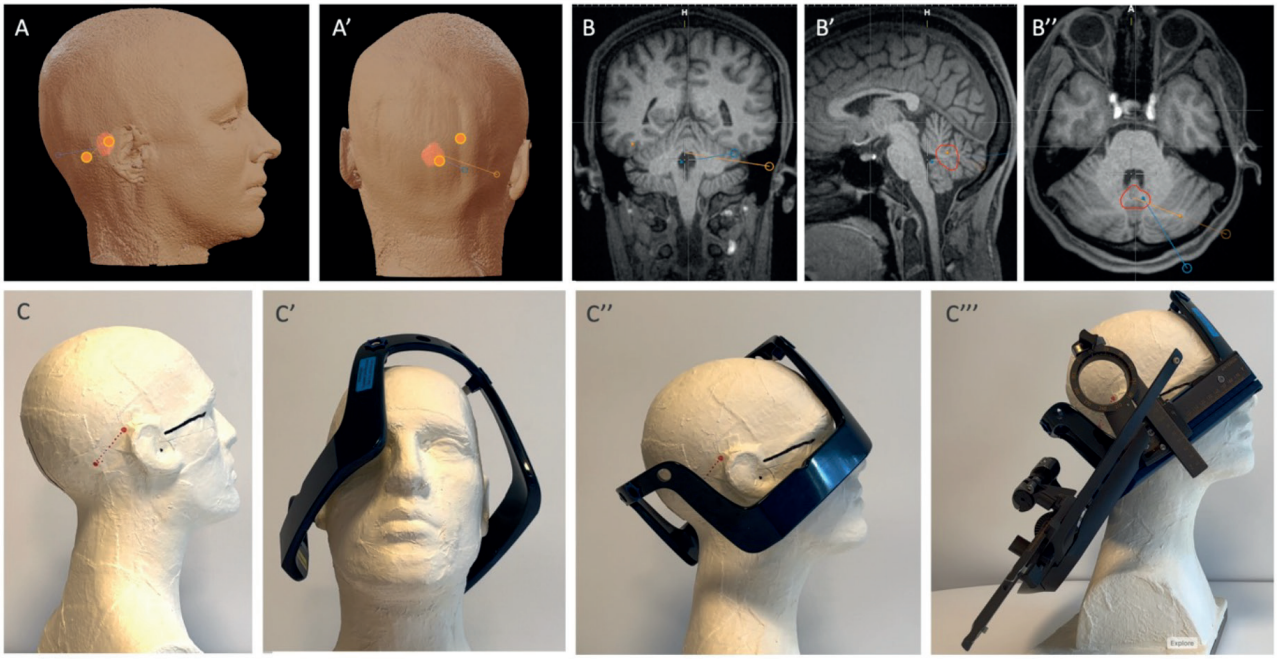

Figure 12. Example of very lateral entry point and steep trajectory that necessitate extreme axial and sagittal frame angles. A, A': using landmarks from 3D model of software. B, B'', B''': using landmarks from raw MRI images to transfer target and entry (red circles) on patient (C). Frame placement with extreme axial (C') and sagittal rotation (C''). C''': with arc system attached.

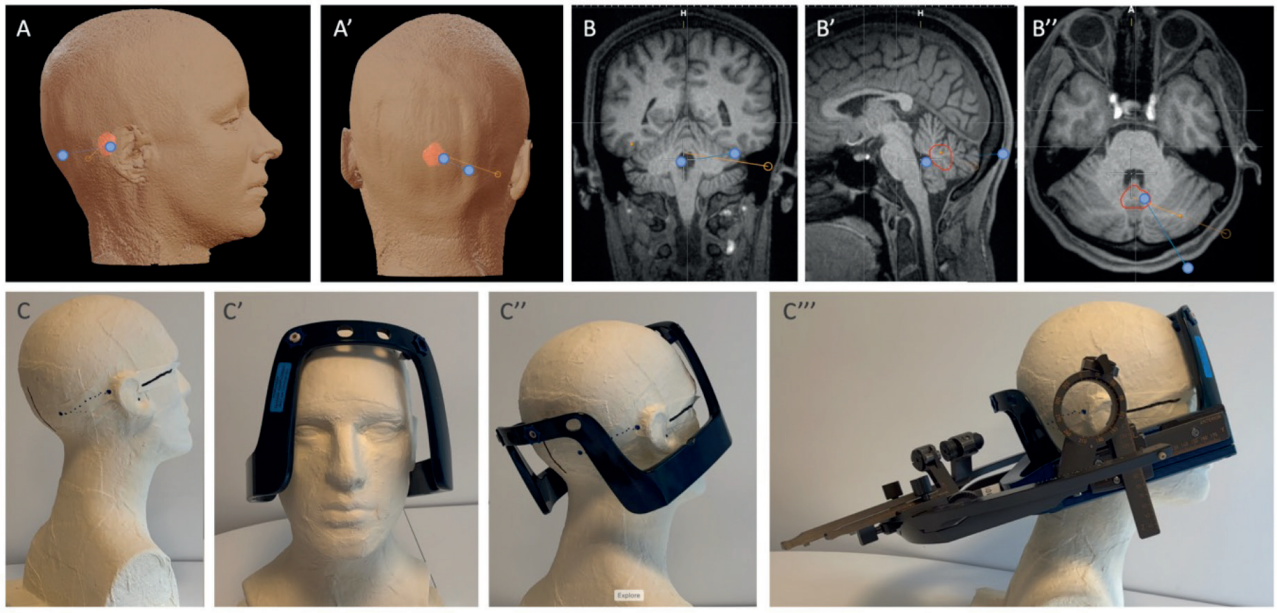

Figure 13. Example of a more medial entry and flatter trajectory that allow frame placement with little axial and sagittal rotation. A, A': using landmarks from 3D model of software; B, B'', B''': using landmarks from raw MRI images to transfer target and entry (blue circles) on patient (C). Frame placement with little axial (C') and sagittal rotation (C''). C''': with arc system attached.

Tip 2

It is recommended to use a lateral-right approach when there is no specific reason to use a lateral-left approach since frame placement mostly tends to be too high and at a too-flat angle. In this case, switching to a lateral-left approach as a default can avoid the necessity of reattaching the frame (Figure 14).

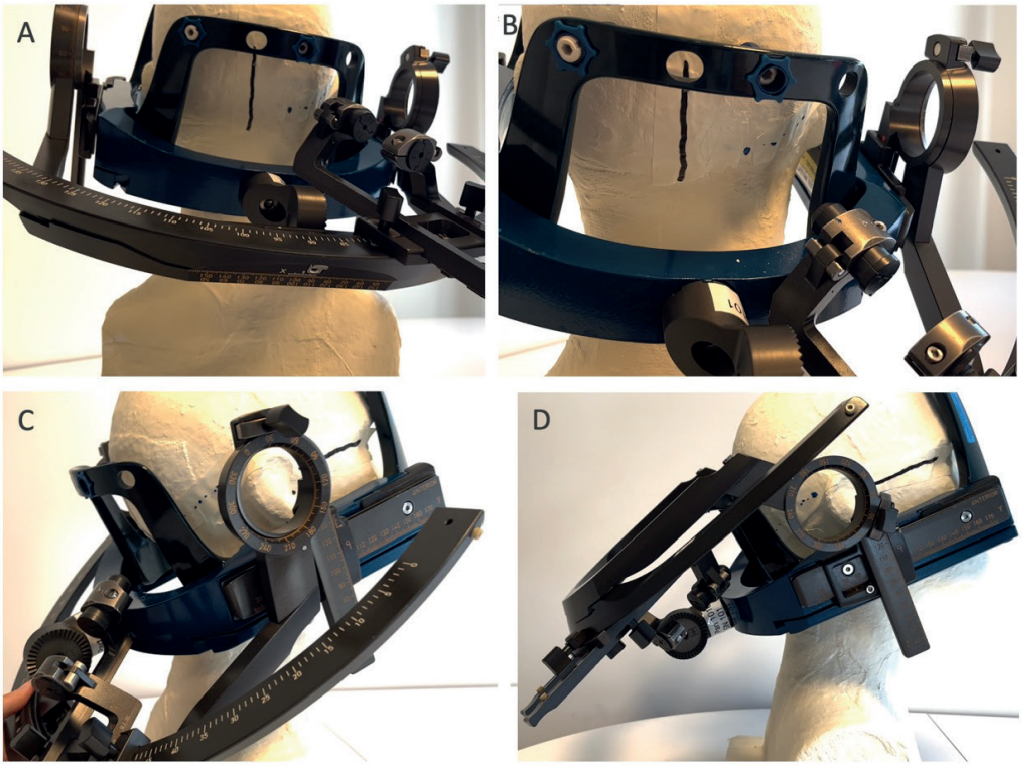

Figure 14. A) The entry point is lower than intended. B) Thus, close access is blocked by the frame holder. C) The trajectory is steeper than intended, thus ring angle is again blocked by the guide holder and frame holder. D) Switching to a lateral-left approach can compensate for both and allows free access to the entry point.

Tip 3

For extreme angles, it is advisable to aim for a lateral-left approach from the start to avoid extreme sagittal frame angles (Figure 15)

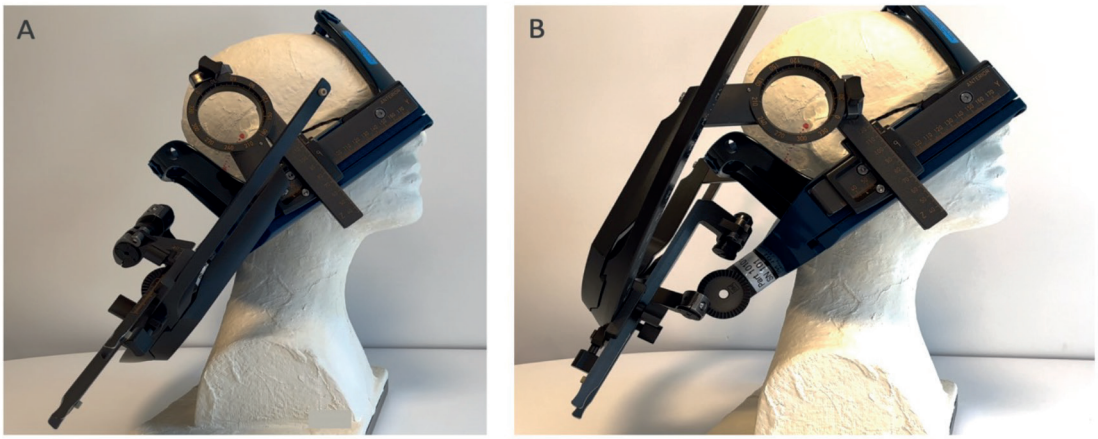

Figure 15. A) If extreme sagittal angles are required, the lateral-right arc approach is often limited by the blocked ring angle. B) In this case it is advised to use the lateral-left arc approach upfront.

Discussion

Careful planning and preparation to determine the required position of the Leksell Vantage head frame on the patient's head can save valuable time on the day of surgery. Otherwise, if it is discovered that the trajectory is not feasible, the frame would need to be removed, repositioned, and additional stereotactic images obtained. This can be avoided using the pre-surgery workflow described in this paper.

Conclusion

Posterior approaches are feasible with the Leksell Vantage Stereotactic System. Once a proper head frame position is obtained, posterior approaches are easy to perform, and the user can have confidence in the sub-millimeter accuracy of the Leksell Vantage Stereotactic system.

References

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Appendix

Posterior procedure: Step-by-step

The posterior procedure with Leksell Vantage Stereotactic System can be summarized by the following steps:

Surgical pre-planning in software tool

1. Plan the target and entry point in a compatible planning software tool prior to the day of surgery.
2. Measure the distance between the entry point and the midsagittal plane.
3. Define the sagittal angle of the planned trajectory in relation to the AC-PC plane. This may be done by studying the sagittal slices where both the AC-PC plane and the planned trajectory is visible.
4. Derive the inferior-superior position of the planned entry point by comparing the location of the entry point in relation to extra-cerebral landmarks. Landmarks such as the ear lobes and the ear-canal are suitable landmarks.

Patient preparations

5. Mark the midsagittal plane on the patient's skin.
6. Mark the horizontal angle of the entry point on the patient's skin.
7. Mark the Nose-Ear-Line on the patient's skin to get a visual reference of the orientation of the AC-PC plane.
8. Mark the sagittal angle of trajectory. Draw this line below the NEL.
9. Based on landmarks identified in the planning software, mark the inferior-superior position of the entry point on the patient's skin.

Head frame attachment

10. Position the head frame with 30–40 mm margin between the upper part of the head frame and the marked entry point.
11. Position the head frame with 30–40 mm margin between the 'post' of the head frame and the marked entry point. The frontal FirmFix screw on the surgery side will normally end up vertically in line with the eye.
12. Position the head frame with 0–10 degrees large angle than the planned trajectory as marked below the NEL.
13. Use FirmFix in appropriate positions on the head frame. FirmFix screws can be attached in any of the four anterior holes and the four posterior holes.

Stereotactic coordinates

14. Acquire stereotactic images.
15. Decide whether to attach the stereotactic arc in lateral-left or lateral-right orientation.
16. Derive stereotactic coordinates and angles in a compatible software tool.
17. Compare the derived coordinates and angles with the feasibility matrix in the publication by Krüger et al. (2022).
18. Carry out the surgical procedure.

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