

Ultrasound in Brain Tumor Resection (anatomy, landmarks)

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and

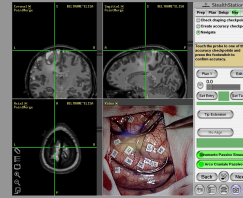
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Johns Hopkins Medical School, Baltimore, MD, USA

Image guided surgery as an aid to
increase the extent of resection of
brain tumors

Mainstays of image guided surgery

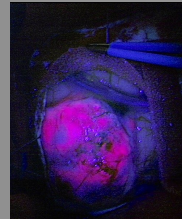
Neuronavigation



Intra-operative MRI



5-ALA

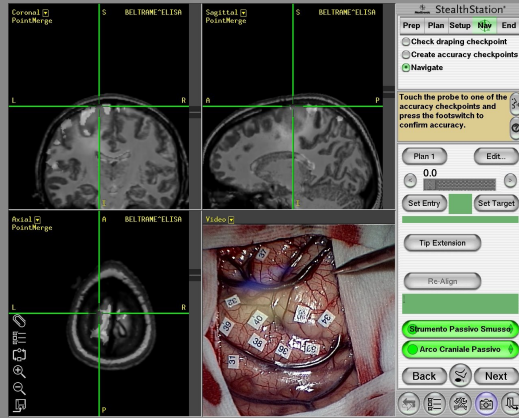


Intra-operative ultrasound



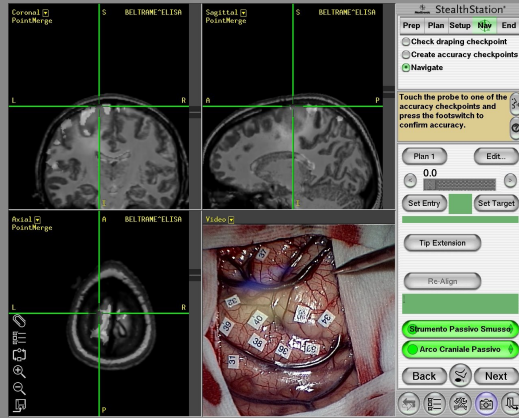
Mainstays of image guided surgery

Neuronavigation



Mainstays of image guided surgery

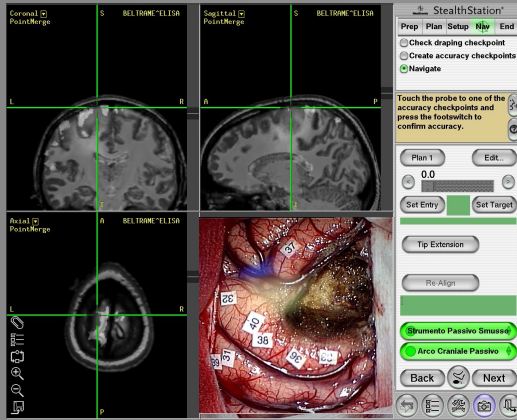
Neuronavigation



- Standard imaging
- Routine use

Mainstays of image guided surgery

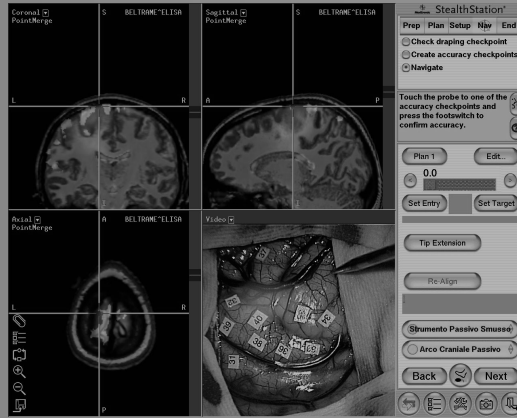
Neuronavigation



- Standard imaging
- Routine use
- *Pre-op imaging*
- *Virtual / No real-time navigation*
- *Brain shift*

Mainstays of image guided surgery

Neuronavigation



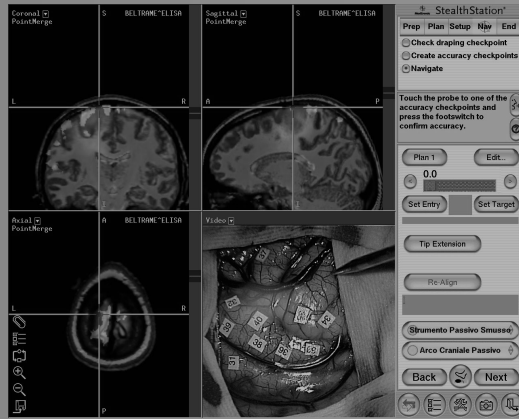
Intraoperative MRI



- Standard imaging
- Accurate

Mainstays of image guided surgery

Neuronavigation



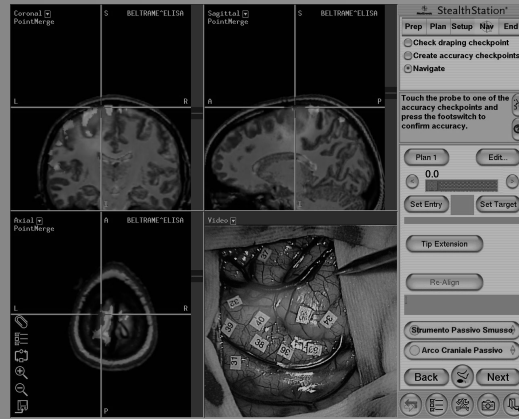
Intraoperative MRI



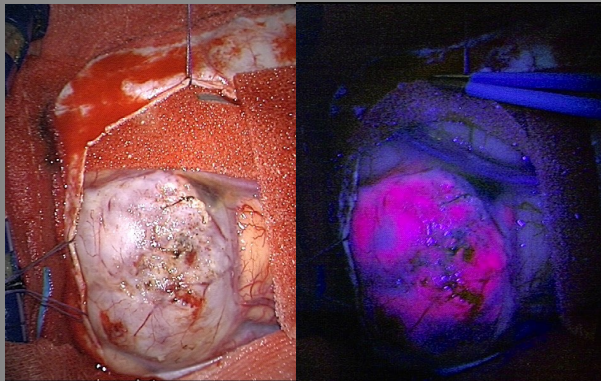
- Standard imaging
- Accurate
- *Dedicated area/tools*
- *Time consuming*
- *Expensive*
- *Non dynamic - offline*

Mainstays of image guided surgery

Neuronavigation



5-ALA



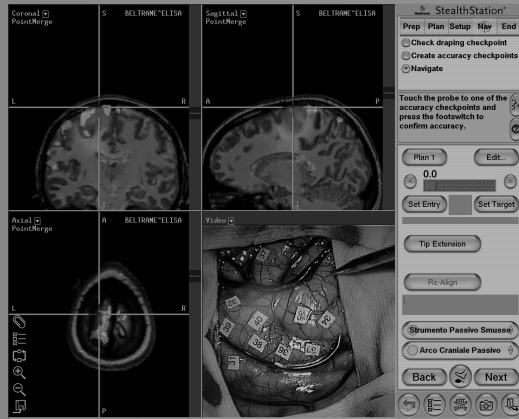
Intraoperative MRI



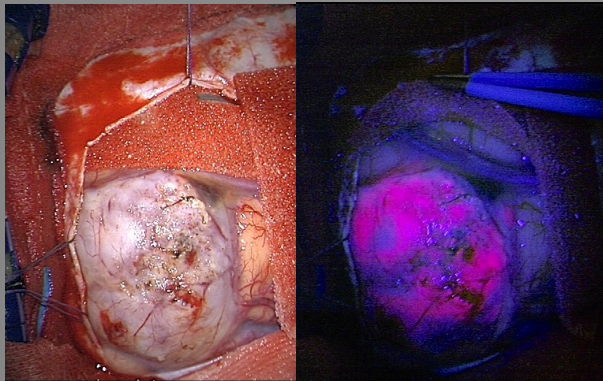
- Real time
- Marks tumor cells

Mainstays of image guided surgery

Neuronavigation



5-ALA



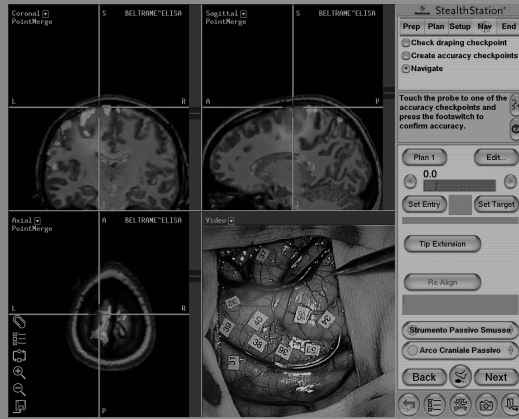
Intraoperative MRI



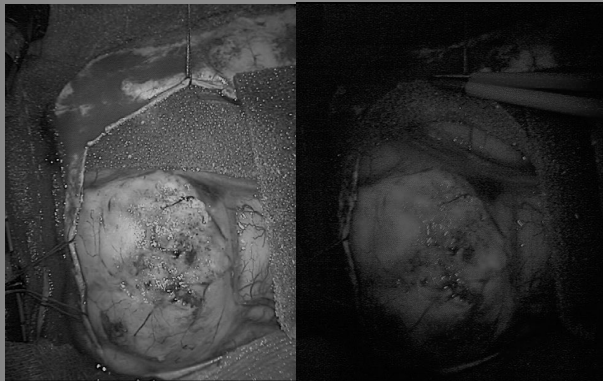
- Real time
- Marks tumor cells
- *Works only on HG gliomas*
- *Visualized only on surface*

Mainstays of image guided surgery

Neuronavigation



5-ALA



Intraoperative MRI



Intraoperative ultrasounds

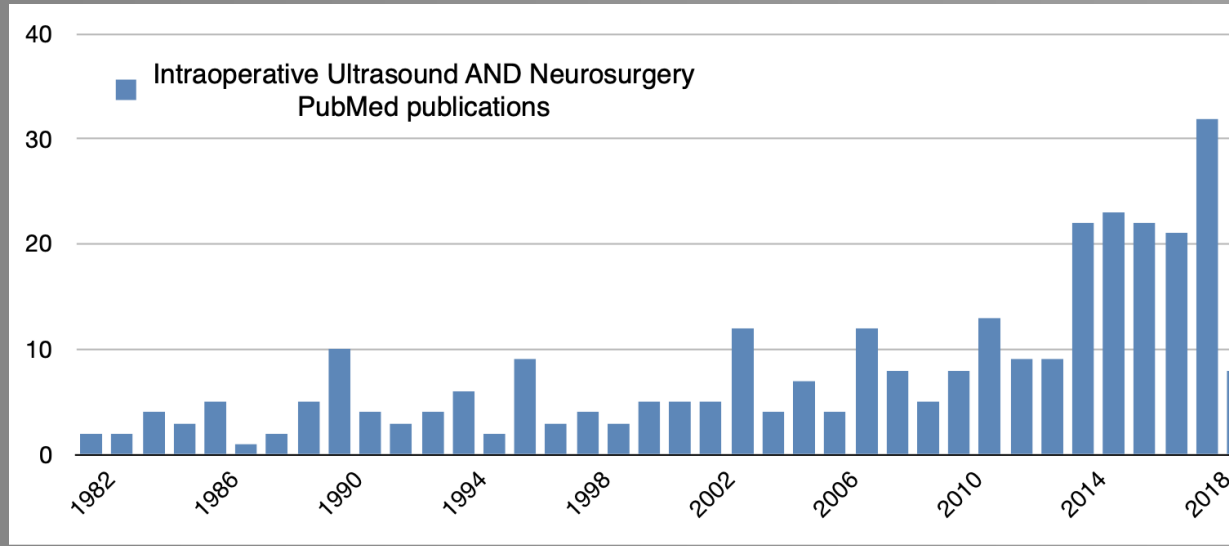


Intraoperative ultrasounds

- Real time
- Dynamic
- Relatively inexpensive



Intraoperative ultrasound in neurosurgery: publications per year *



* Keywords: Intraoperative ultrasound neurosurgery

Intraoperative ultrasounds - advantages

- Recent dramatic improvement of resolution and image definition



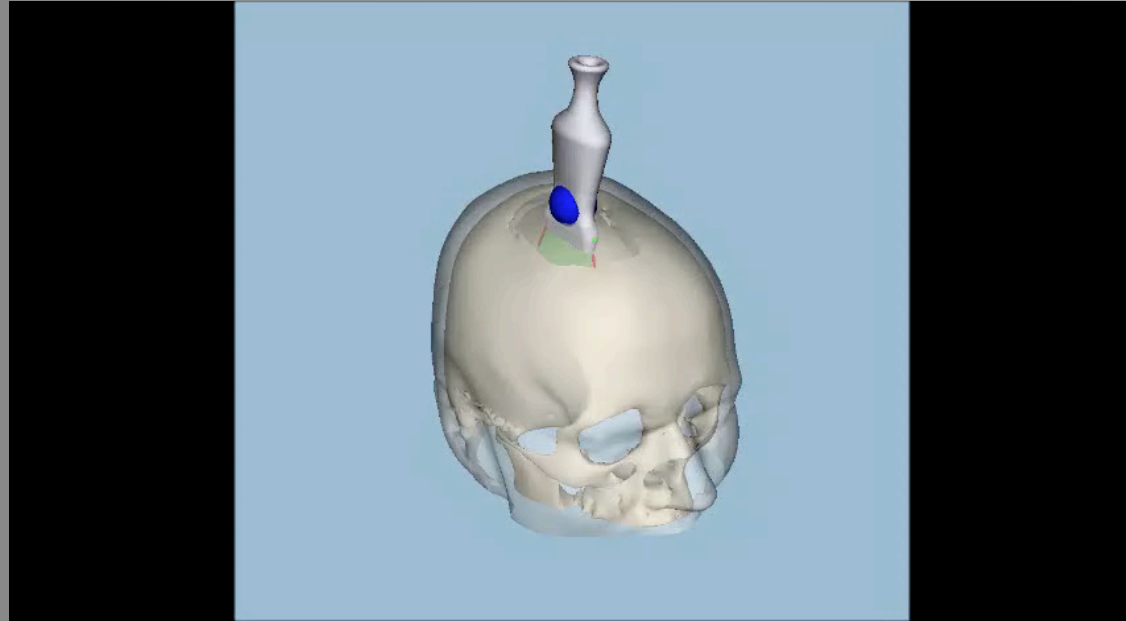
Intraoperative ultrasounds - downsides

- Unusual imaging



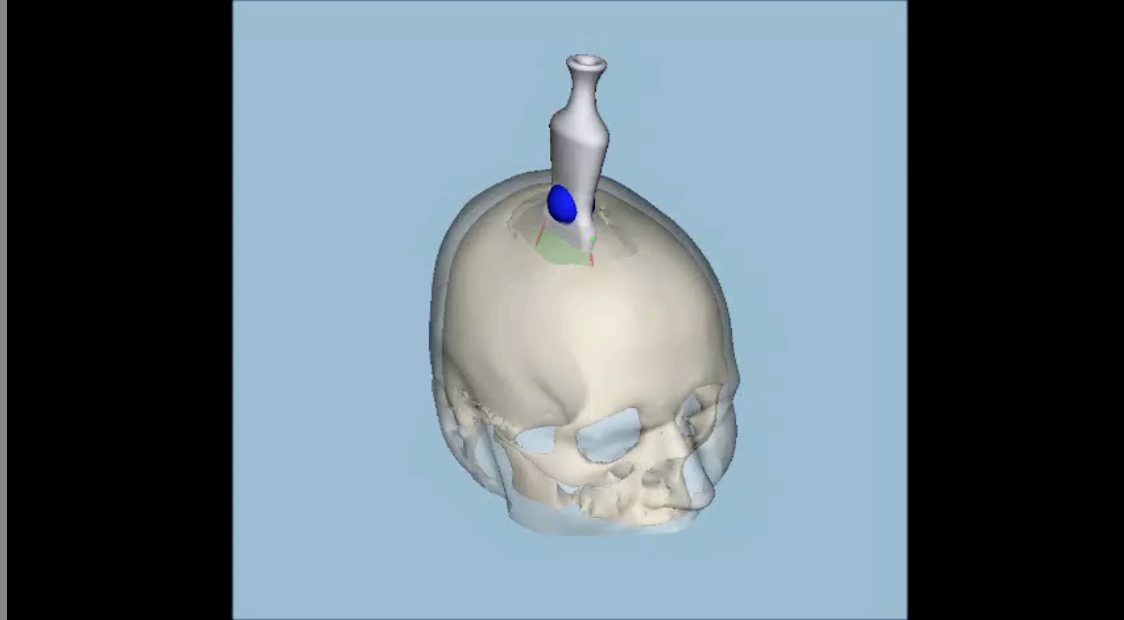
Intraoperative ultrasounds - downsides

- Unusual imaging
- Orientation difficulties



Intraoperative ultrasounds - downsides

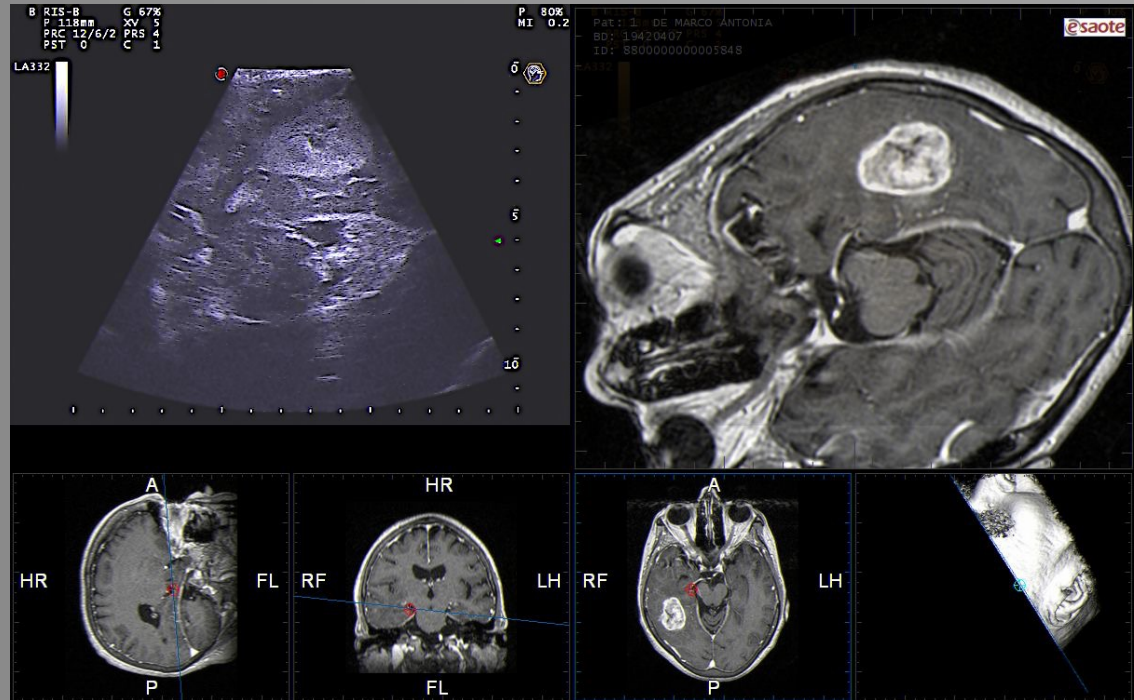
- Unusual imaging
- Orientation difficulties
- Technical artifacts



ioUS - unusual imaging/orientation

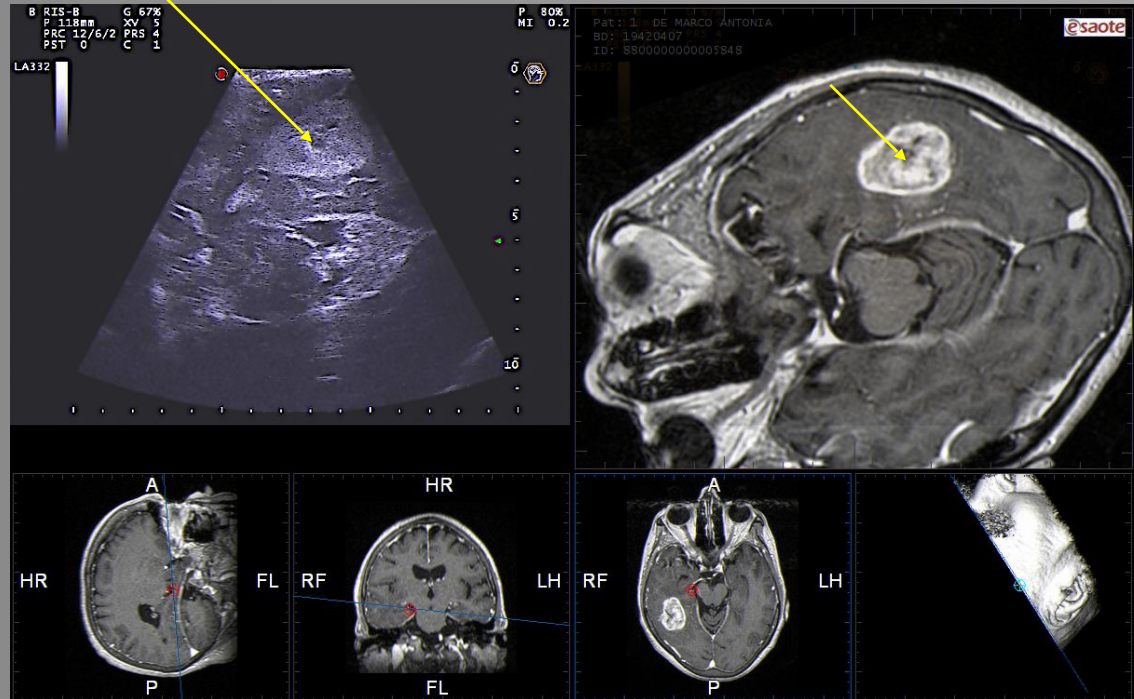


ioUS - unusual imaging/orientation

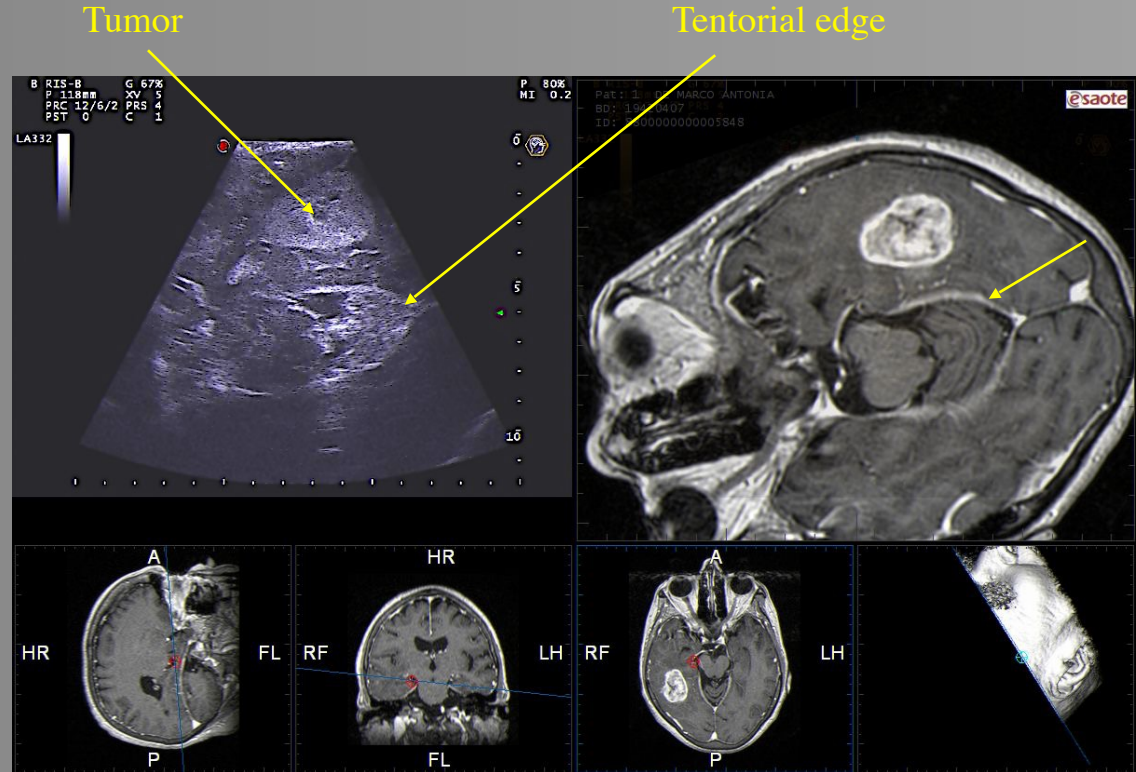


ioUS - unusual imaging/orientation

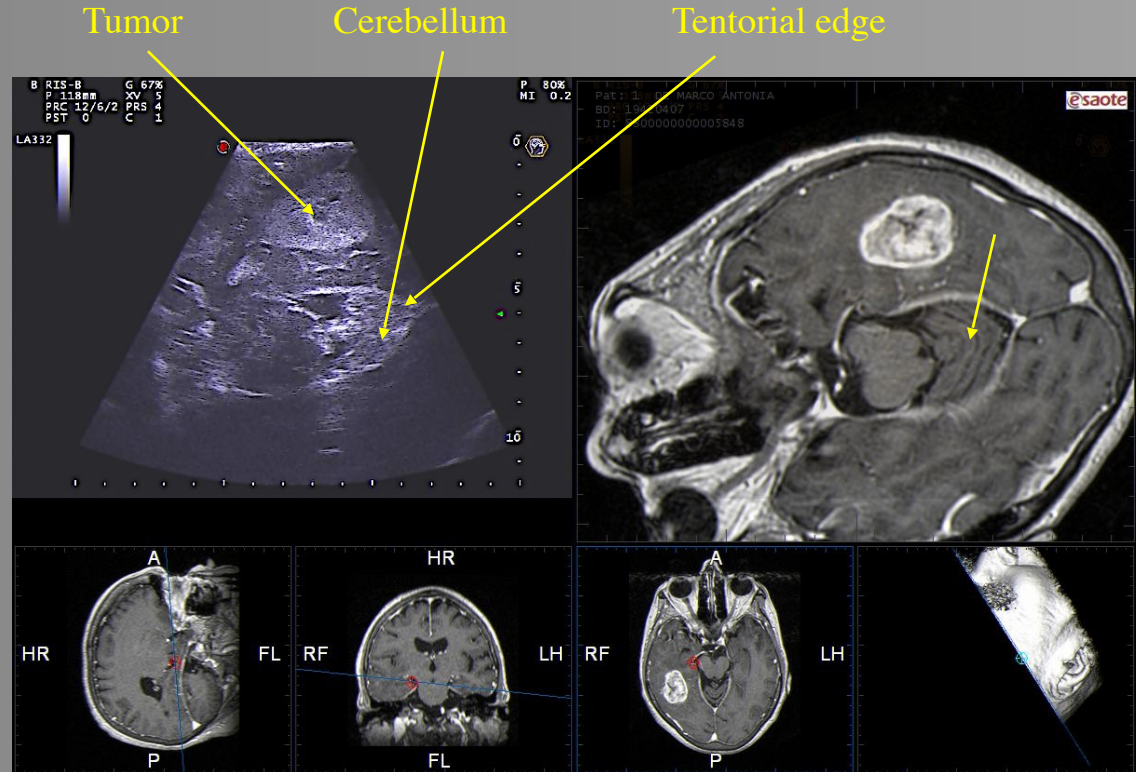
Tumor



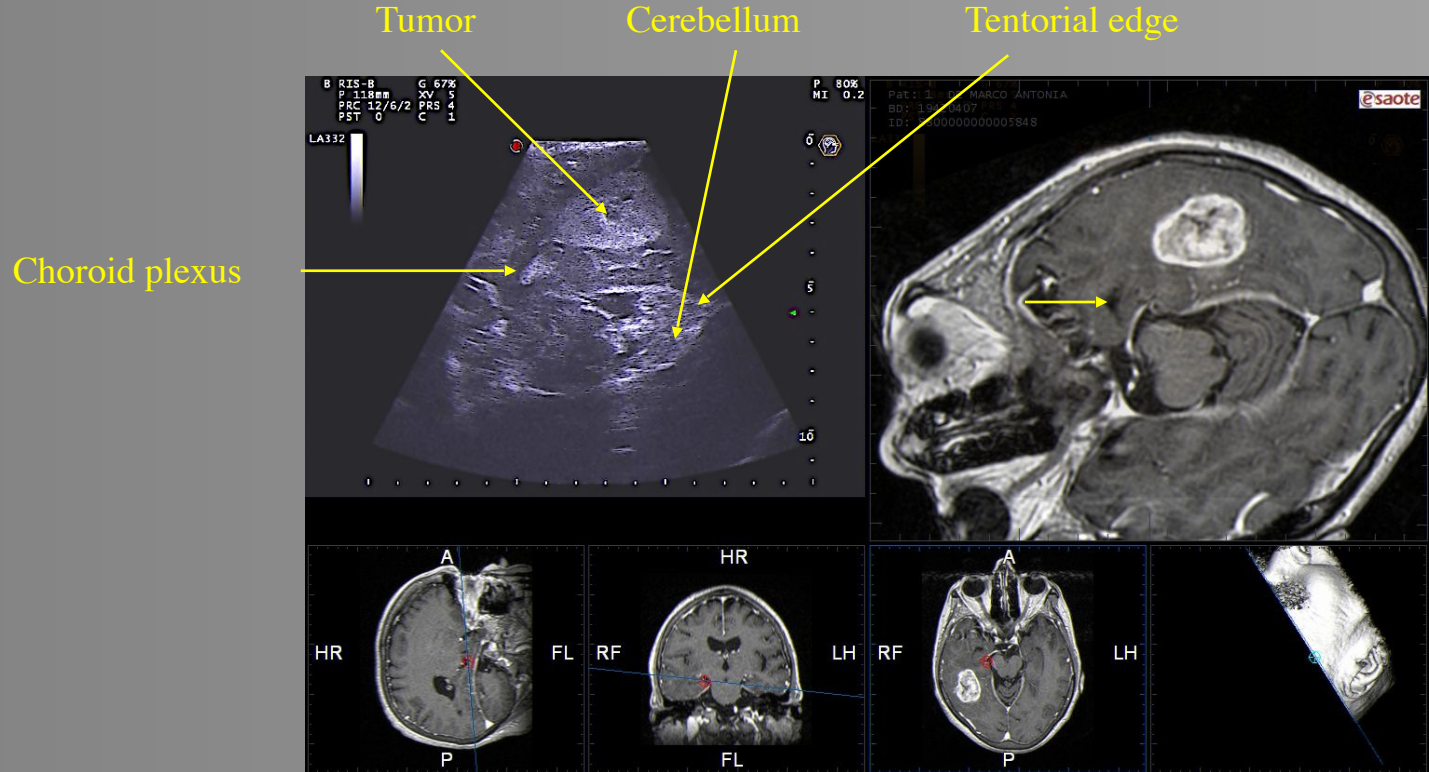
ioUS - unusual imaging/orientation



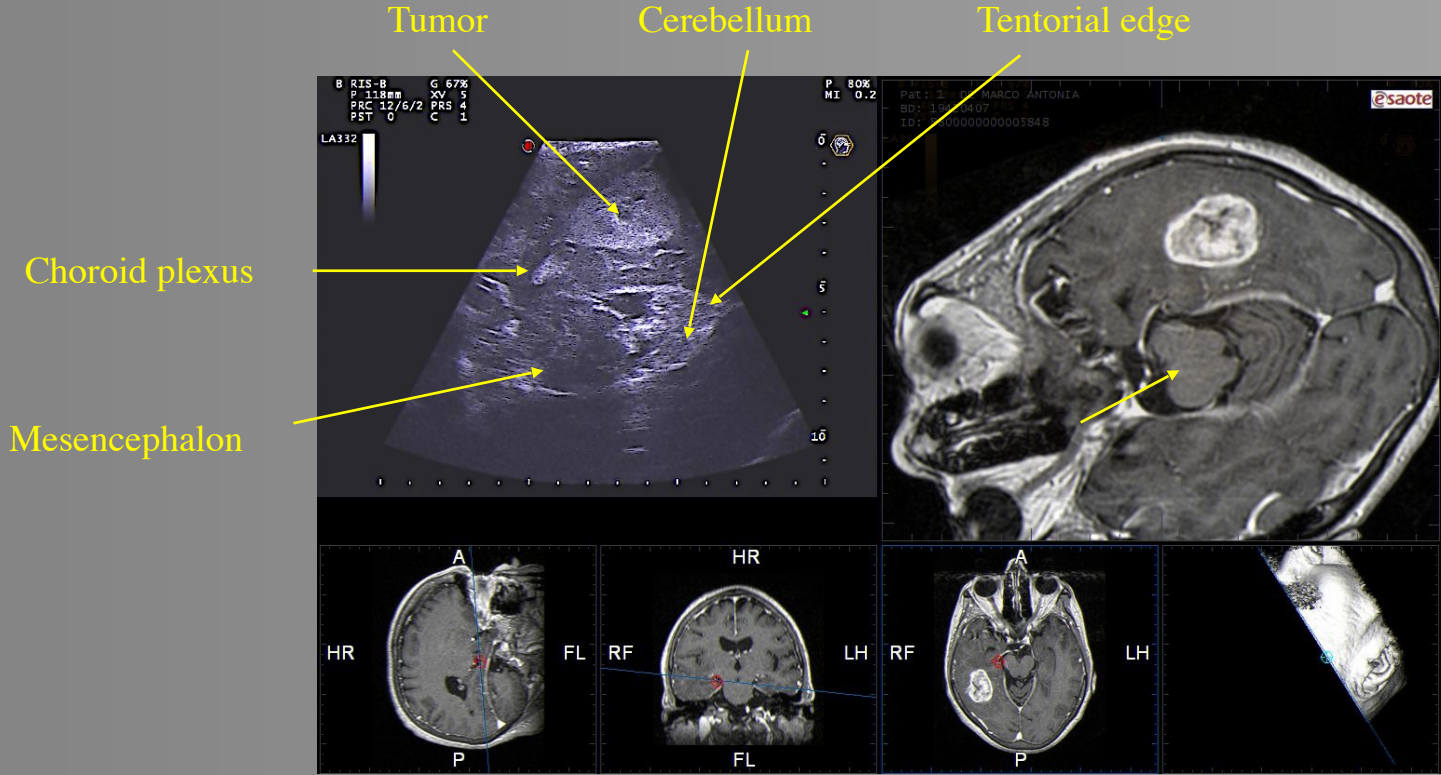
ioUS - unusual imaging/orientation



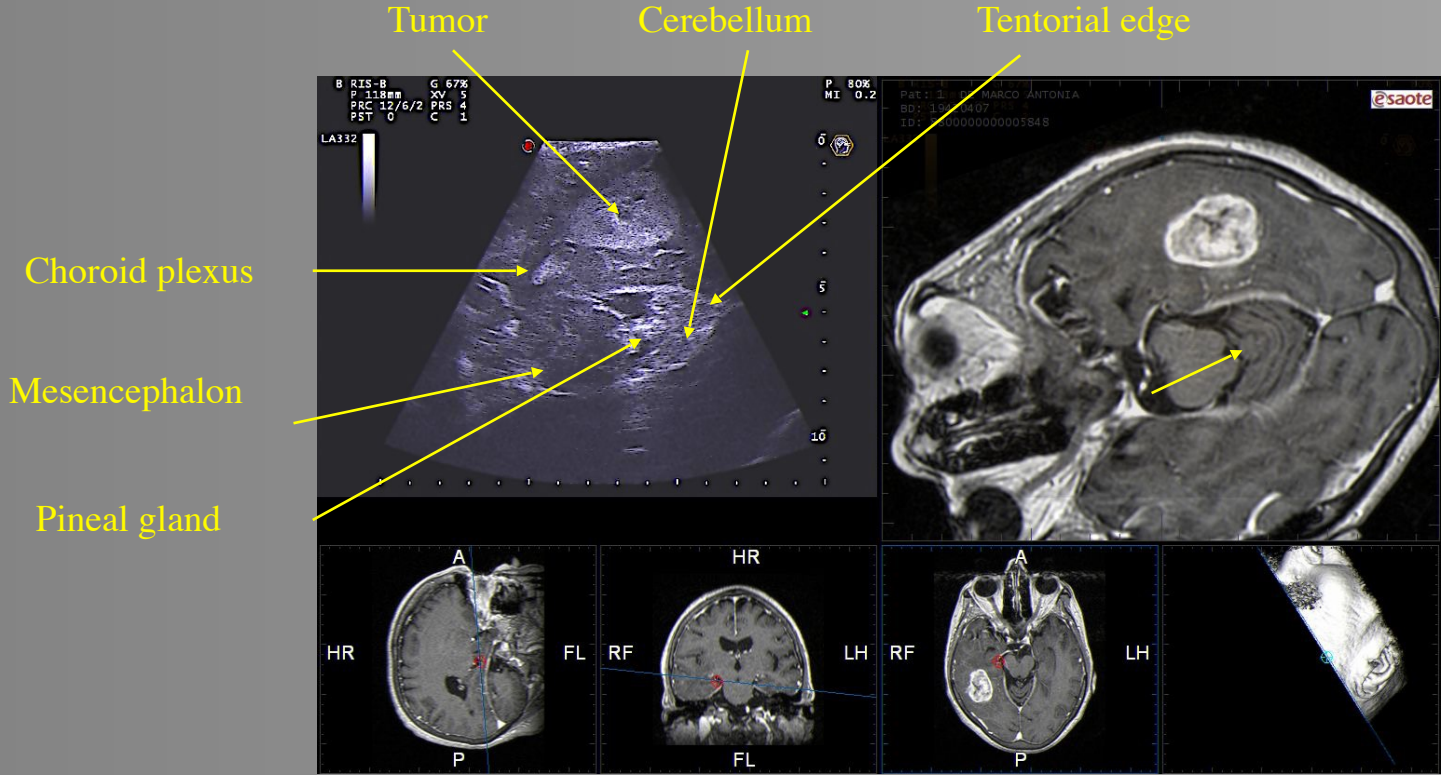
ioUS - unusual imaging/orientation



ioUS - unusual imaging/orientation

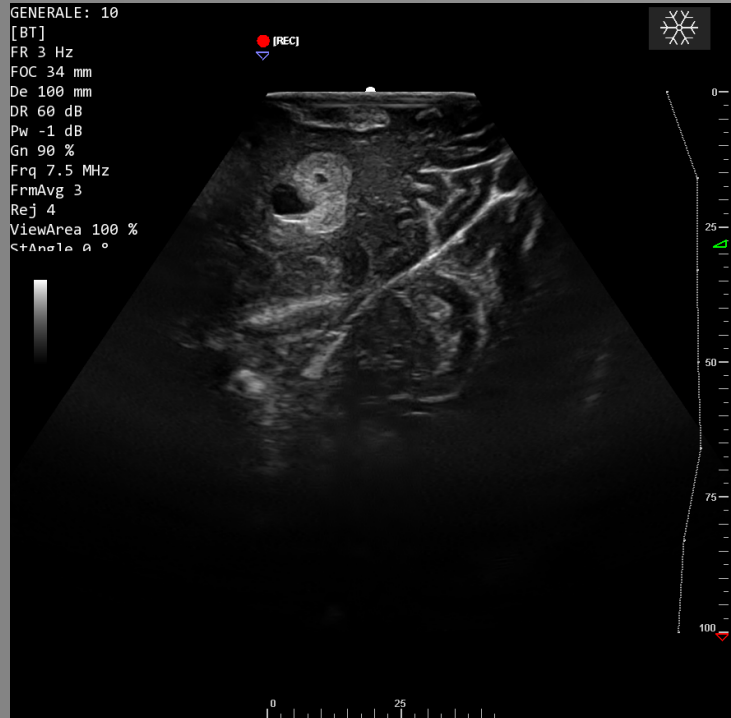


ioUS - unusual imaging/orientation



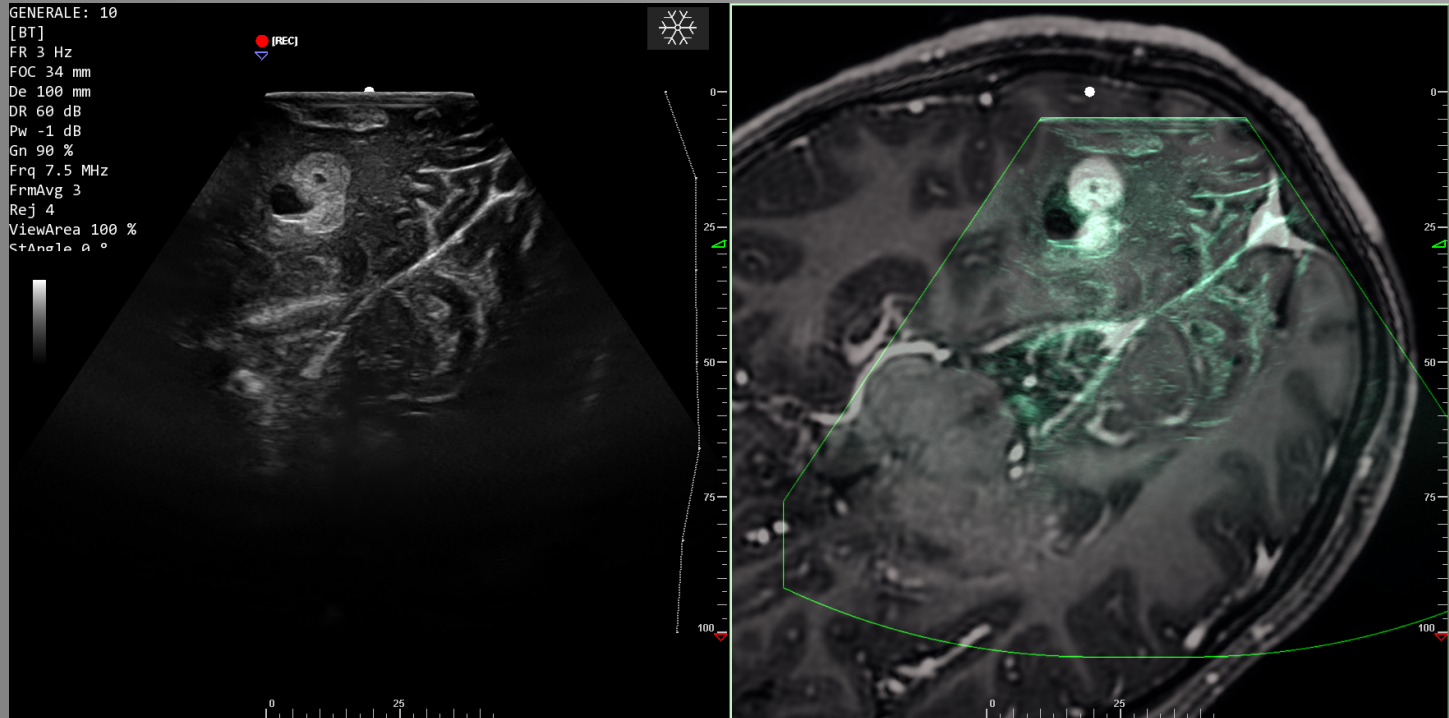
ioUS - unusual imaging/orientation

Real time images for anatomical landmarks identification



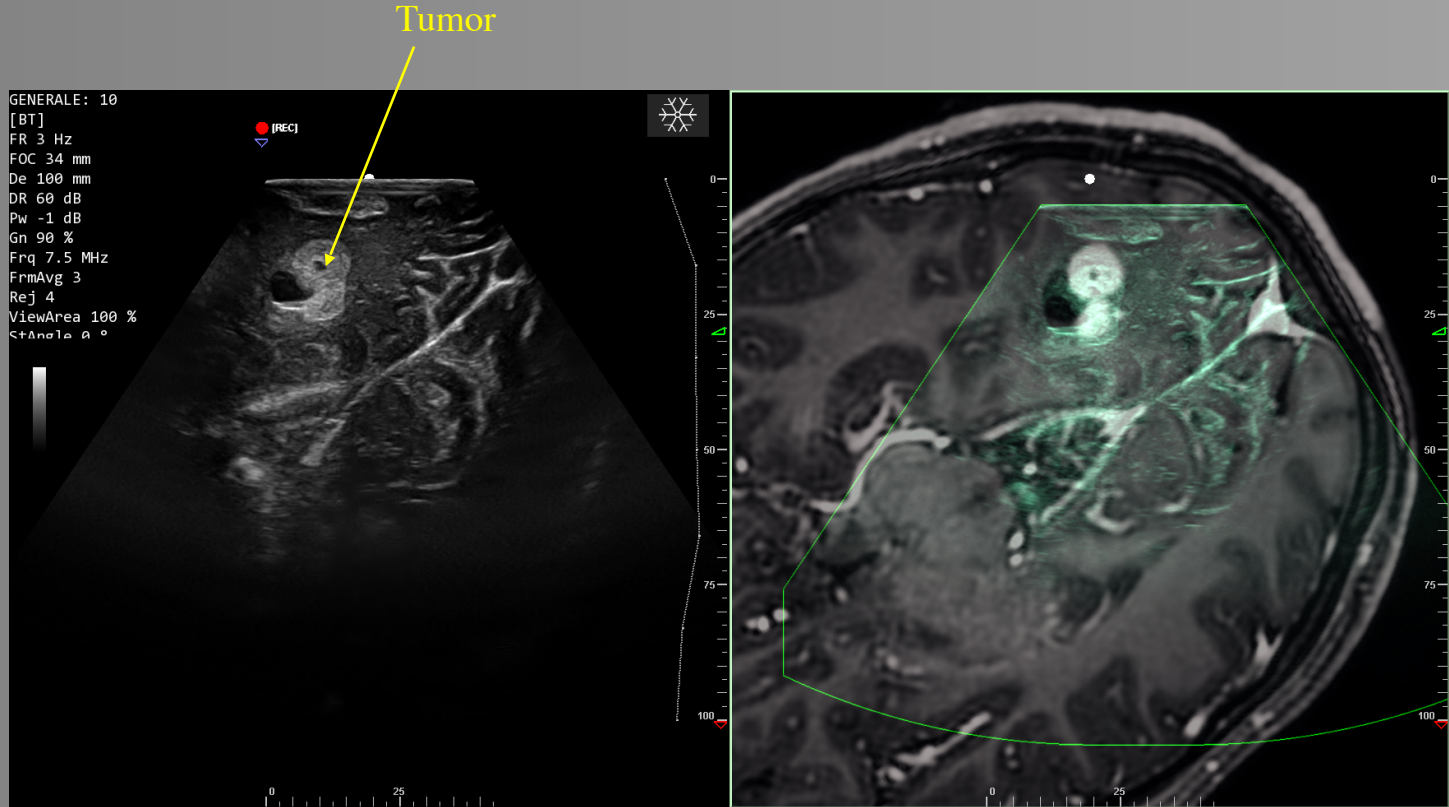
ioUS - unusual imaging/orientation

Real time images for anatomical landmarks identification



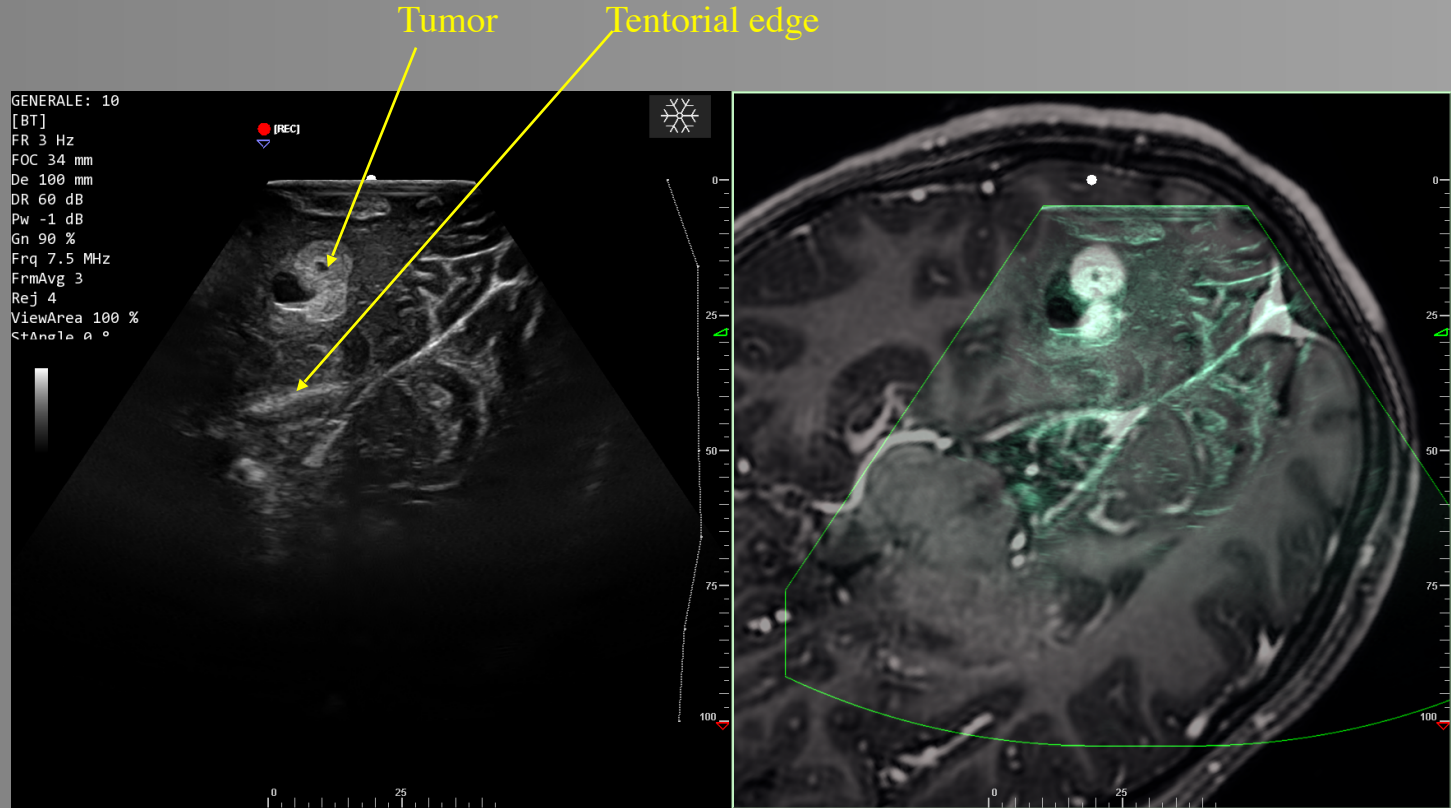
ioUS - unusual imaging/orientation

Anatomical landmarks identification



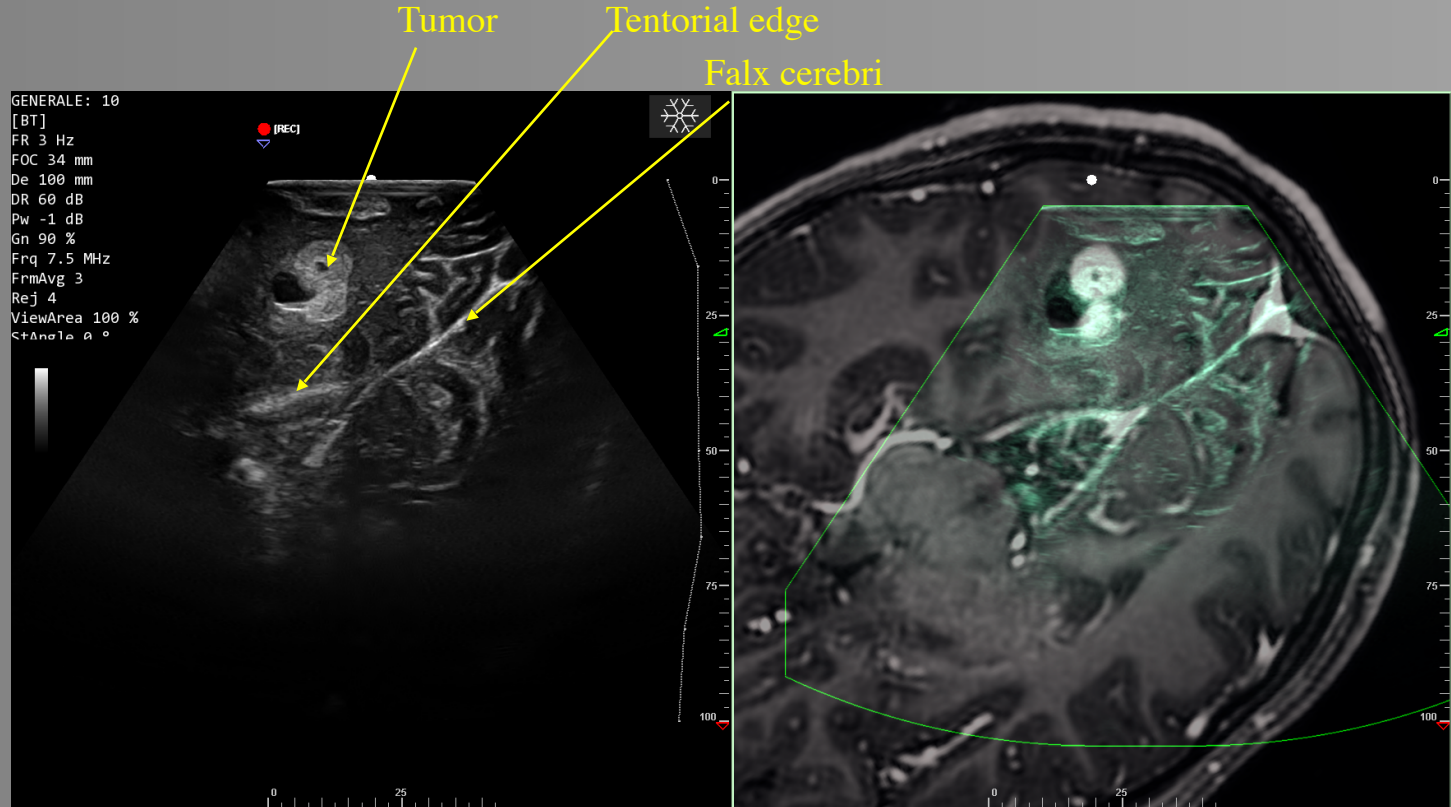
ioUS - unusual imaging/orientation

Anatomical landmarks identification



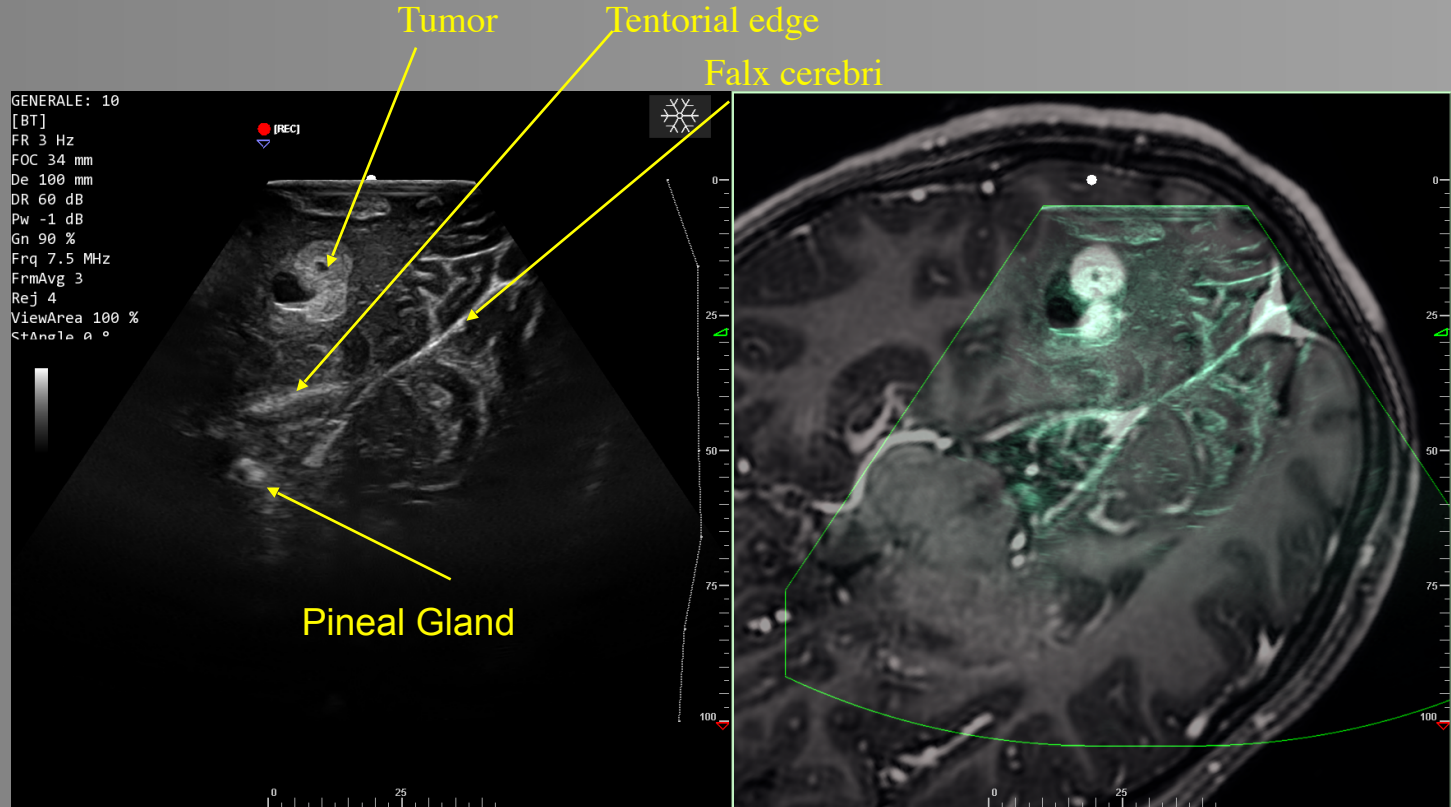
ioUS - unusual imaging/orientation

Anatomical landmarks identification



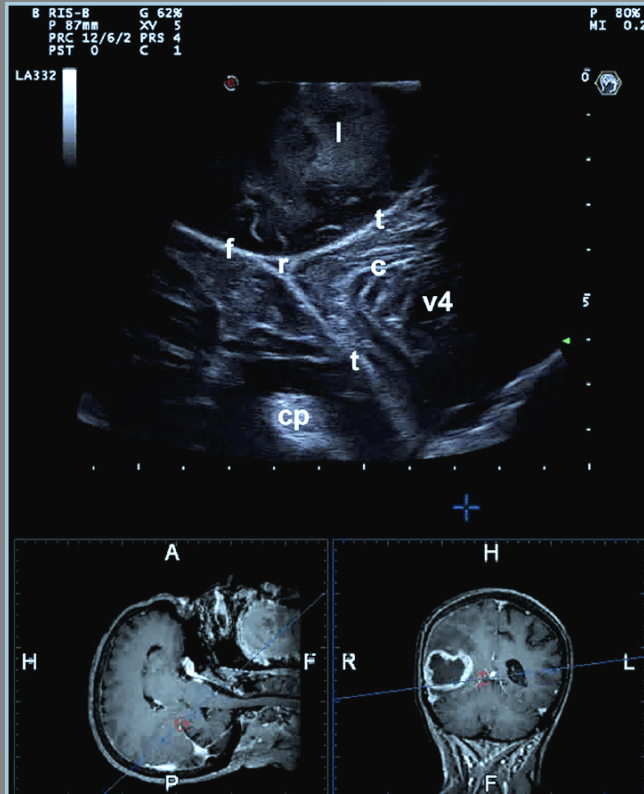
ioUS - unusual imaging/orientation

Real time images for anatomical landmarks identification



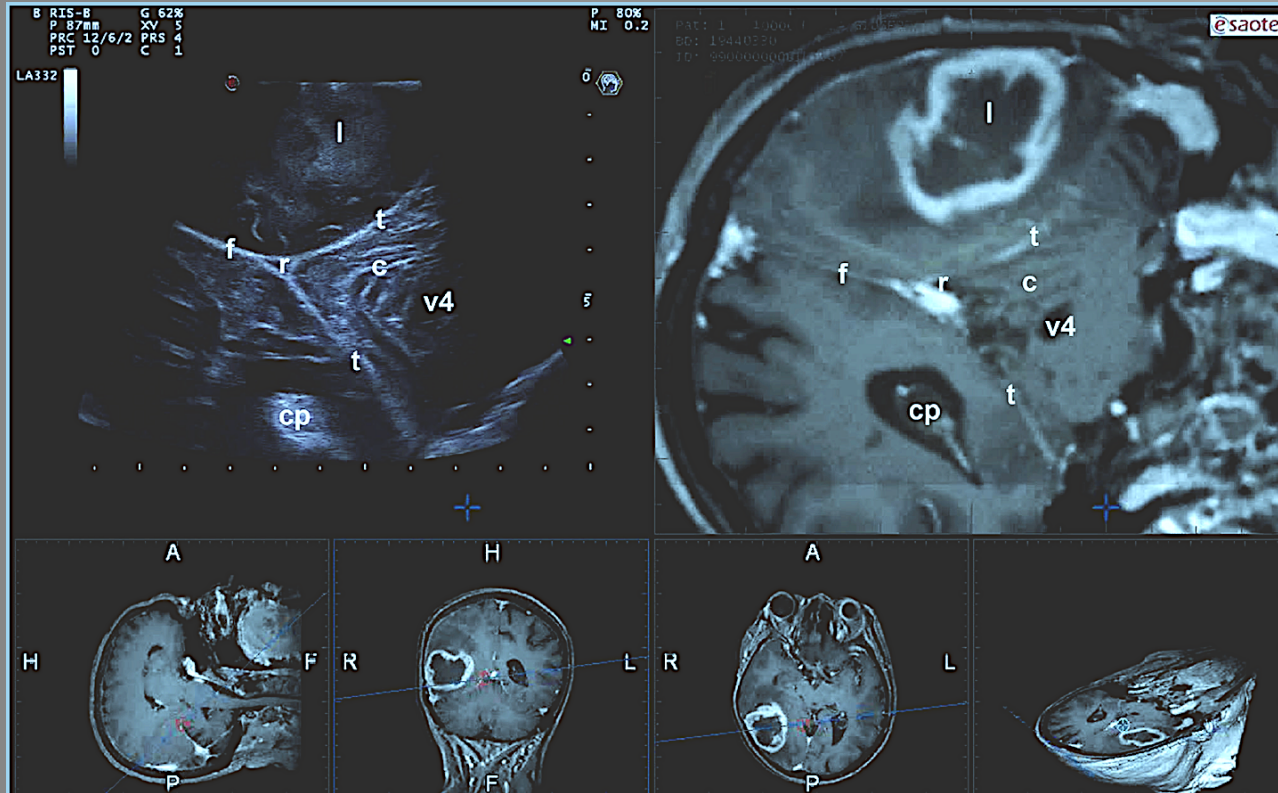
ioUS - unusual imaging/orientation

Anatomical landmarks identification

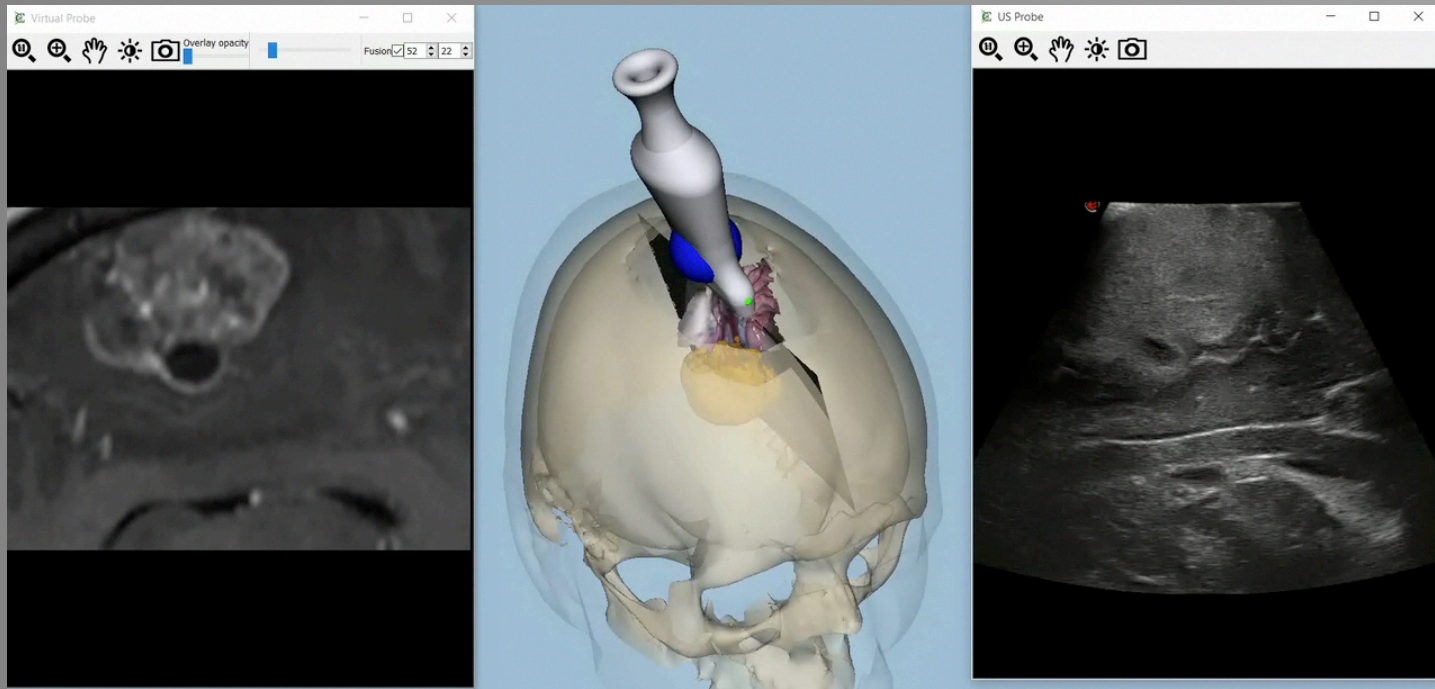


ioUS - unusual imaging/orientation

Anatomical landmarks identification



Integrated Intra-operative MR/US neuronavigation



Integrated Intra-operative MR/US neuronavigation

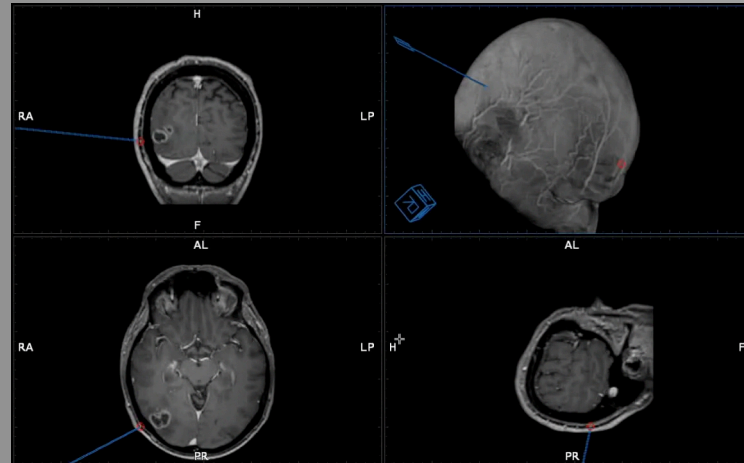


Surgical planning

Probe tracking

Preop MRI and US imaging fusion

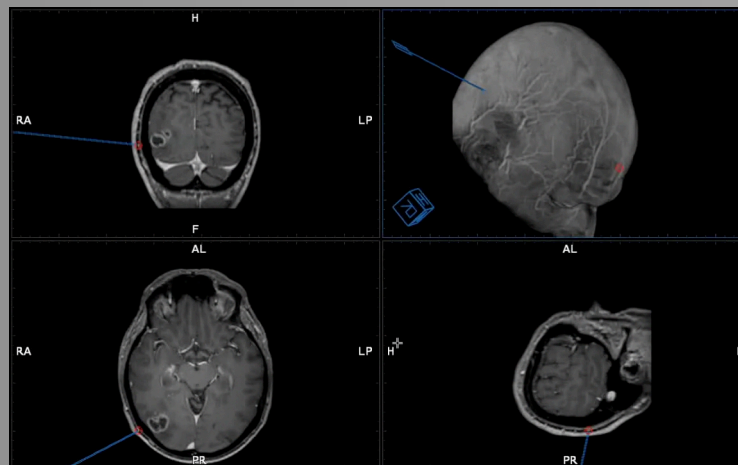
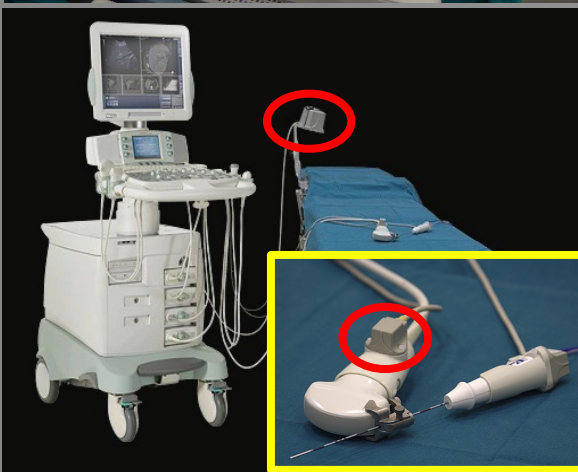
Real-time intraop navigation



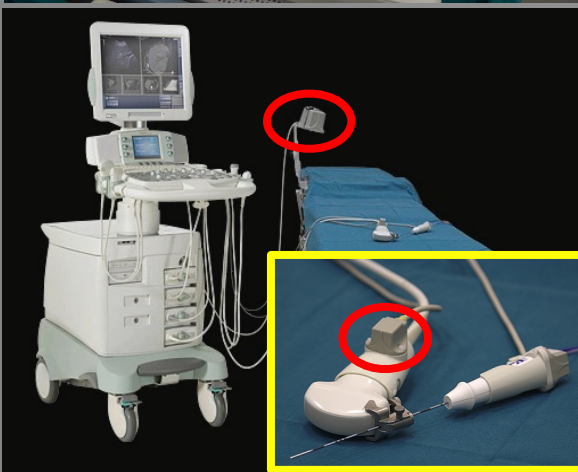
Integrated Intra-operative MR/US

Validation study:

41 gliomas
8 metastases
6 meningiomas
2 cavernomas
1 ependymoma

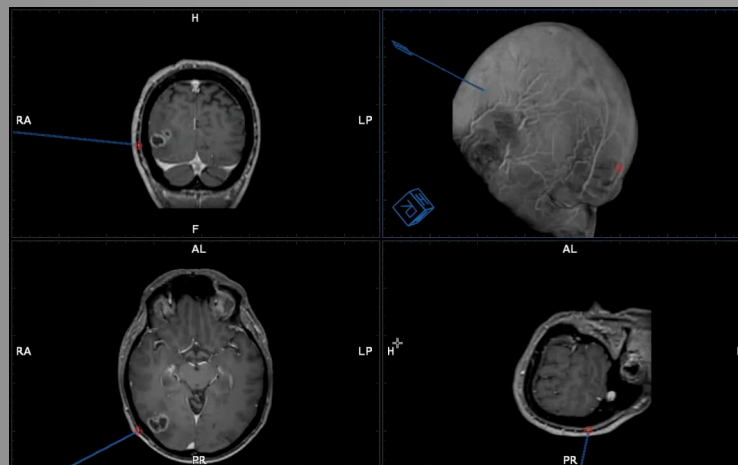


Integrated Intra-operative MR/US



Validation study:

- ✓ Registration error $< 2\text{mm}$
- ✓ Initial brain shift in all cases
- ✓ $> 4\text{ mm}$ in 48 cases



Integrated Intra-operative MR/US neuronavigation



Integrated Intra-operative MR/US neuronavigation



Validation study:

24 gliomas

3 metastases

11 meningiomas

1 radionecrosis



Integrated Intra-operative MR/US neuronavigation



Validation study:

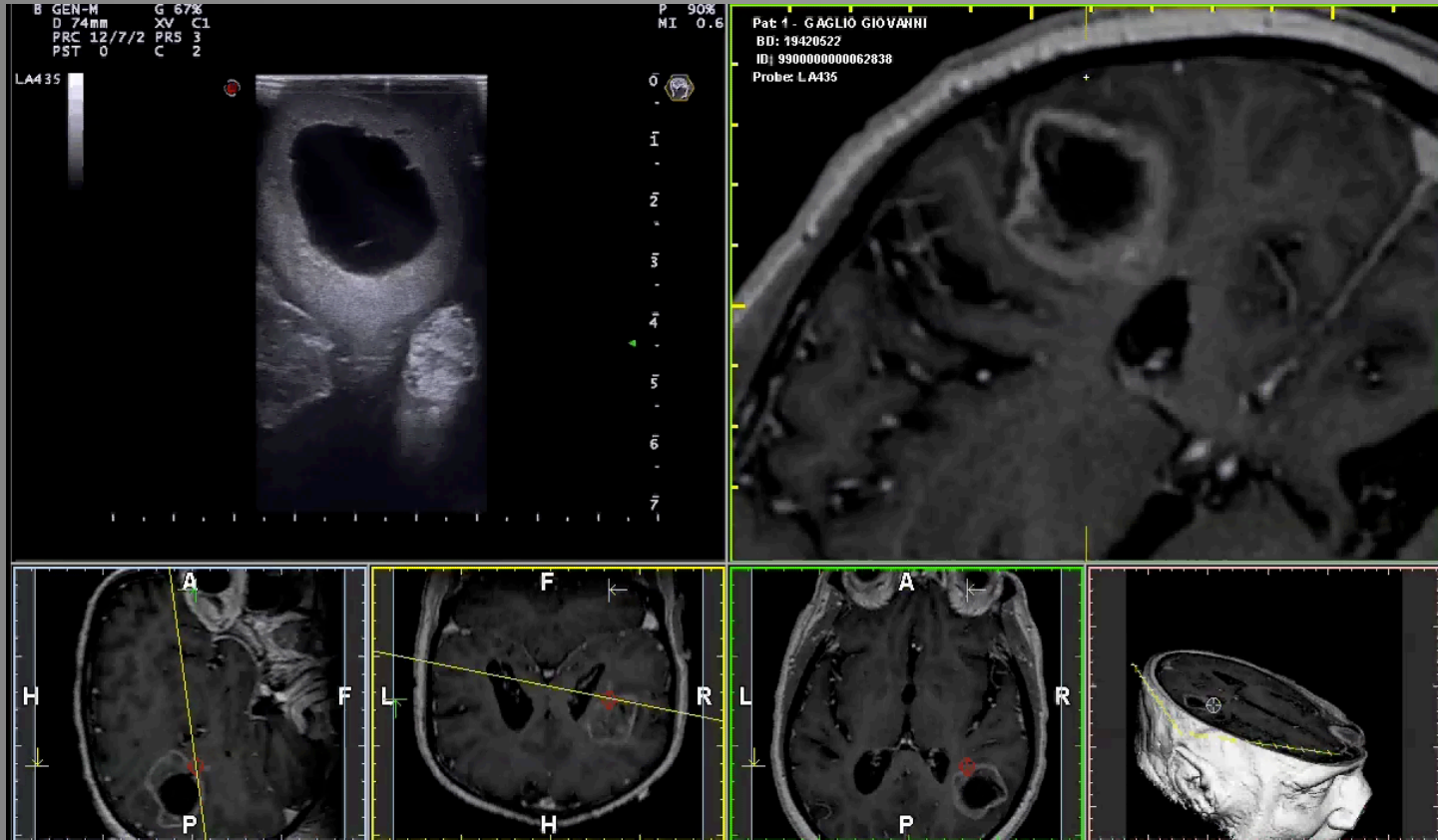
Registration error: $< 1\text{mm}$

Error after craniotomy: 2.5 mm

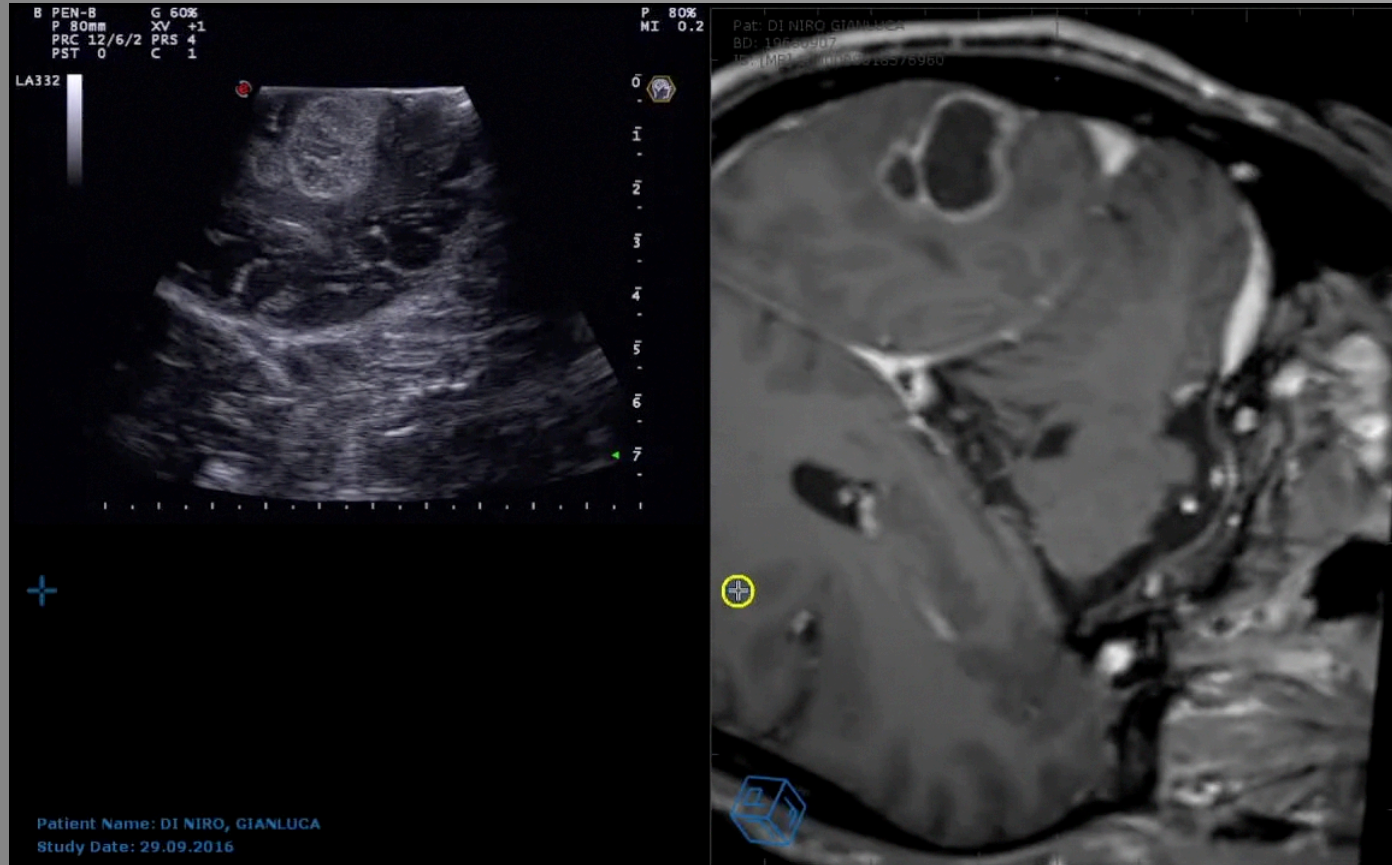
Brain shift after dural opening: 5 mm



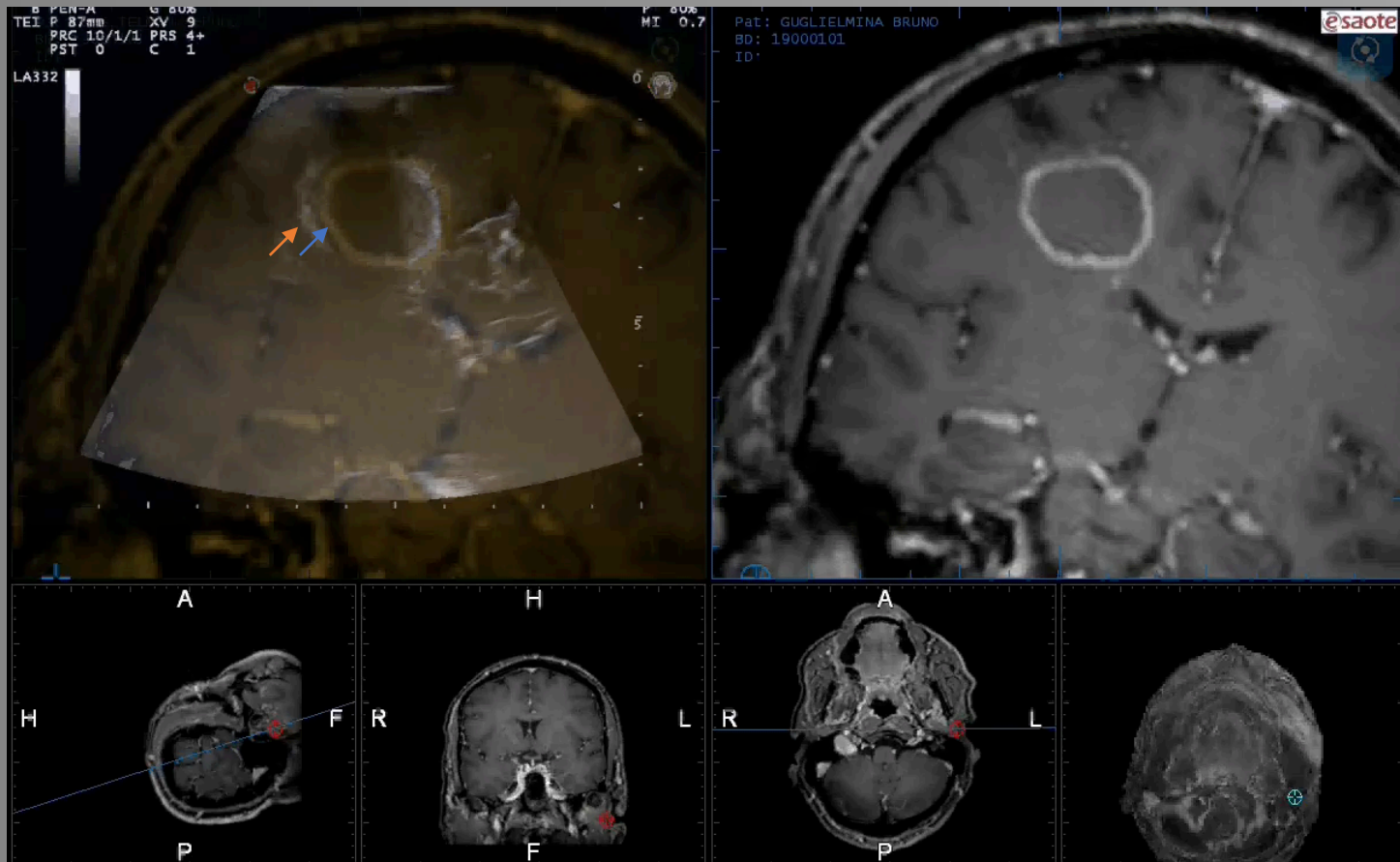
Integrated Intraoperative MR/US neuronavigation



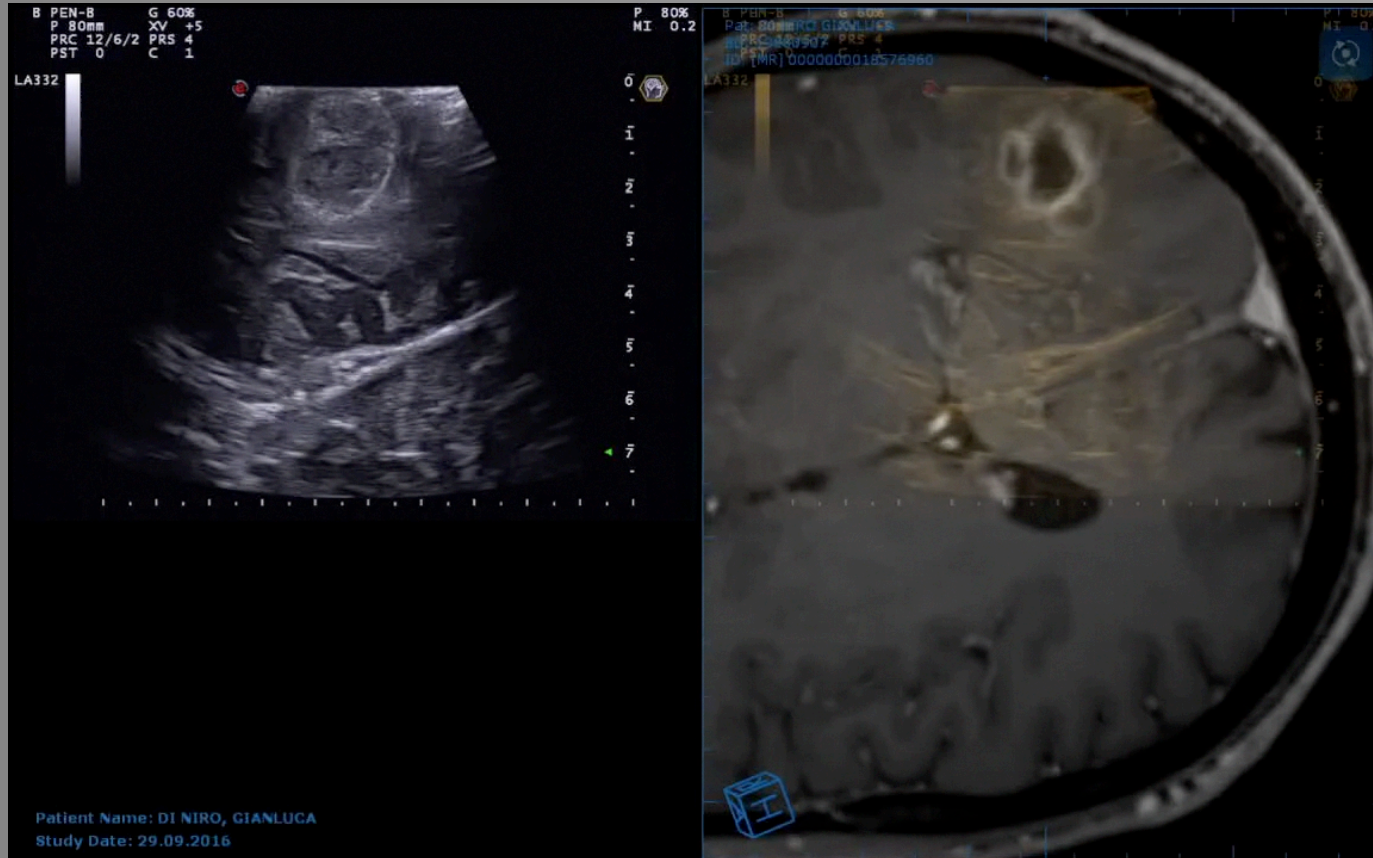
Integrated Intraoperative MR/US neuronavigation



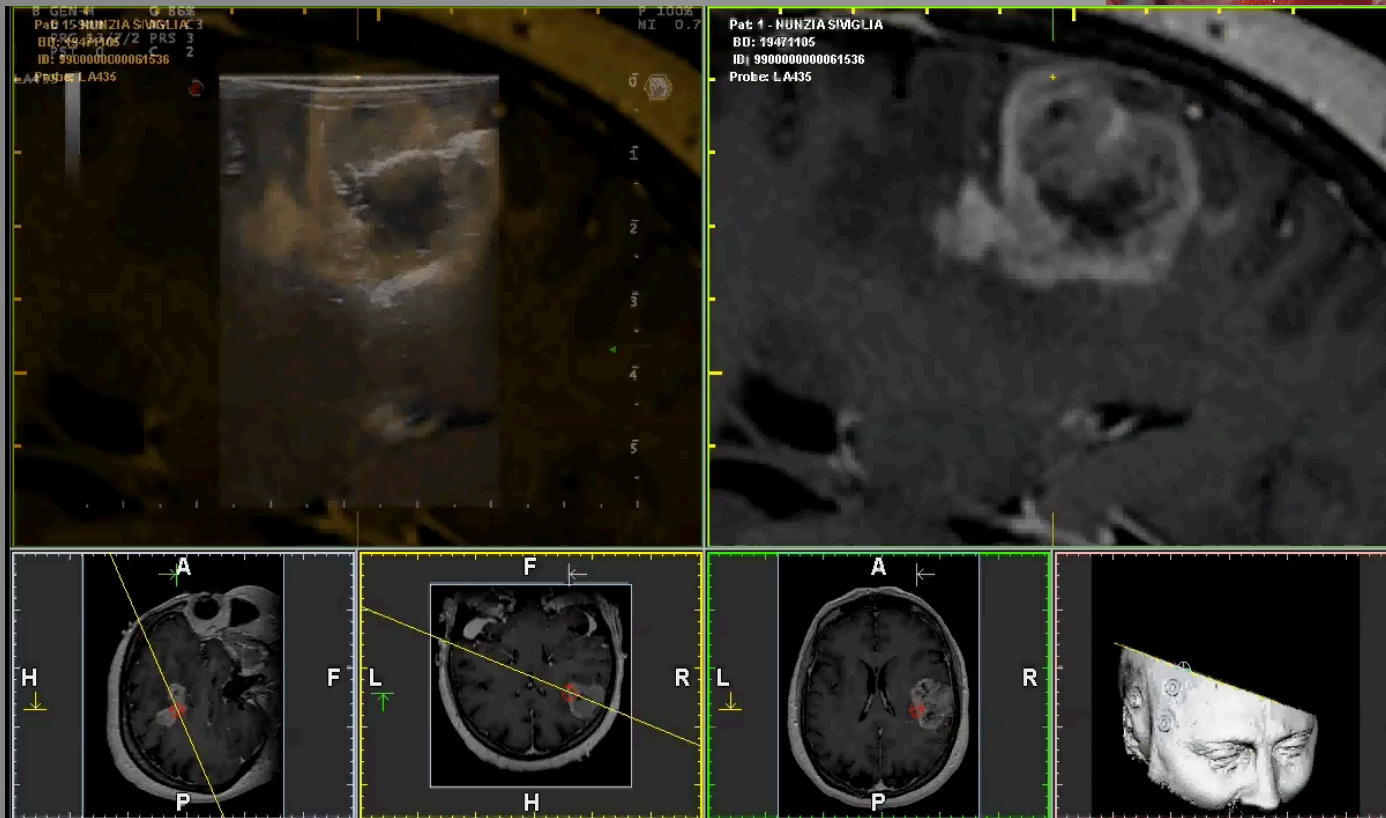
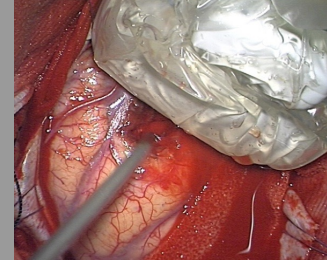
Brain shift correction



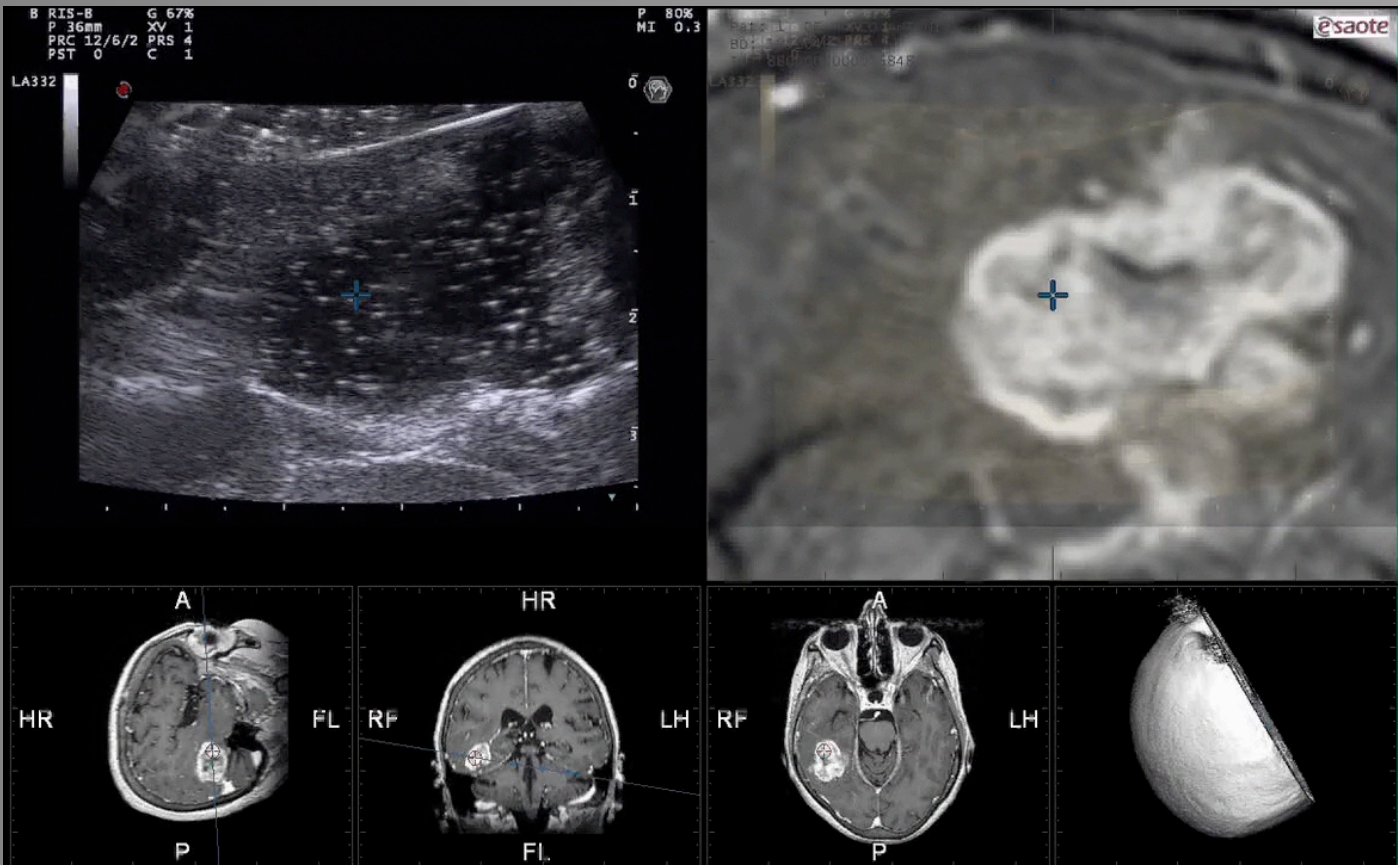
Brain shift correction



Resection control



Resection control



ioUS drawback: technical artifacts

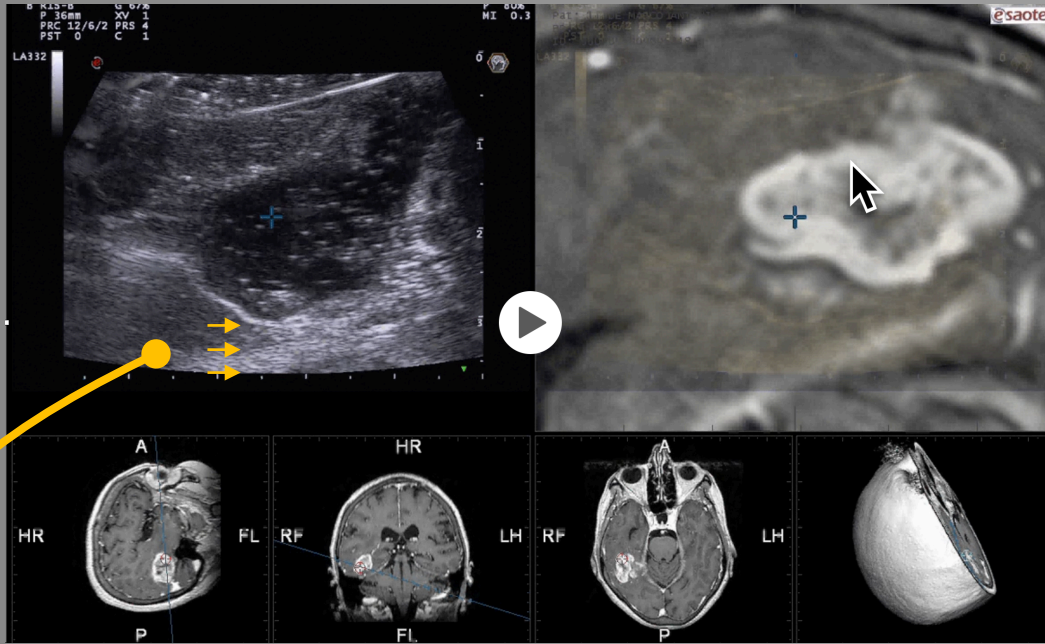
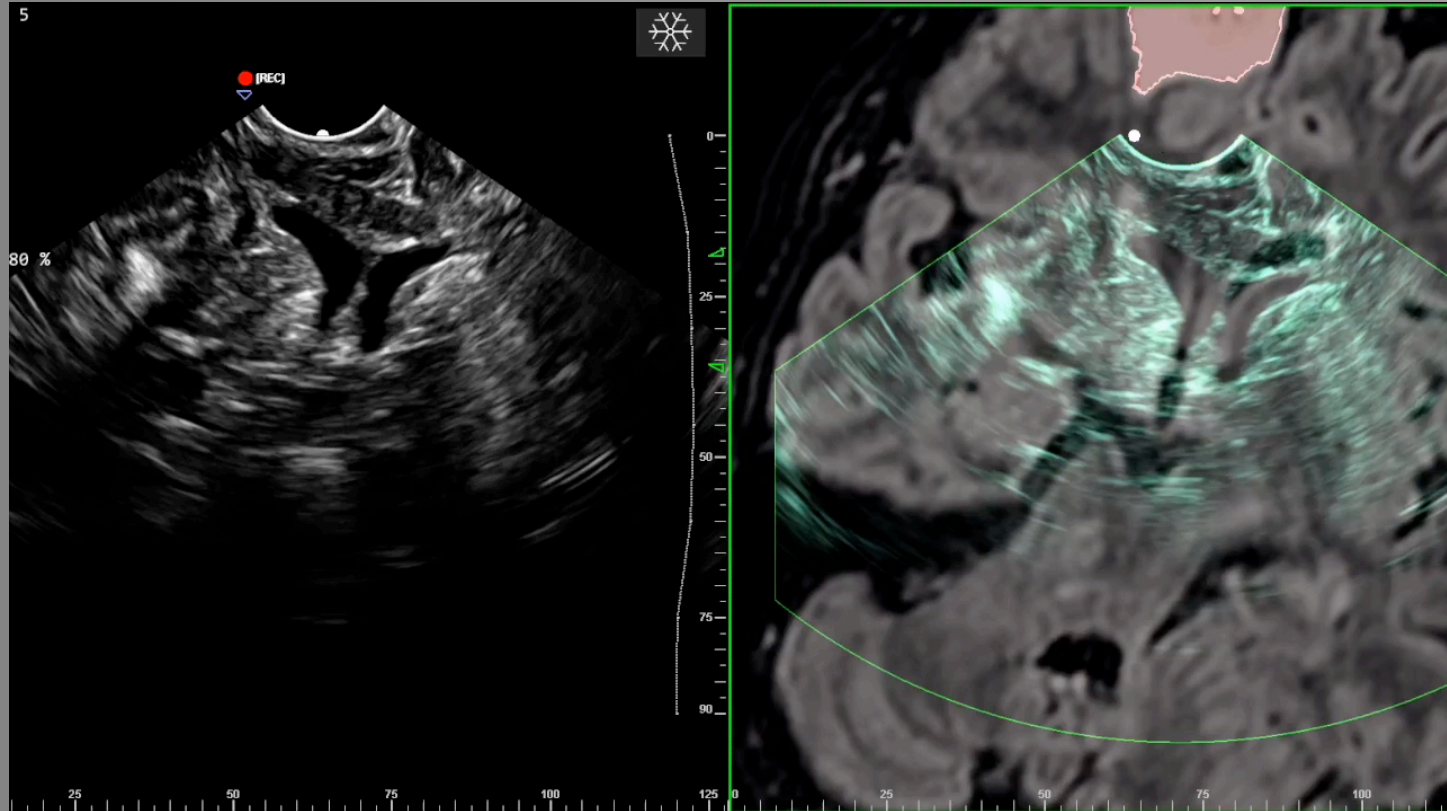


Image artifacts due to the acoustic properties of saline

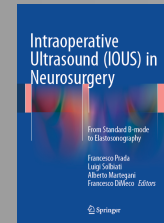
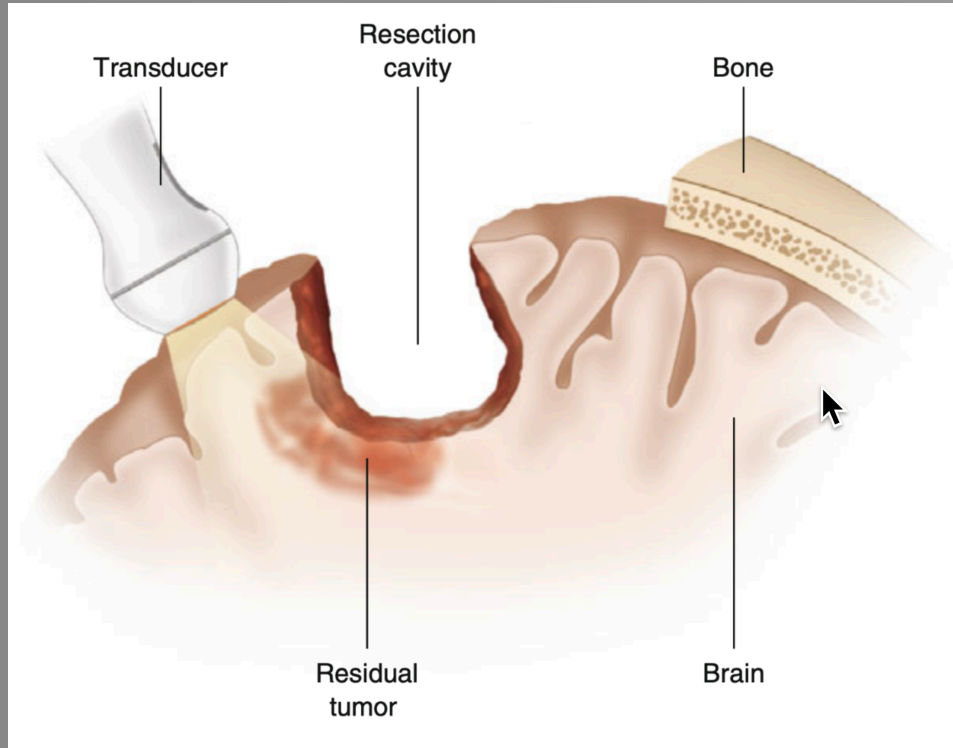
Solution #1

smaller probe at the bottom of the cavity



Solution #2

probe orientation avoiding the saline/brain interface

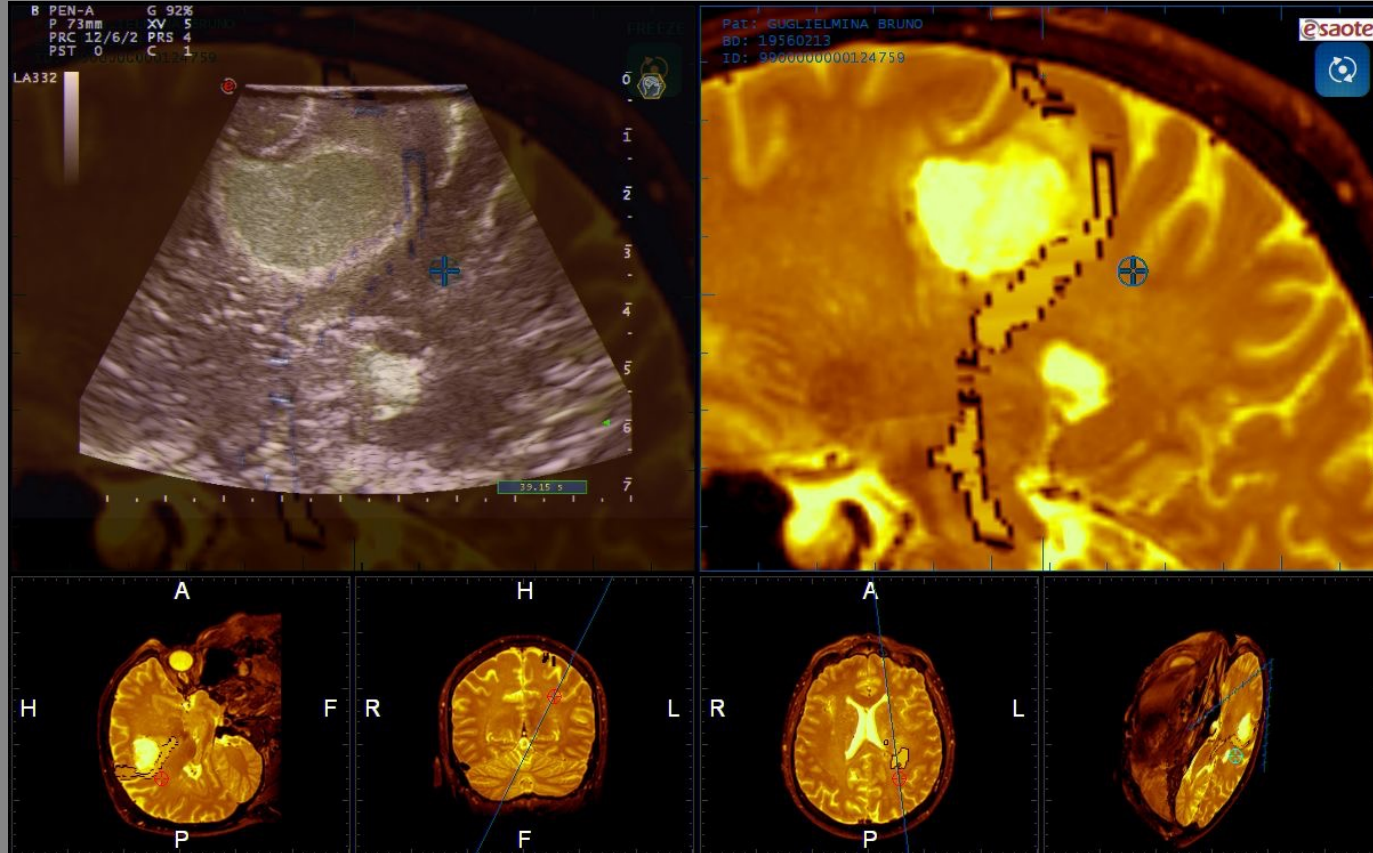


Coburger, et al.

Solution #3

Fluids with acoustic properties coupling with brain parenchyma are currently under evaluation

US – MR DTI integrated neuronavigation

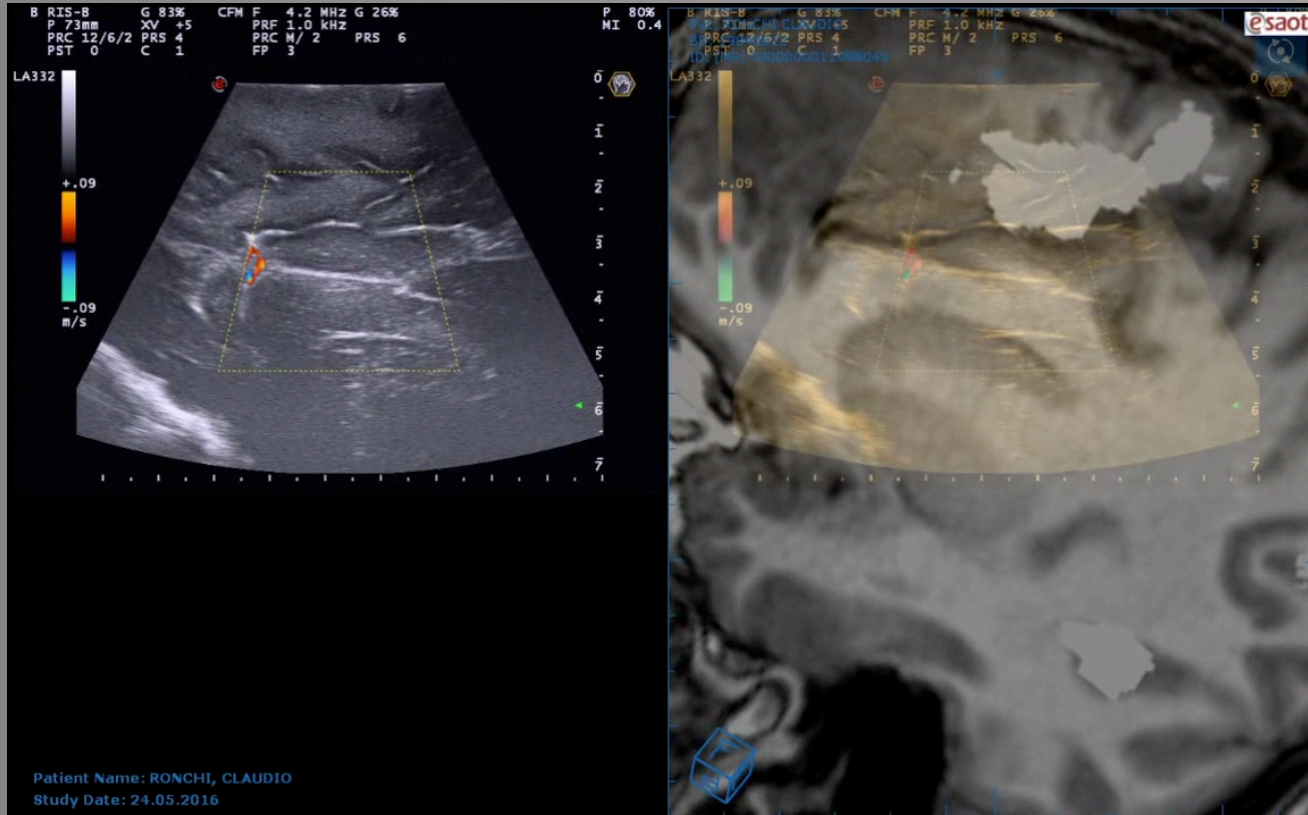


ioUS - Additional Features

- Doppler
- Elastosonography
- Contrast-enhanced Ultra-Sound (CEUS)

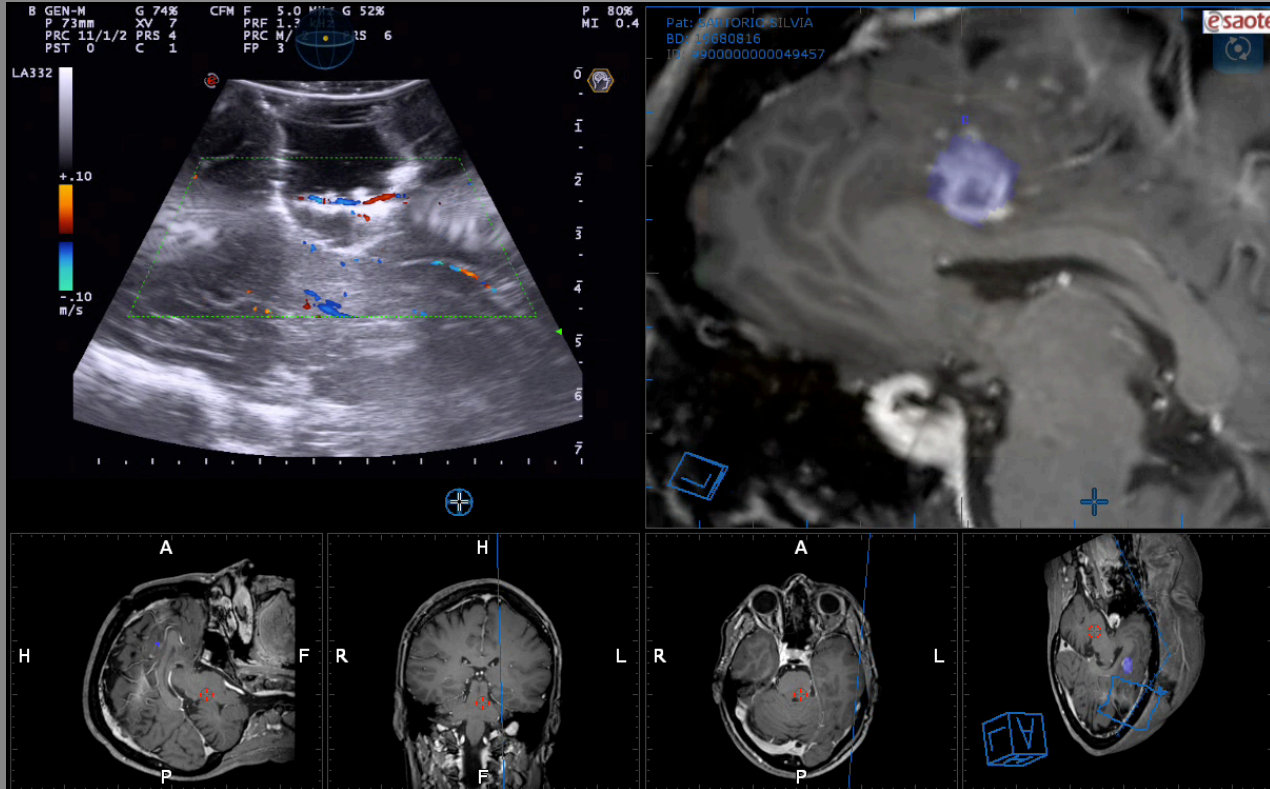
ioUS - Additional Features

1 - Doppler



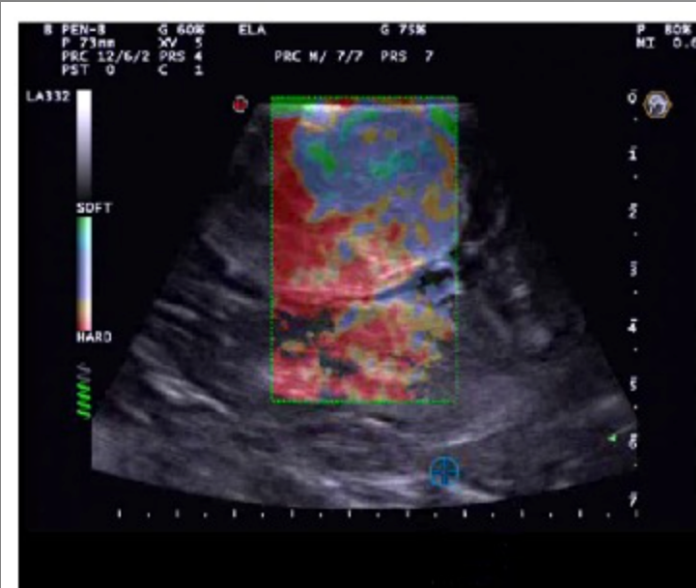
ioUS - Additional Features

1 - Doppler

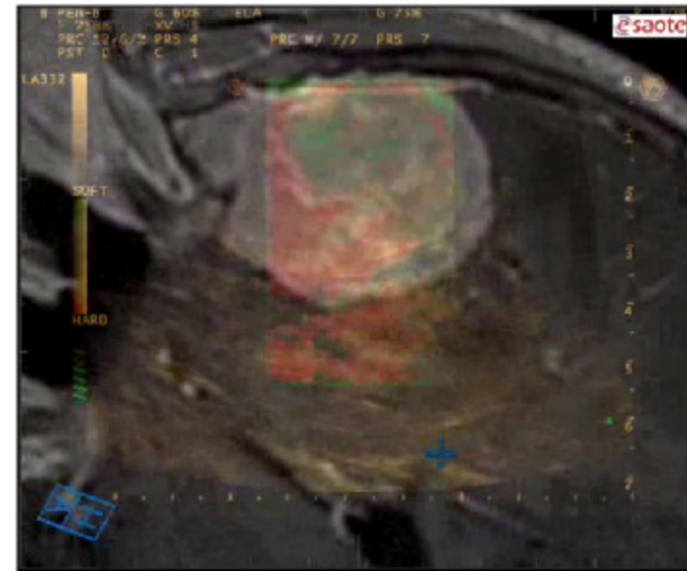


ioUS - Additional Features

2 - Elastosonography



(a)



(b)

[Biomed Res Int. 2015;2015:925729. doi: 10.1155/2015/925729.](https://doi.org/10.1155/2015/925729) Epub 2015 May 25.

From Grey Scale B-Mode to Elastosonography: Multimodal Ultrasound Imaging in Meningioma Surgery-Pictorial Essay and Literature Review.

Prada F¹, Del Bene M¹, Moiraghi A², Casali C¹, Legnani FG¹, Saladino A¹, Perin A¹, Vetrano IG², Mattei L², Richetta C², Saini M¹, DiMeco F³.

ioUS - Additional Features

3 - CEUS

- Enhancing anatomical landmarks
- Hints about histology
- Angiosonography
- Identifying tumor remnants
- BBB disruption

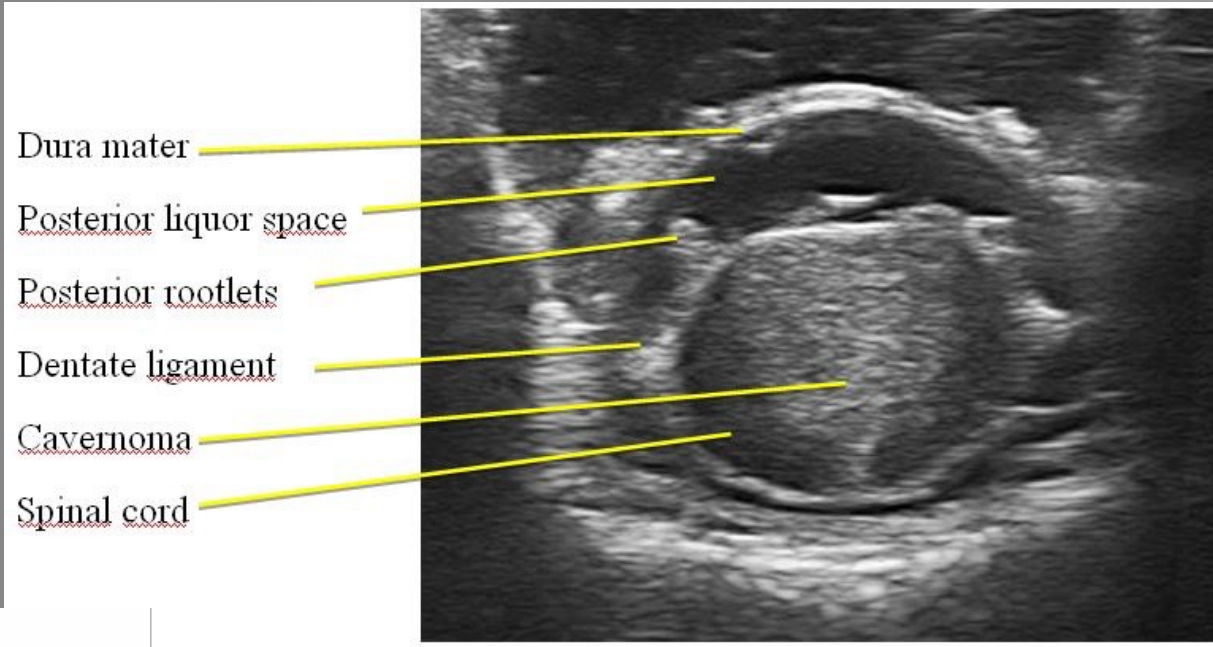
ioUS - Not only Brain!

Spine

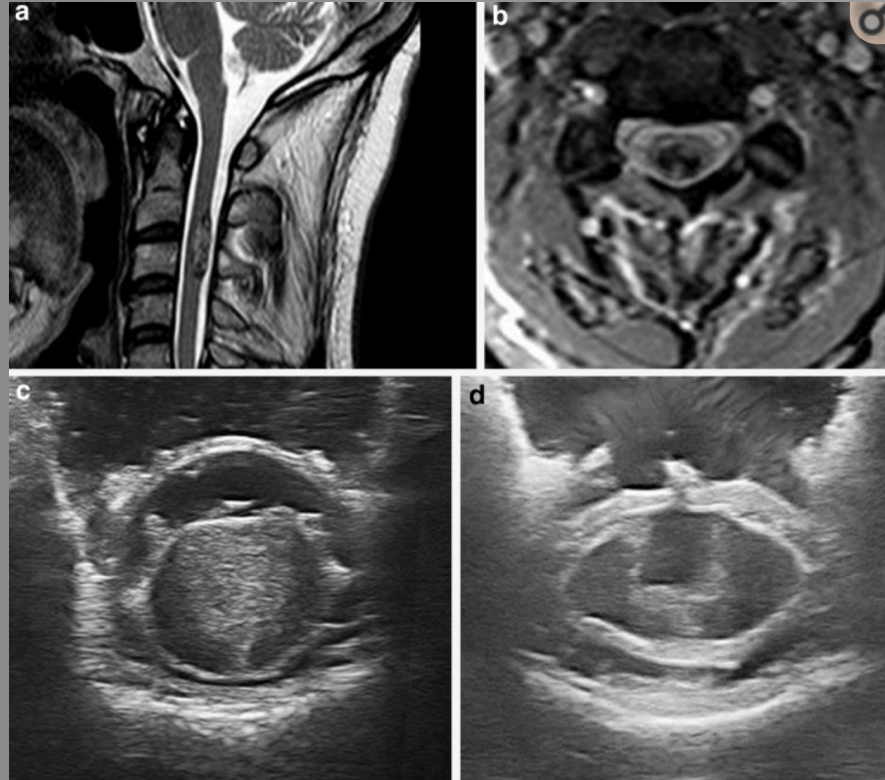
Intramedullary Cavernoma



Intramedullary Cavernoma

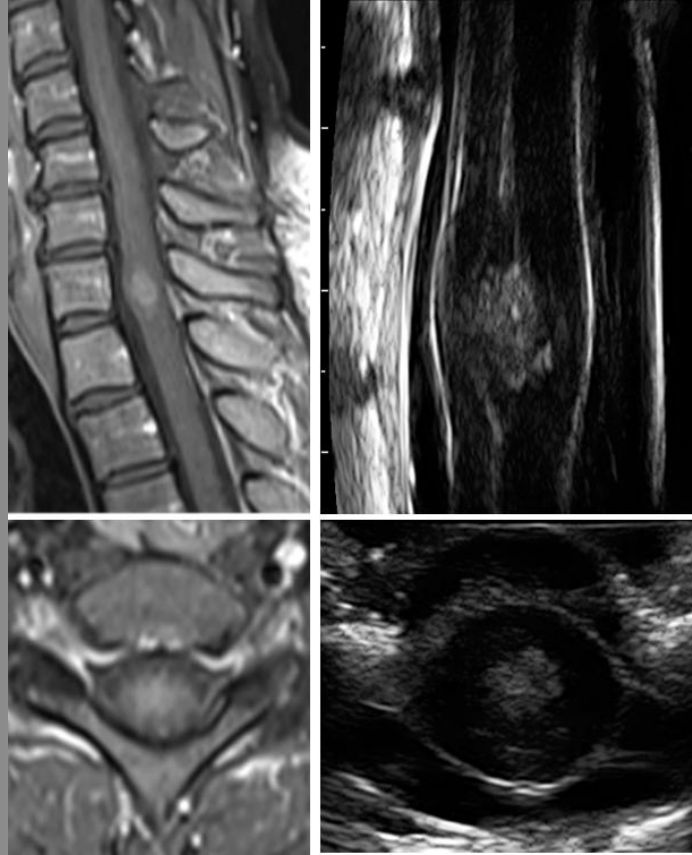


Intramedullary Cavernoma

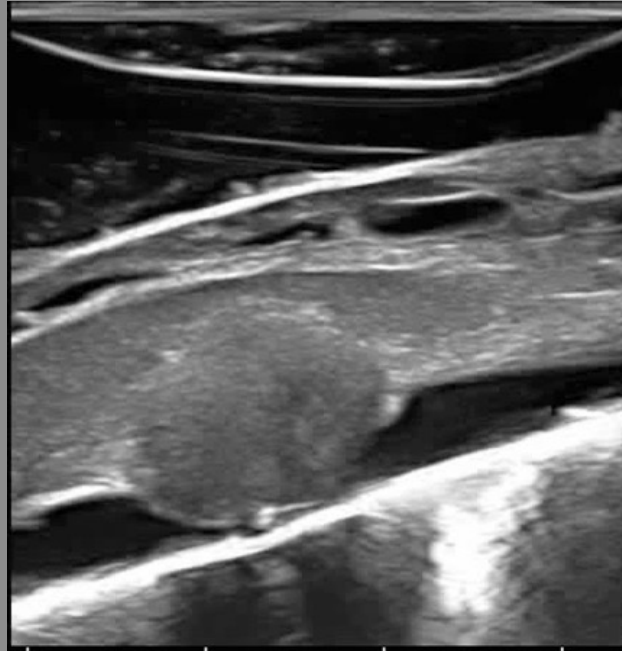


Intraoperative ultrasound in spinal tumor surgery

Ependimoma



Neurinoma (extramedullary)



Neurinoma



Meningioma



Intraoperative Ultrasound (IOUS) in Neurosurgery

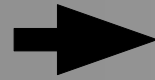
From Standard B-mode
to Elastosonography

Francesco Prada
Luigi Solbiati
Alberto Martegani
Francesco DiMeco *Editors*

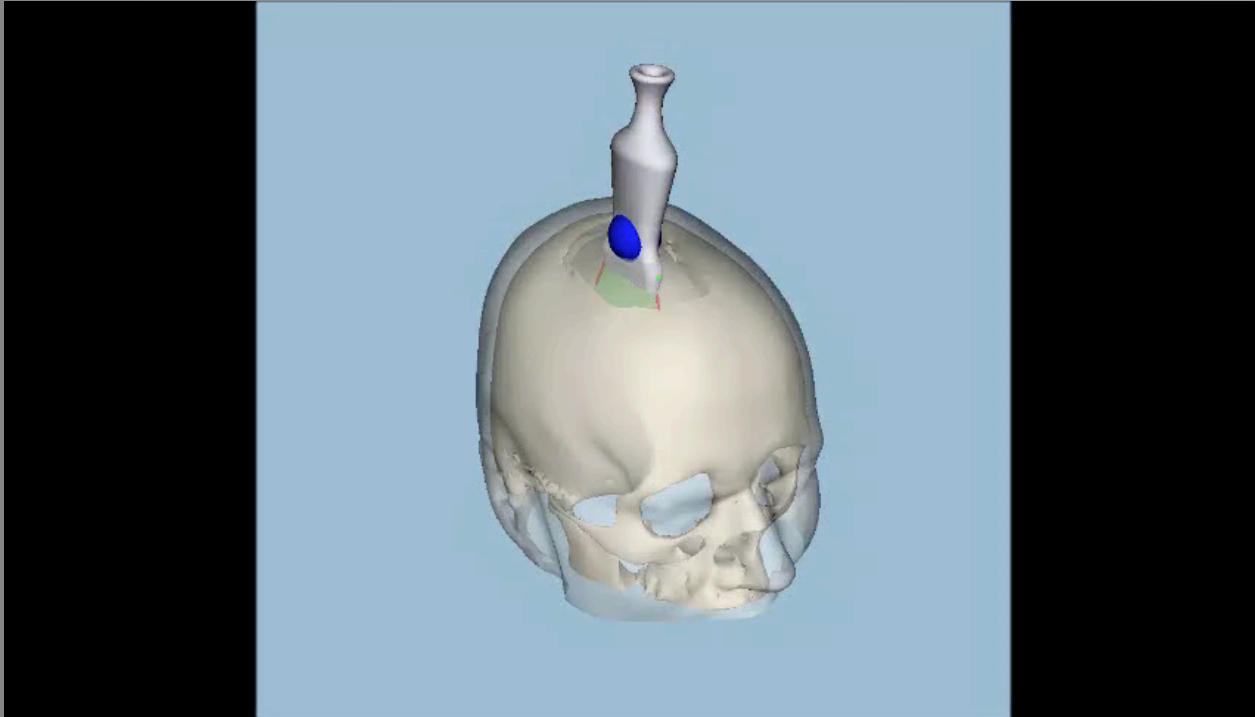
 Springer

Intraoperative ultrasounds - downsides

- *Unusual imaging*
- *Orientation difficulties*



Operator dependent



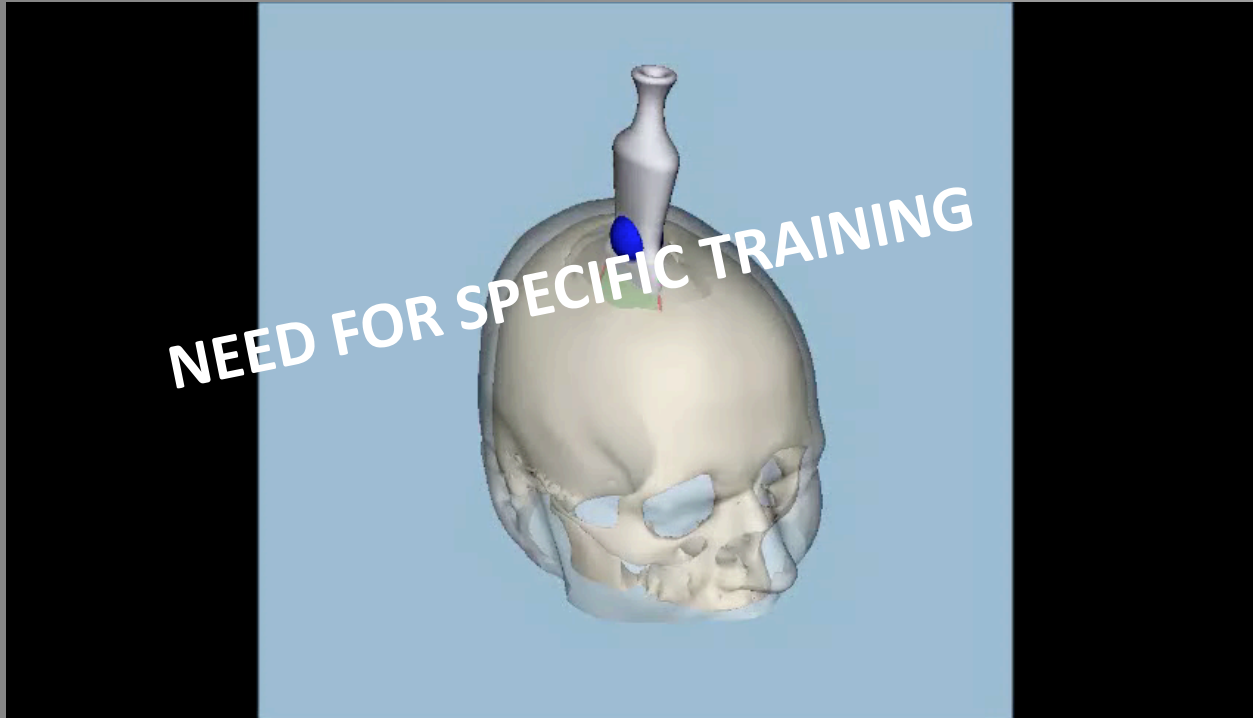
Intraoperative ultrasounds - downsides

- *Unusual imaging*



Operator dependent

- *Orientation difficulties*



Simulation of intraoperative ultrasound neurosurgical cases

CONCEPTS, INNOVATIONS AND TECHNIQUES

USim: A New Device and App for Case-Specific, Intraoperative Ultrasound Simulation and Rehearsal in Neurosurgery. A Preliminary Study

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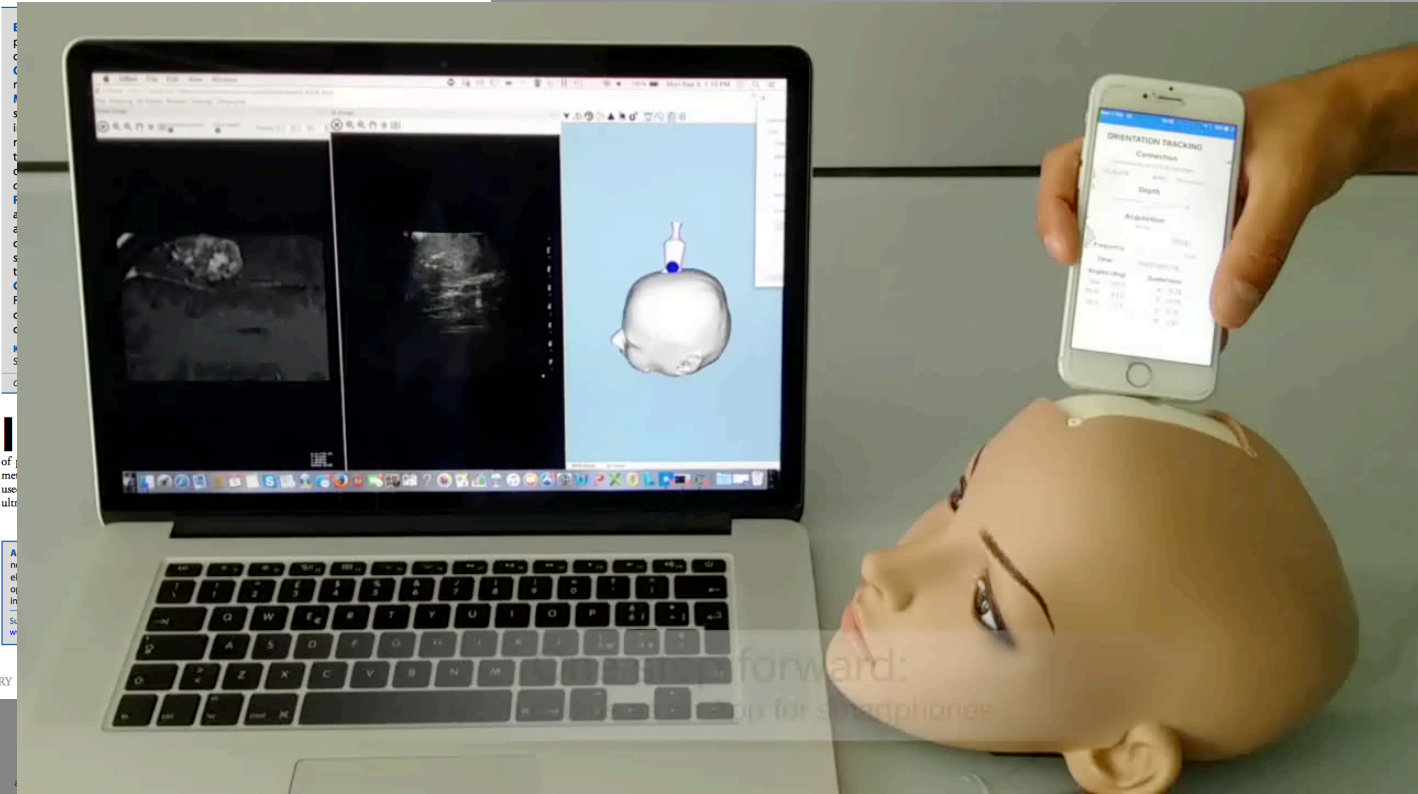
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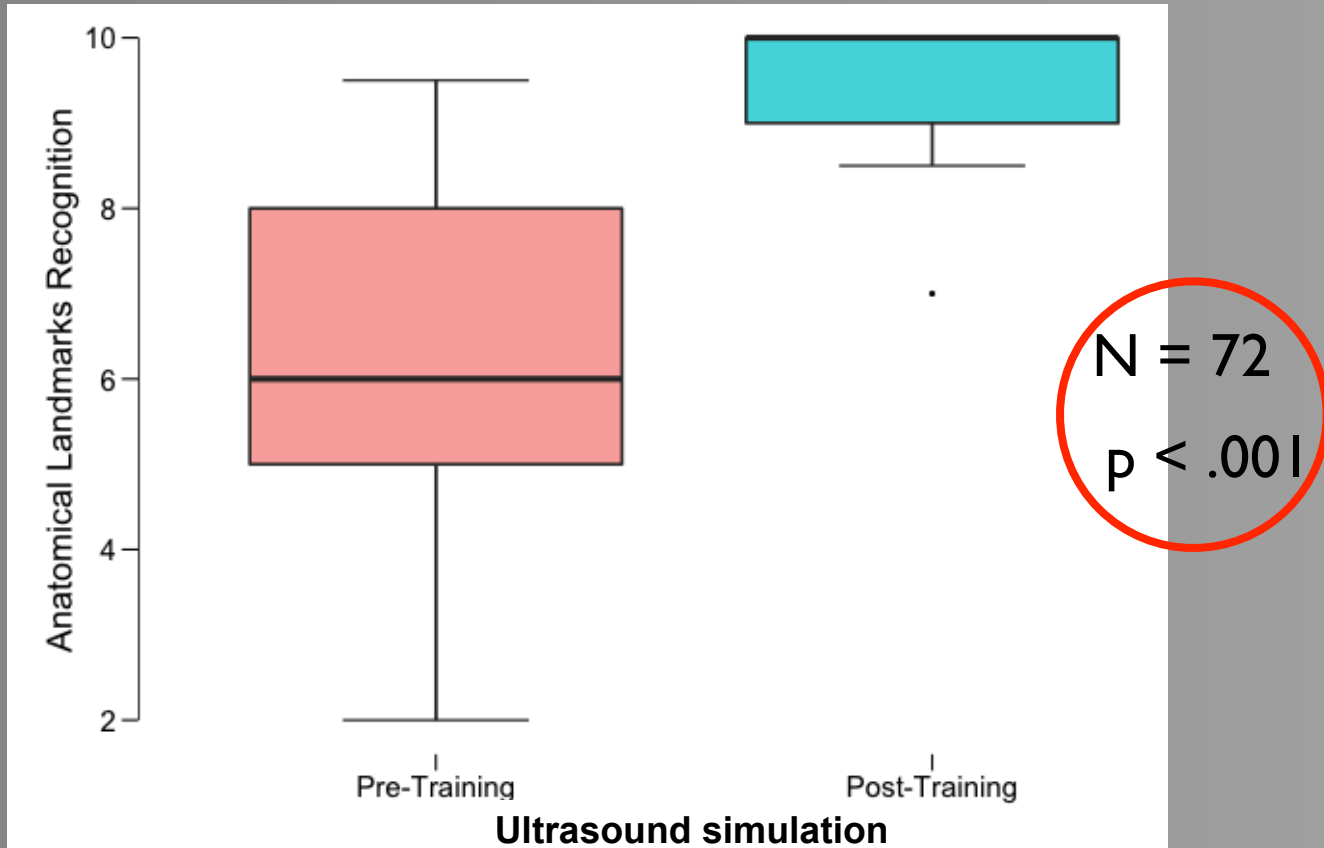
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OPERATIVE NEUROSURGERY



forward:
up for smartphones

Ultrasound simulation: results on 72 residents



ioUS - key points

- ioUS provides real time images
- Fusion of neuronavigation and ioUS helps to understand US semeiotics
- Fusion of neuronavigation and ioUS may correct the major drawback of neuronavigation: **the brain shift**
- Some anatomical landmarks have specific echoic characteristics
- US is a dynamic surgical tool, therefore scan the entire area moving and orienting the probe in all possible directions
- Exploit all US features (B-mode, doppler, CEUS, elastosonography)
- When possible, use tricks to overcome some drawbacks

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Dip NCH INN C.Besta



