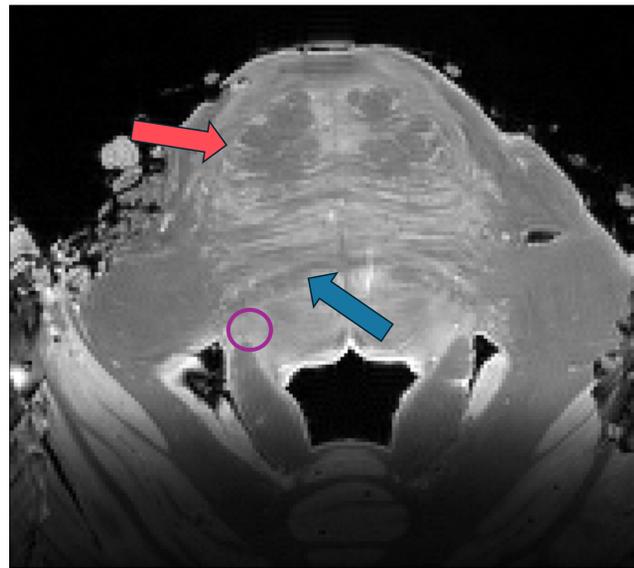


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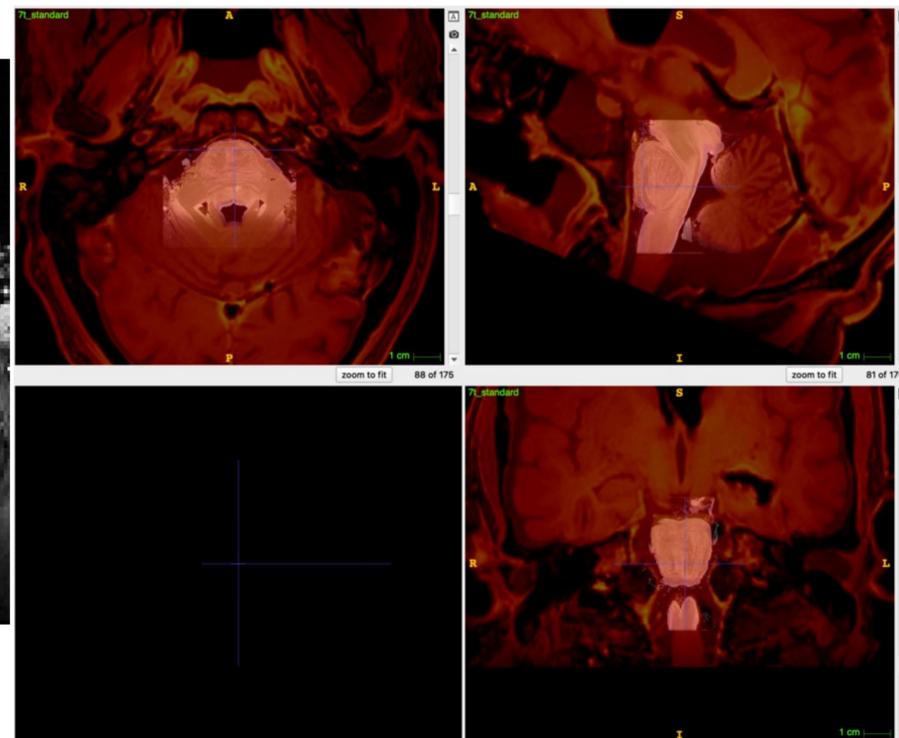
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## Introduction

- Quantitative cadaver studies of surgical “freedom” in brainstem safe entry zones (SEZs) are limited due to decoupled intrinsic brainstem anatomy from surgical corridor, which may **inflate numerical estimates of surgical freedom**.
- In vivo* 3T MRI offers high-fidelity structural imaging, but reliable diffusion tractography is challenging in cadaver tissue.
- Ex vivo* MR microscopy (MRM) provides superior resolution compared with 3T MRI, with white matter tracts directly visualized on T1-weighted imaging (T1WI).
- However, most MRM studies require extraction of small specimens, severing the link between surgical trajectory and intrinsic anatomy unless complex registration is performed.
- As a result, the **surgical value of MRM for SEZ assessment remains largely unexplored**.



**Figure 1.** On T1WI MRM, CST (red) and MLSTM (blue) were visually identifiable on this axial slice of cadaveric pontine sample. The approximate location of CN V (purple) was inferred by neuroanatomical knowledge.

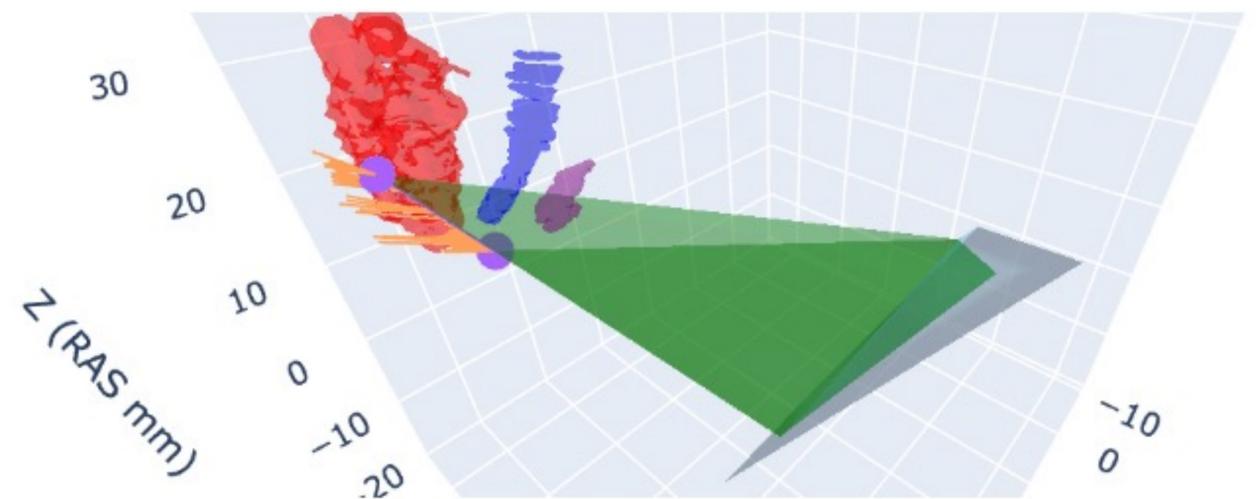


**Figure 2.** Using ITK-SNAP, the 3T neuronavigation scan (red) was registered to the 7T MRM scan space (white). Overlap color map demonstrated near perfect registration results. This registration accuracy is sufficient for trajectory analysis.

**Goal: Demonstrate a novel 3T-7T hybrid MR approach that integrates the extended retrosigmoid surgical corridor with intrinsic brainstem anatomy on the same cadaver, enabling quantitative assessment of surgical freedom for the inferior trigeminal zone (ITZ).**

## Methods

- Cadaver brain (83 yo M, post-mortem interval 72 h) underwent clinical 3T T1-weighted neuronavigation scan with registration using Medtronic StealthStation S8 for coordinate collections.
- Extended retrosigmoid craniotomy (35×34 mm bone window) was performed.
- 10 surgical corridor landmarks were collected – 4 bone window corners, 4 dura window points, inferior point of CN V root entry zone (REZ) and superior point of CN VII REZ.
- Brainstem rehydrated *ex vivo* in PBS doped with gadobutrol for 2 weeks, immersed in Fomblin, degassed within an airtight MR-compatible container, imaged using 7T Bruker scanner (0.1×0.1×0.8 mm resolution, scan time = 2h 32min).
- Using manual and rigid registration, 3T Stealth coordinates were converted to 7T space.
- Corticospinal tract (CST), medial lemniscus/spinothalamic tract (MLSTM) and CN V nuclei were manually segmented.
- Computational algorithm searched for straight trajectories that traverse the bone window, the dura window and the ITZ line while remaining lateral or posterior to CST or MLSTM, or anterior or lateral to CN V nuclei.
- Surgical freedoms reported in both intra-brainstem depth of freedom and angular freedom.



**Figure 3.** 3D abstract rendering of safe external surgical corridor (green) and intra-brainstem trajectories (yellow) traversing the bone window (grey), the ITZ line (light purple line) without violating the CST (red), MLSTM (blue), and CN V nuclei (dark purple).

## Results

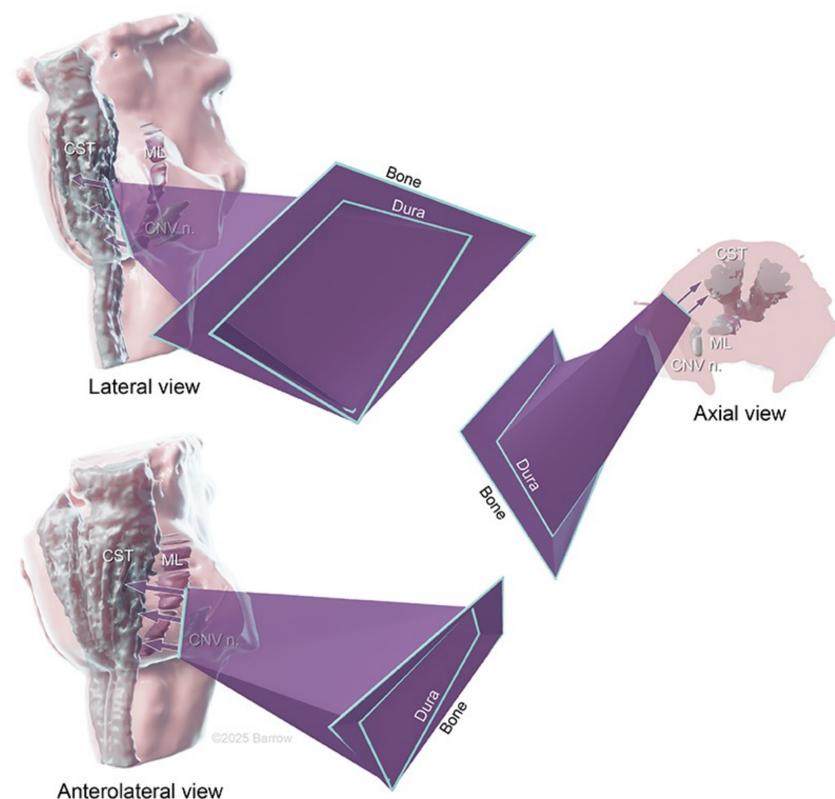
- Bone window area = 1178.48 mm<sup>2</sup> and dura window area = 680.21 mm<sup>2</sup>.
- Length of the ITZ = 12.76 mm.
- Algorithm detected **257 straight trajectories** meeting the restrictions stated above.
- Mean ± SD of intra-brainstem depth of freedom = **2.59±1.44 mm**.
- Mean angular freedom = **21.0±8.1 degrees**.

**Key Findings:** Using this hybrid 3T-7T MR approach, quantification of surgical freedom is achievable.

## Conclusions

- Registering 3T surgical coordinates to ex vivo 7T MRM from the same cadaver allows direct linkage of the external retrosigmoid surgical corridor with intrinsic brainstem anatomy.**
- This approach enabled quantitative assessment of surgical freedom at the ITZ.**
- Integrating corridor geometry with intra-brainstem anatomy may overcome limitations of dissection-only or geometry-only approaches and reduce overestimation of surgical feasibility**
- This framework supports more realistic evaluation of brainstem safe entry zones and relationships of subsurface anatomy with surgical approach.**

### Surgical Freedom with a Focus on the Infra-trigeminal Safe Entry Zone



**Figure 4.** 3D rendering of the safe trajectory volume that extended from the bone window to the intraparenchymal space beyond the ITZ line. Contrary to prior studies, this is the first-of-its-kind 3D volumetric demonstration of safe entry zone enabled by intricate measurement of coordinates on a cadaveric sample.

## Acknowledgements

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