Intraoperative ultrasound in glioma surgery – experiences from everyday use of Intraoperative Navigated 3D Ultrasound

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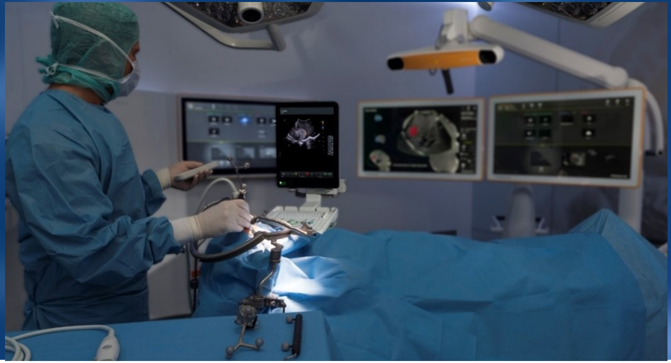
Have used navigated 3D US since 1996

US with integrated navigation

Neurocenter,
St Olav University Hospital,
Trondheim,
Norway



When new Neurocenter was built (2005) we had the chance to get an iMRI. We decided to use 3D US for intraoperative imaging because of

positive experience with 3D US for many year

Flexible and inexpensive solution that met our needs

INTRAOPERATIVE IMAGING

	iMRI	iCT	iUS
Capital Cost	Very high	High	Low
Imaging Hazards	Yes – metal in O.R., patient implants	Yes - radiation	No
Time to Prep/Acquire Scan	40–60 minutes	10 –30 minutes	30 seconds
Soft Tissue Quality	Great	Poor	Very Good

Learning needed to benefit from intraoperative ultrasound

6th International Training Course: 3D Ultrasound and Neuronavigation

Live video transfer from the OR of the future at St. Olavs university hospital, Trondheim, Norway

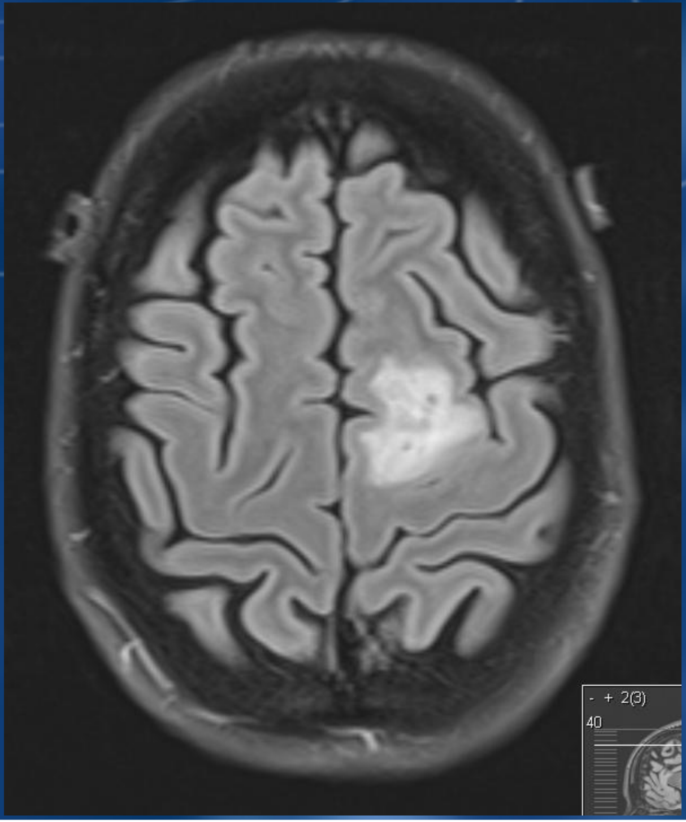
National Competence Center for Ultrasound and Image Guided Therapy - www.usigt.org

ST. OLAVS HOSPITAL
TRONDHEIM UNIVERSITY HOSPITAL

SINTEF

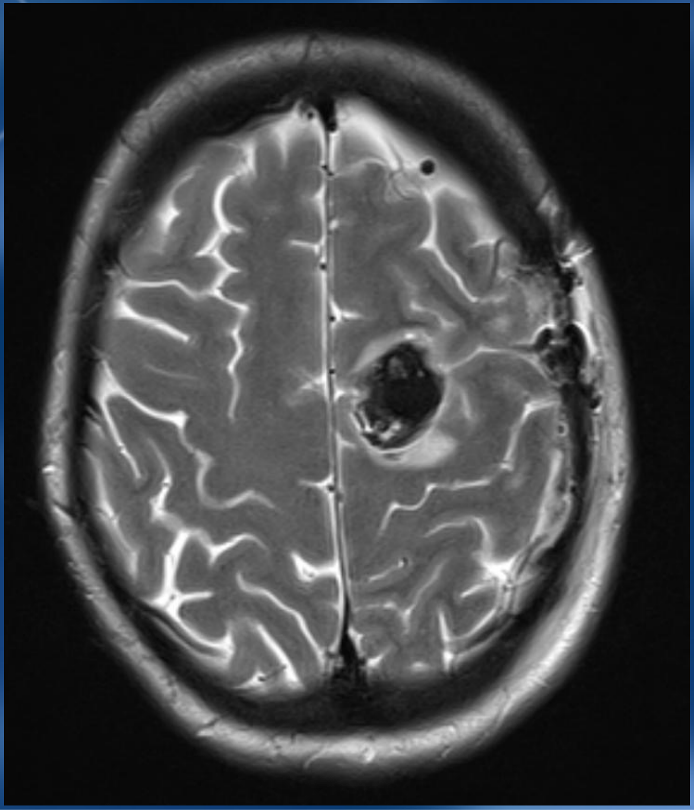
NTNU
Norwegian University of Science and Technology

Preop MR



MR one day after operation, GTR

A small temporary paresis in right hand owing to ischemic lesion, normalized in a week

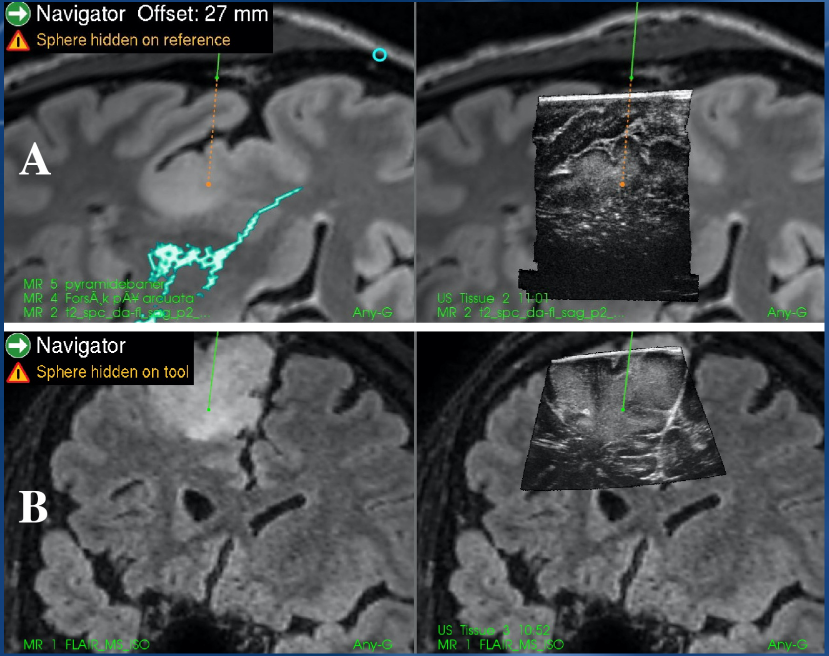


The most important point for ultrasound guided operations is:

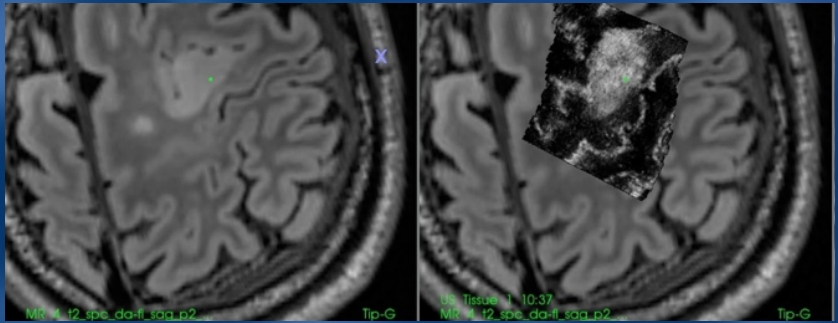
IMAGE QUALITY

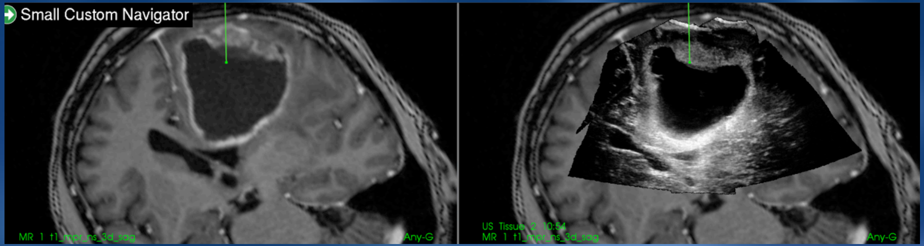
At the start of an operation it is easy to obtain US image quality that is just as good as in the preop MR

LGG

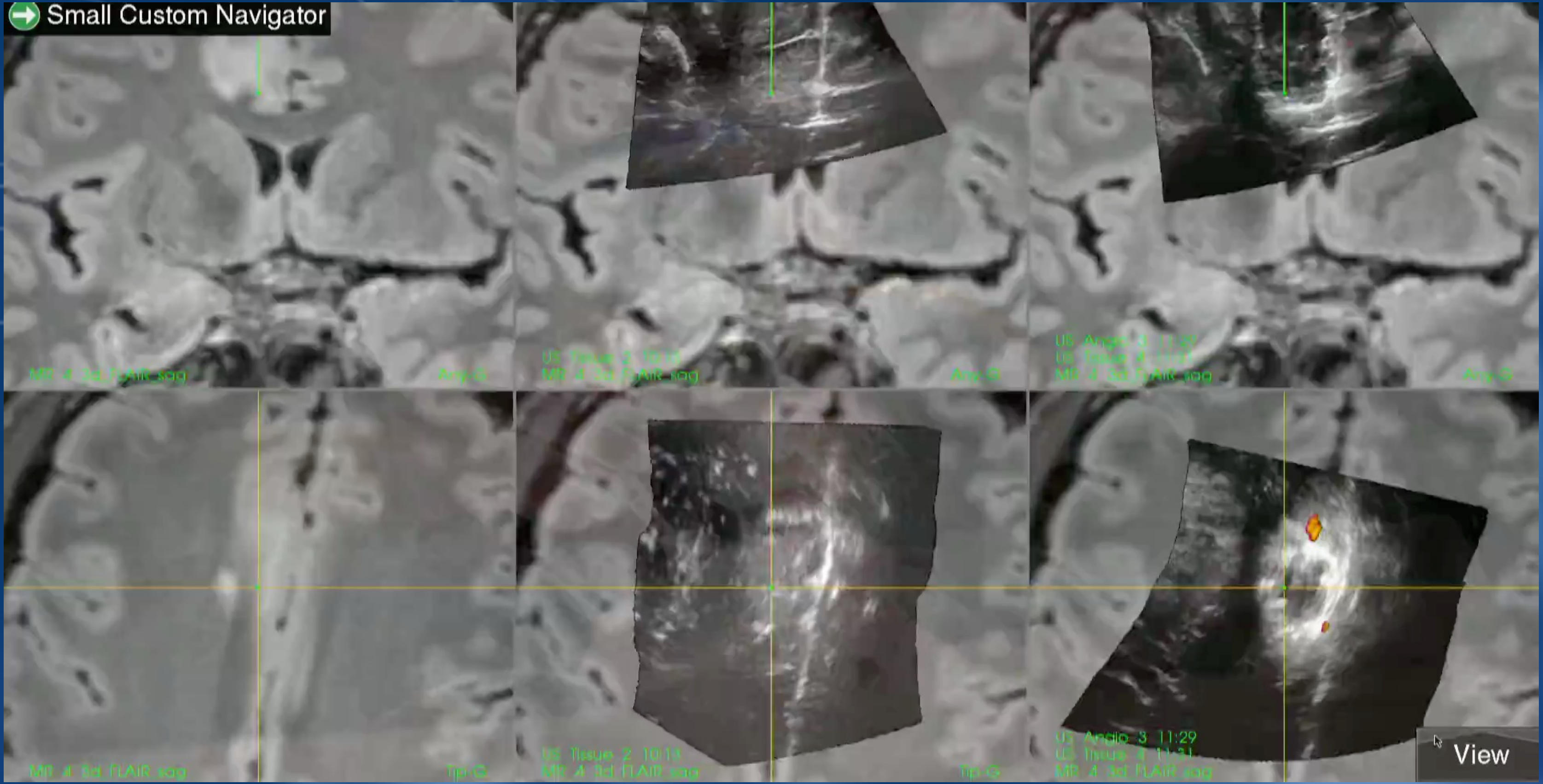


HGG



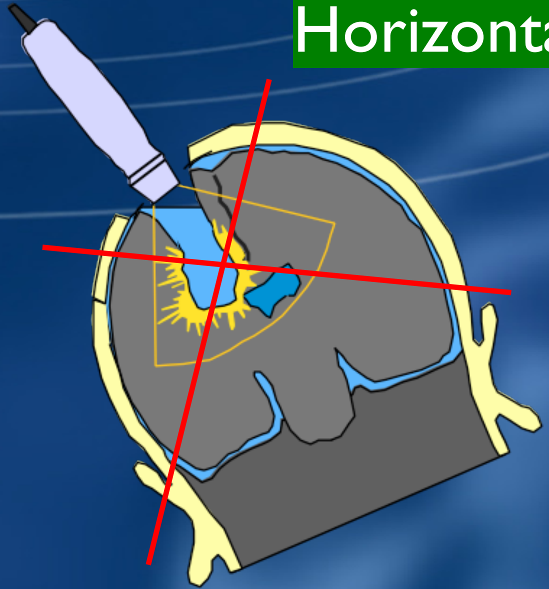


Challenging to keep high-quality ultrasound images during and towards the end of resection



Optimal positioning of the patient

Horizontal craniotomy, vertical access



It is very difficult to achieve good acoustical contact when the cavity is tilted

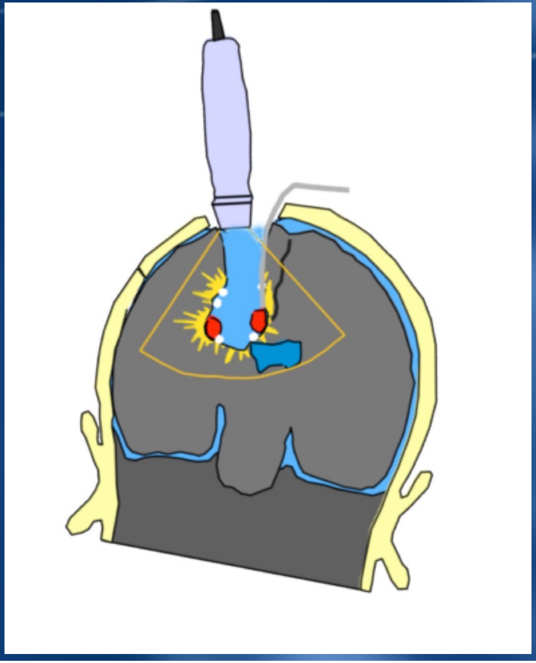
Positioning to obtain a horizontal craniotomy

Immediately in front of the central sulcus:
Supine position with flexed neck

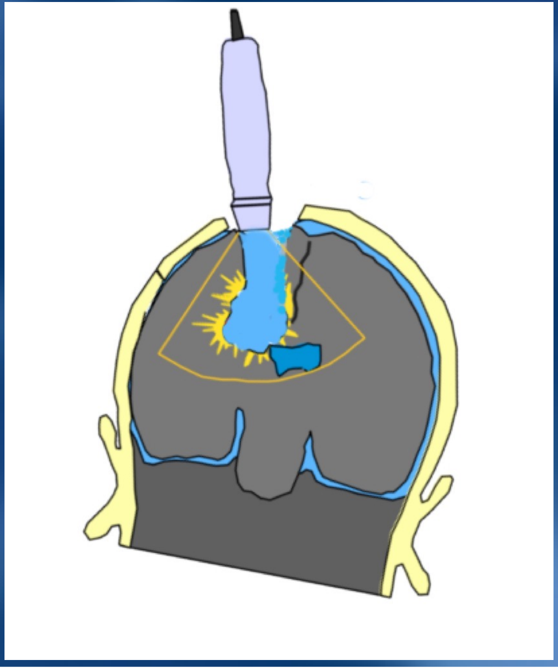
Behind the central sulcus:
Modified Park Bench position

Acquisition of images during surgery

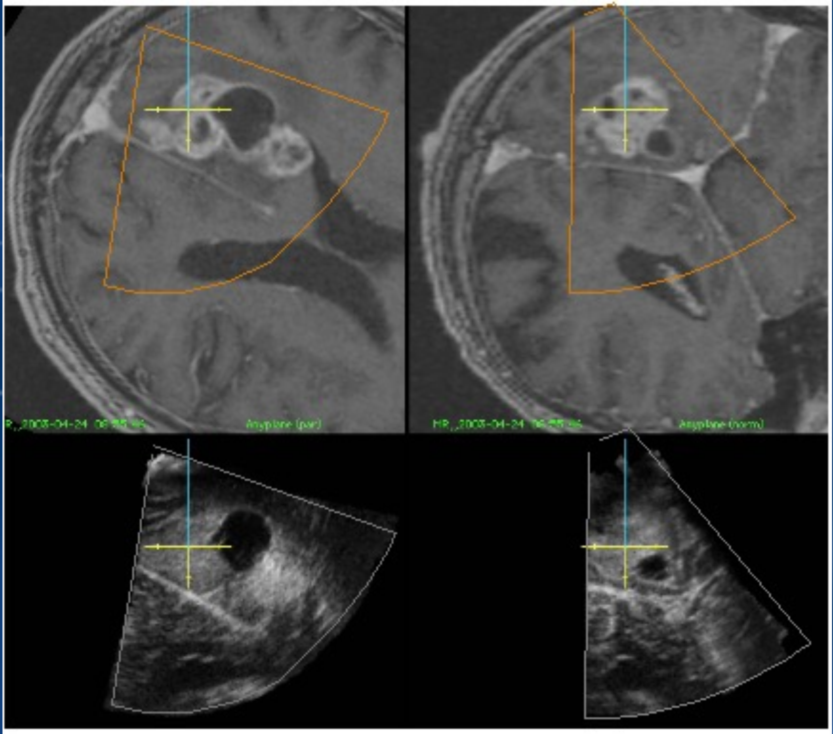
Obtain hemostasis
Remove spatulas and surgical patties
Air bubbles – will surface with vertical access



- Clean cavity without spatulas, paddings or blood
- Horizontal craniotomy: Cavity that can be filled with fluid



Ultrasound and navigated preoperative MRI have different strength and limitations



Navigated preop MR:
- Large overview
- Limited accuracy

Intraoperative Ultrasound:
- High accuracy
- Limited overview

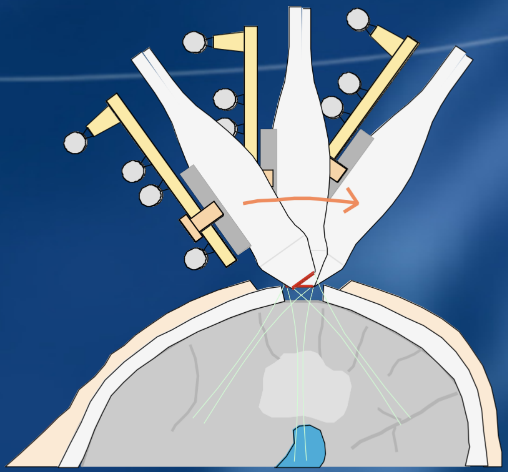
The overview of the MR and the accuracy of the ultrasound can be combined by navigated 3D US

Integration of US with the neuronavigation system to obtain 3D US highly improves the benefit of US

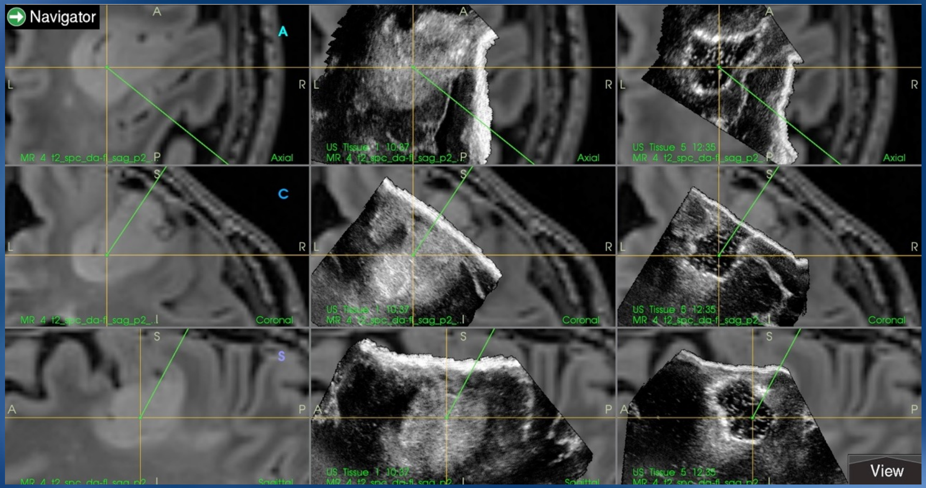
Acquisition of 3D US volumes

Always try to make a large 3D ultrasound scan in order to include landmarks in the data set

1) Start were you can **not** see the lesion
2) Go past it
3) Finish were you can **not** see it anymore

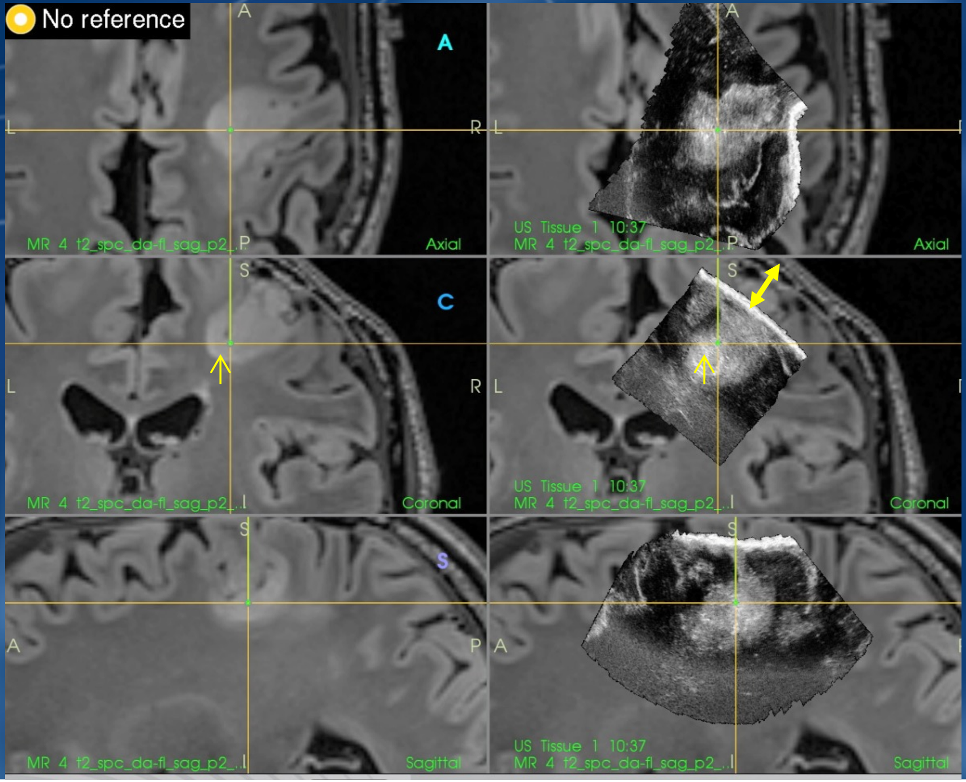


A wide ultrasound scan requires flexible movement of the probe



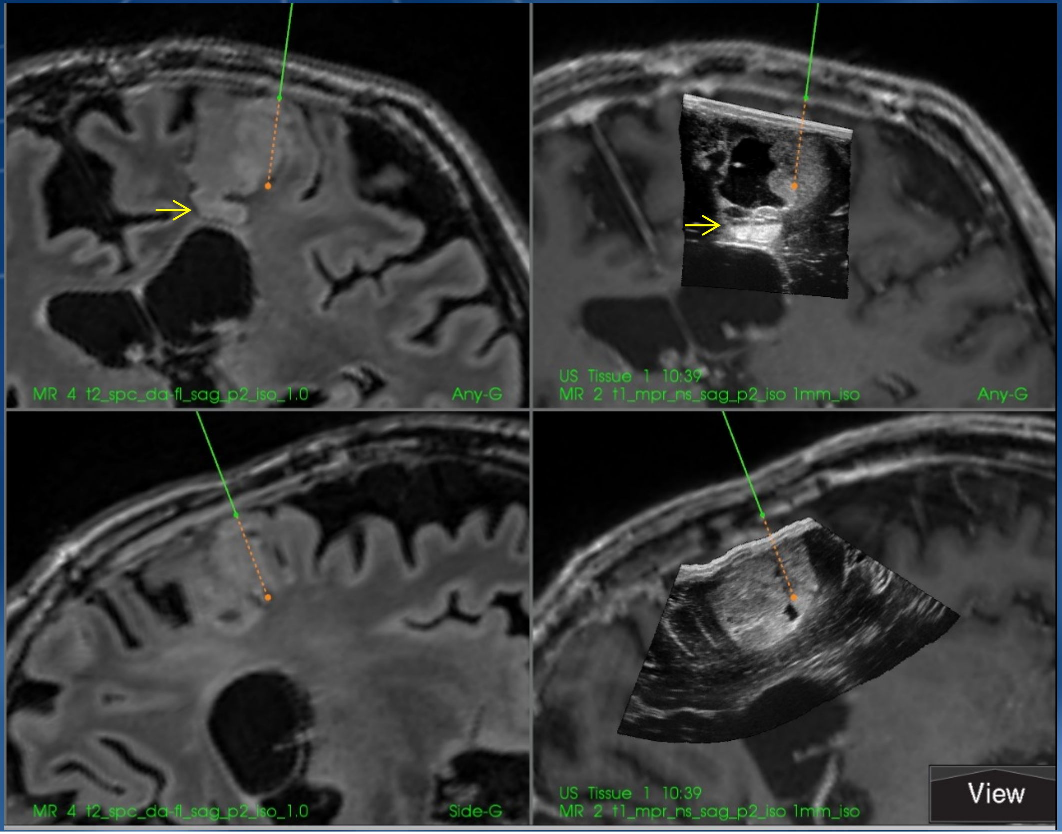
Several benefits by integrating 3D US with navigated preop MRI

Register the brain shift



Benefits by integrating 3D US with MRI navigation:

Makes the interpretation of US easier



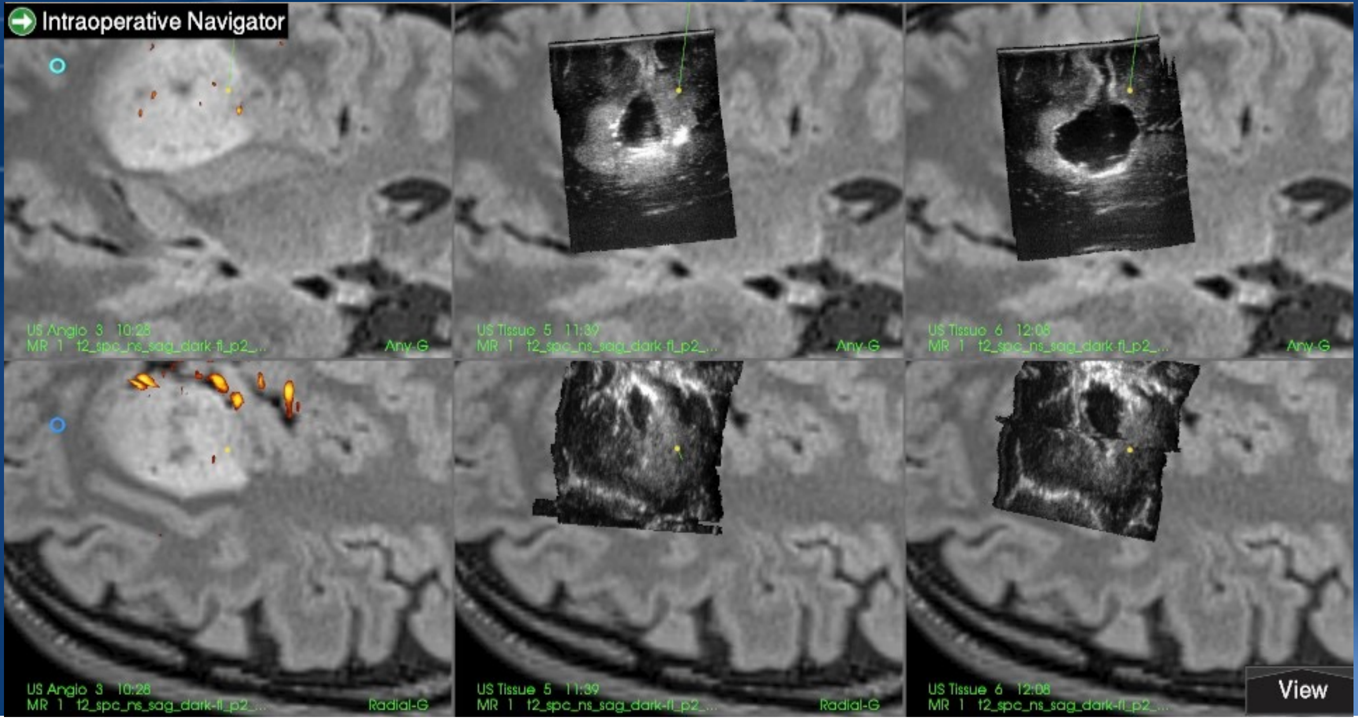
Benefits by integrating 3D US with MRI navigation:

Follow the progression of the operation

Low grade glioma:

Preop MR with US angio

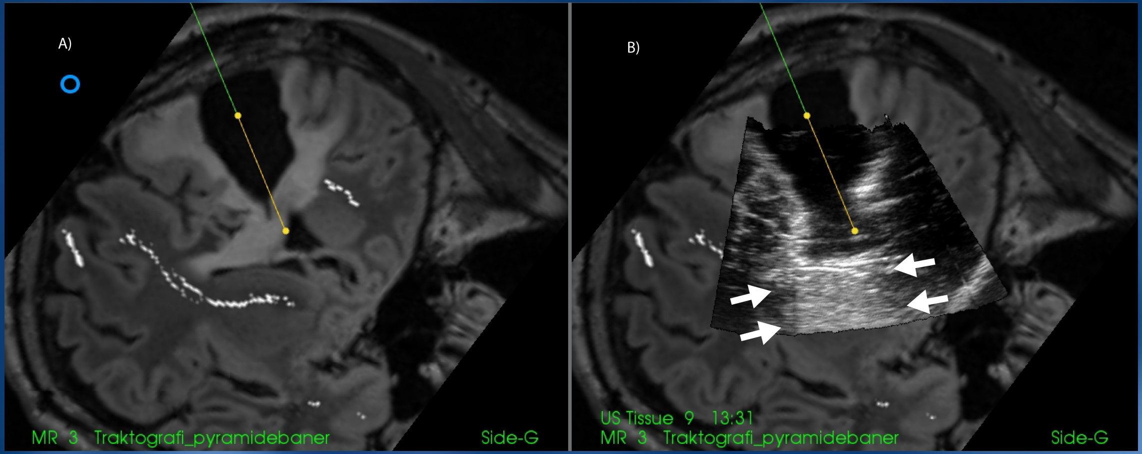
US during resection



Enhancement artifacts

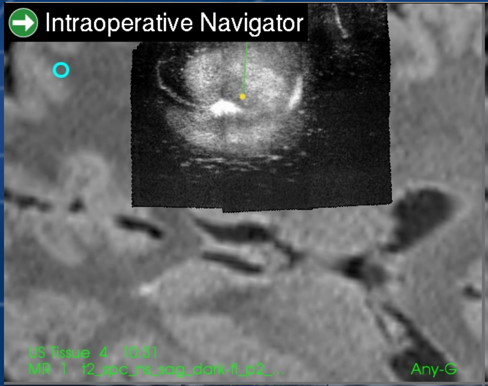
Enhancement artefacts can be a big problem for US image interpretation

3D US recordings of the progression of the operation may help to reduce this problem

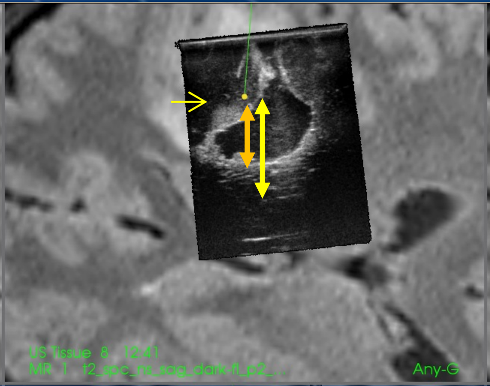


Enhancement artifacts

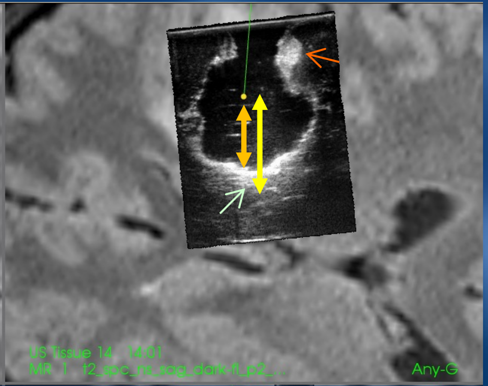
Low grade glioma:



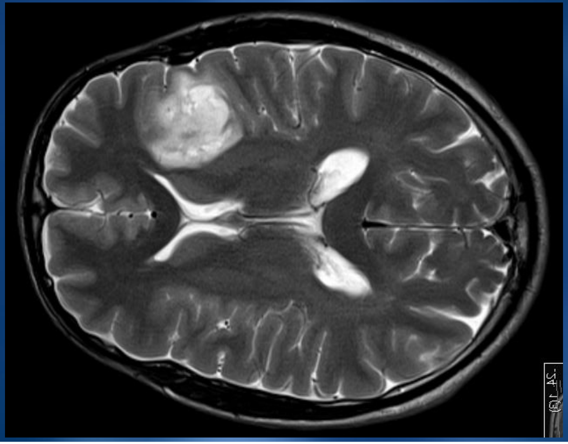
US towards the end of the operation
Some residual tumour tissue



US at the end of resection
Notice harm from spatula (red arrow) and attenuation artifact (green arrow

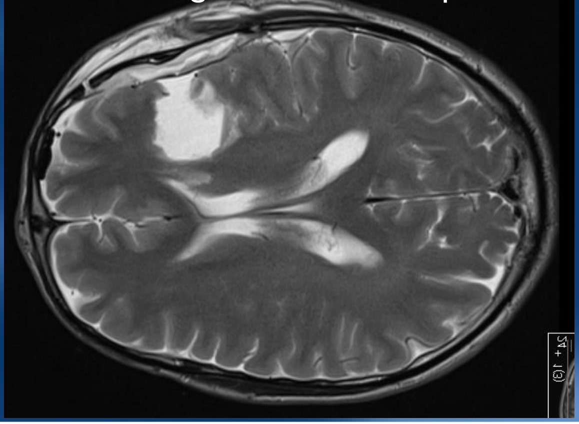


MR before operation



MR one day after operation. No residual tumour

No neurological deficit after operation

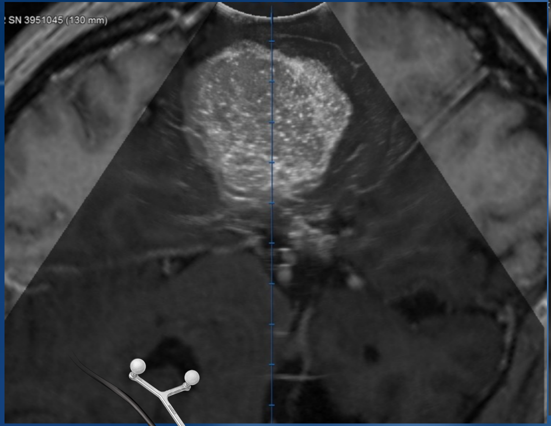


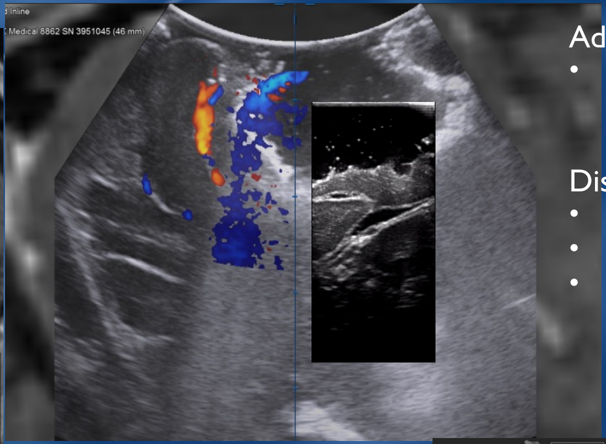
Enhancement artifacts

SMALL HIGH FREQUENCY PROBE IN THE CAVITY
COMBINE HIGH SPATIAL RESOLUTION WITH LARGE FOV

Stacking feature – stack overlays of multiple probes

Account for enhancement artifacts as surgery progresses



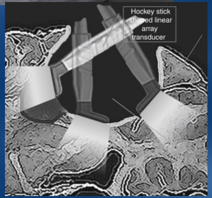


Advantage:

- Reducing the distance will reduce the noise

Disadvantages:

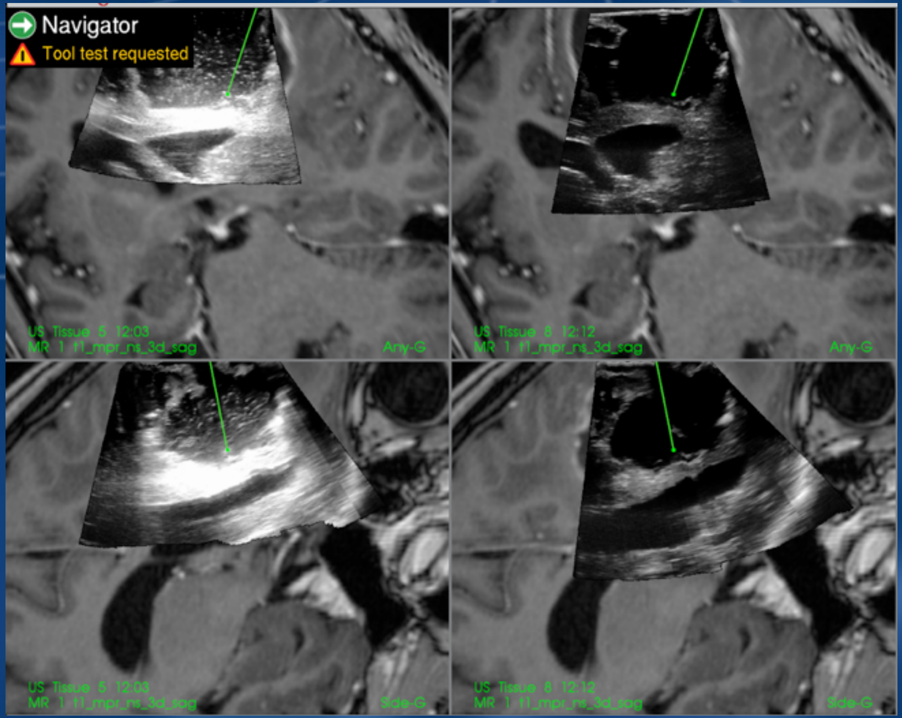
- Reduced field of view
- Cumbersome to use
- Potential risk of harming tissue by manipulating a probe in the cavity



Courtesy: Brainlab

Enhancement artifacts

Removing enhancement artifacts with ACF



With Ringer in the cavity we get enhancement artifacts

With an acoustic fluid that removes enhancement artifacts

ACF is a coupling fluid that has the same damping effect as the tissue

attenuation coefficient water: 0.0022 dB/(MHz*cm)
attenuation coefficient brain: 0.85 dB/(MHz*cm)

Enhancement artifacts

Acta Neurochirurgica , May 2019

A new acoustic coupling fluid with ability to reduce ultrasound imaging artefacts in brain tumour surgery—a phase I study

Geirmund Unsgård, Lisa Millgård Sagberg, Sébastien Müller & Tormod Selbekk

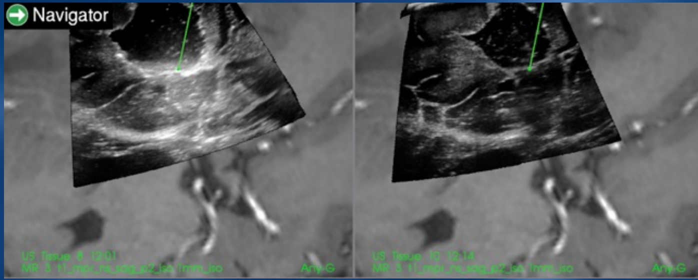
A Phase I Technical and Safety Study
15 glioblastoma patients

The novel acoustic coupling fluid (ACF) was able to remove artefacts that appeared in ultrasound images towards the end of tumor removal.

Adverse events in this study were within the limits of what have been reported in other glioblastoma publications.

Results of ACF vs. Ringer solution for the 3 questions (across 15 images and 5 raters)

1. How easy is it to differentiate between surrounding brain tissue and tumour tissue
2. How easy is it to interpret the ultrasound image below the resection cavity?
3. How easy is it to use the image to identify residual tumour tissue

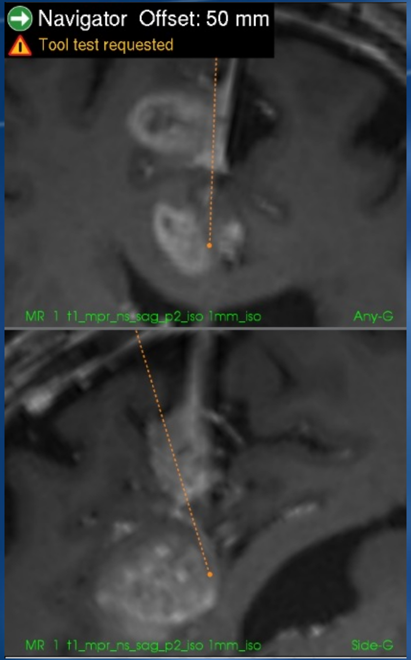


Question	N per solution	Mean (SD) Ringer	Mean (SD) ACF	Difference ACF-Ringer (95% CI)	P-value
1	75	4.77(2.07)	7.11(1.65)	2.33(1.73,2.94)	<0.0001
2	75	3.71(1.90)	7.20(1.68)	3.49(2.91,4.07)	<0.0001
3	75	4.16(2.23)	7.19(1.68)	3.03(2.39,3.66)	<0.0001

Enhancement artifacts

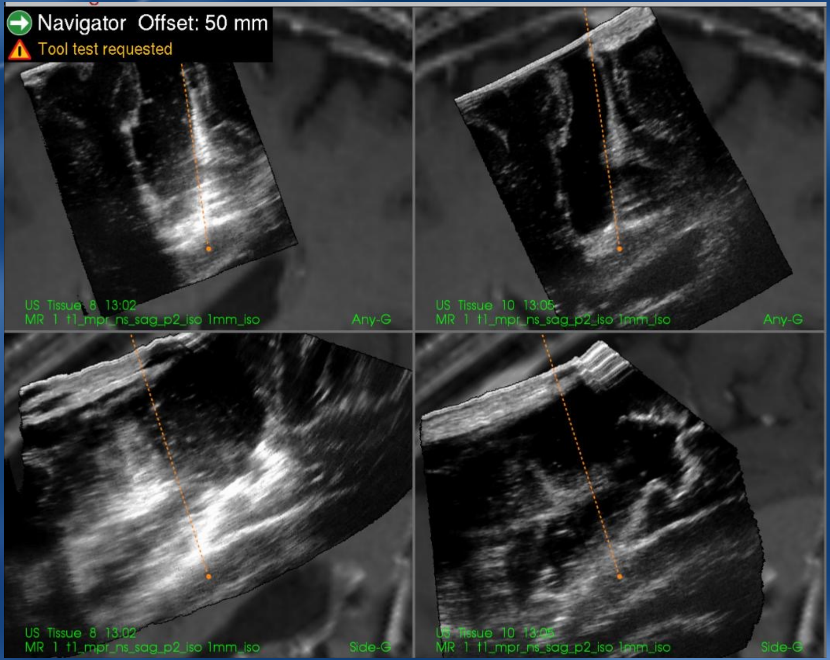
An acoustic coupling fluid(ACF) that dampen the sound waves to the same degree as the normal brain removes the artifacts

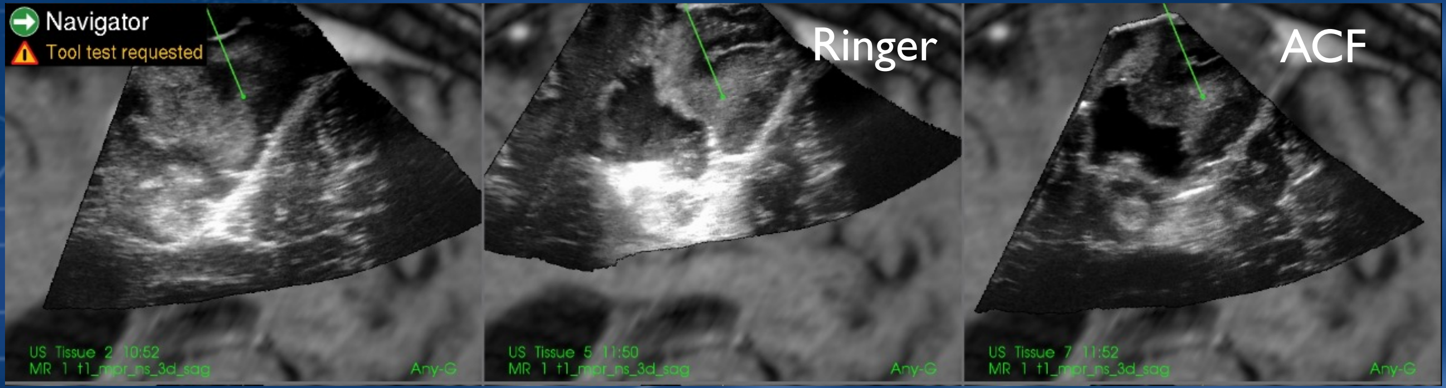
Glioblastoma



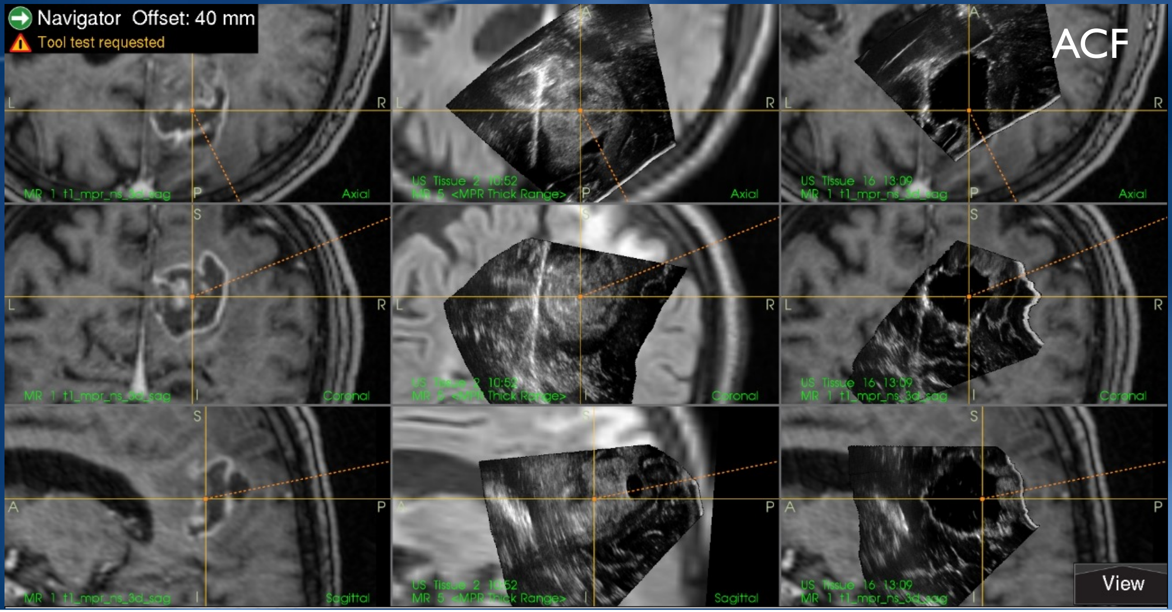
Ringer in the cavity

ACF in the cavity





Occipital glioblastoma



ACF, no artifacts

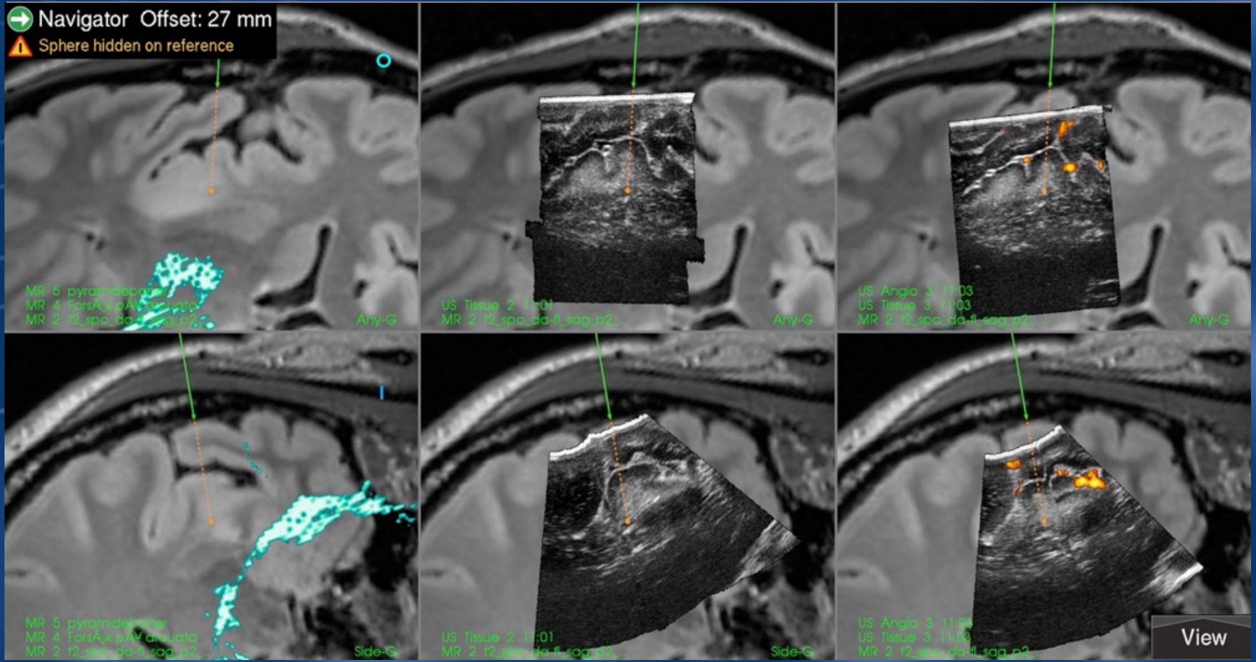
Navigated ultrasound aspirator (CUSA)

Insula gliomas

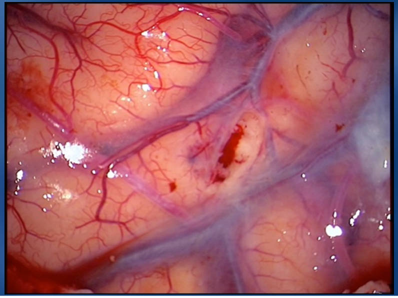
- 25 % of all LGG
- 10% og Glioblastomas

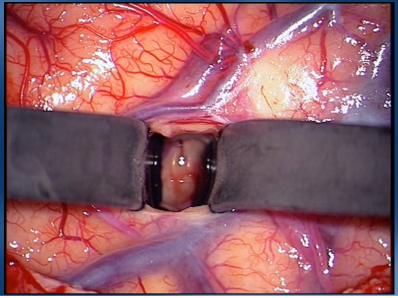
Small insula tumor left side

Transcortical resection guided by navigated 3D US

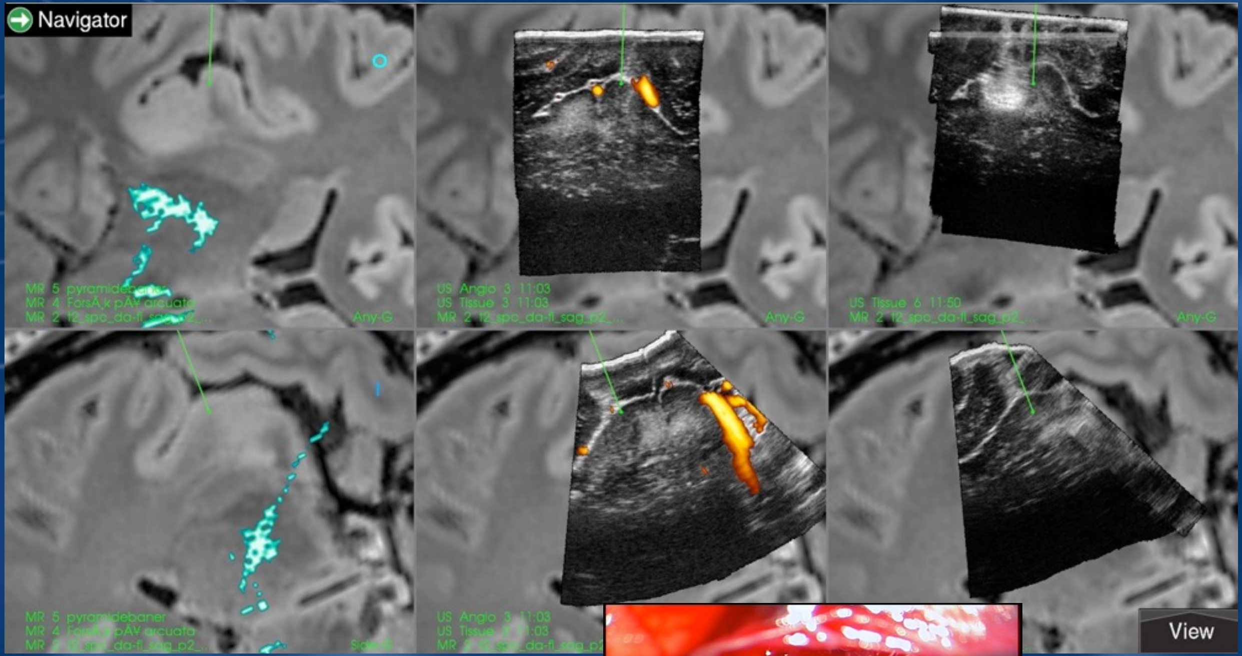


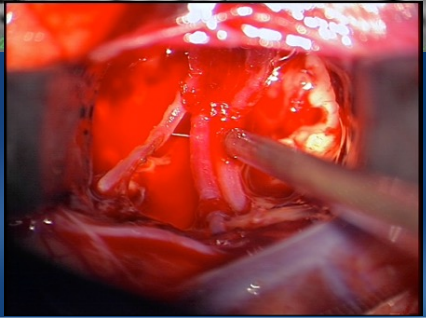
Small opening in cortex



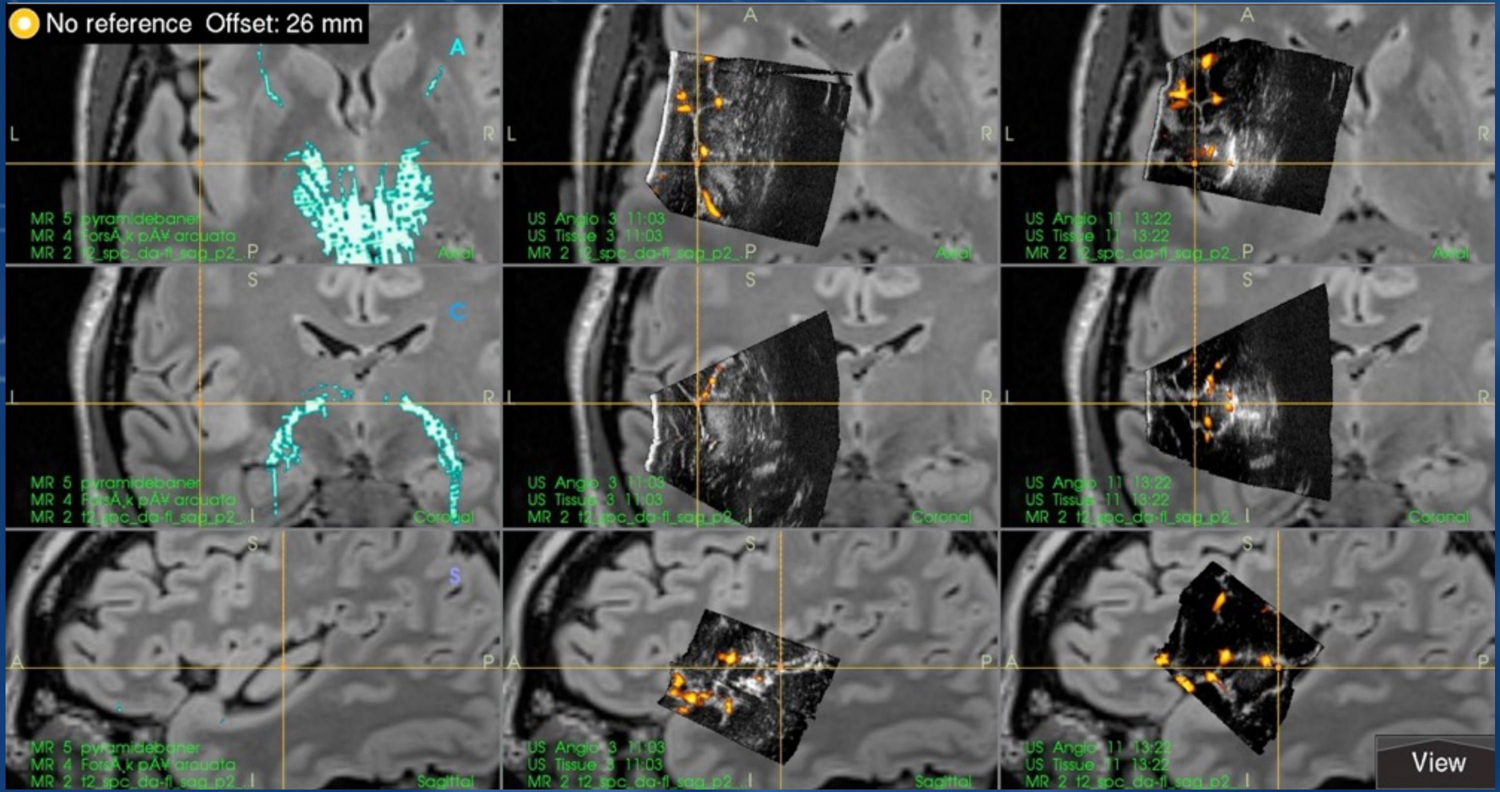


After some resection



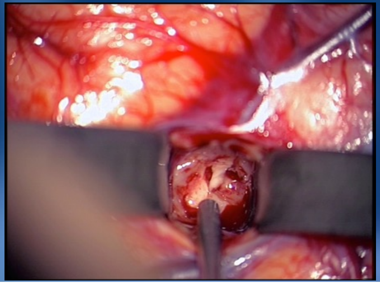


3D US angiography
help localize the
insula vessels



Dominant side.
Patient was very well with no neurological deficit already a few hours after the operation.

Postop MR one day after the operation showed GTR

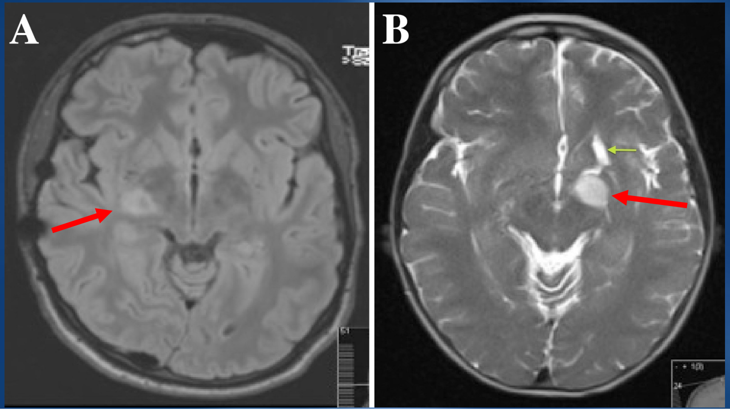


Navigated CUSA is especially useful in deep seated lesions with narrow access

“3D US guided resection of low-grade gliomas: principles and clinical examples”
Neurosurgical Focus 47 (6):E9, Des 2019

Both patients operated guided by 3D US, and with navigated CUSA

Patients with tumors in amygdala
A 19 years old (A) and a 14 years old (B) boy
Tumors close to pyramidal tracts and
indsitinguishable from optic tracts



“3D US guided resection of low-grade gliomas: principles and clinical examples”
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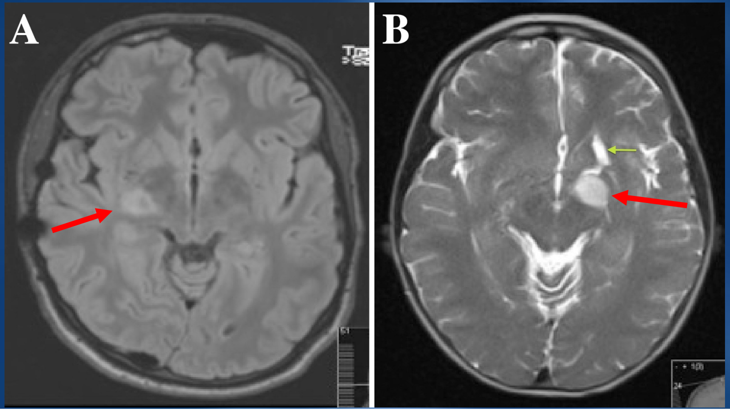
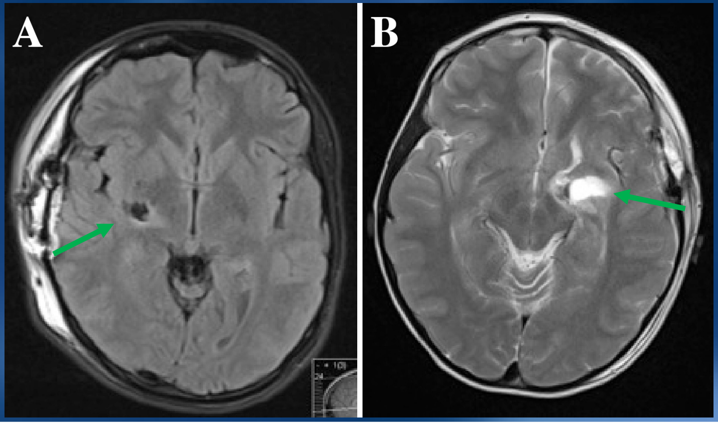
Both patients operated guided by 3D US, and with navigated CUSA

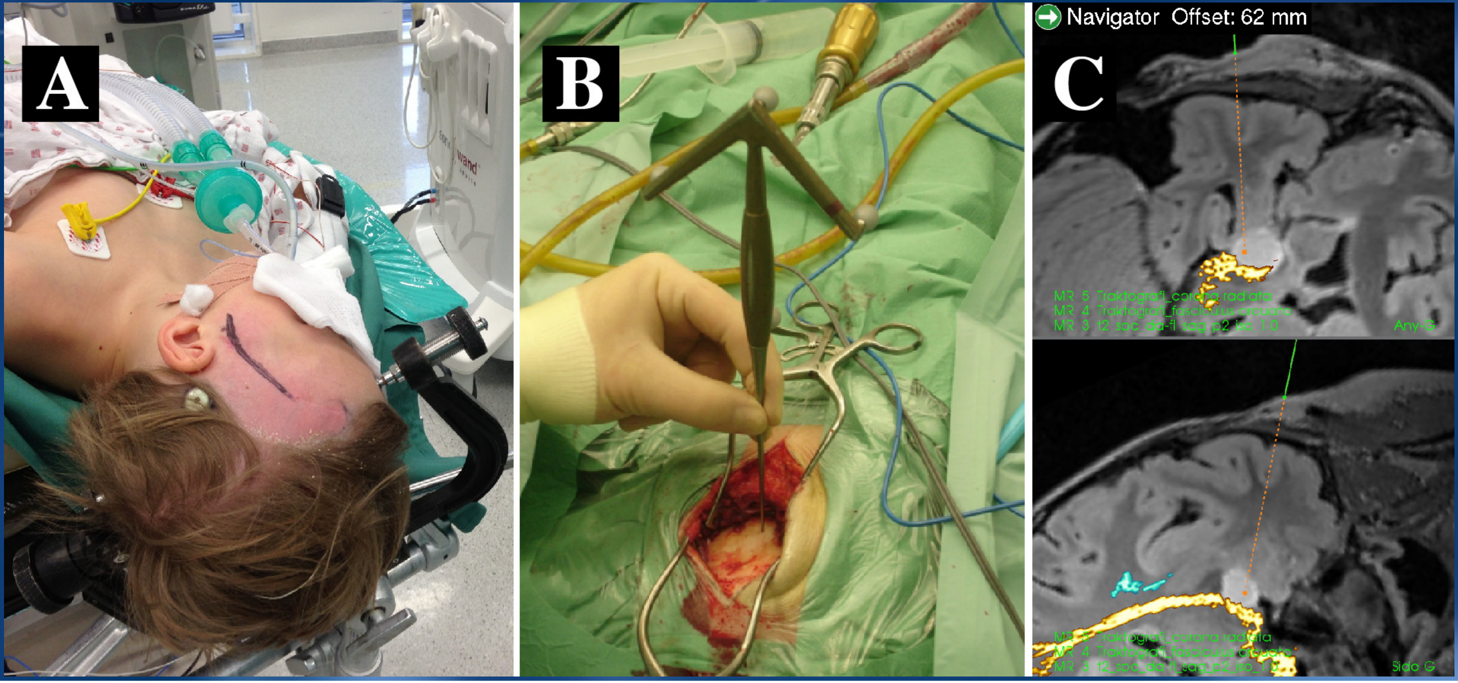
Patients with tumors in amygdala
A 19 years old (A) and a 14 years old (B) boy
Tumors close to pyramidal tracts and indsitinguishable from optic tracts

MRI one day after the operation
GTR, no neurological deficit
Patient B had a hardly noticeable parafacia

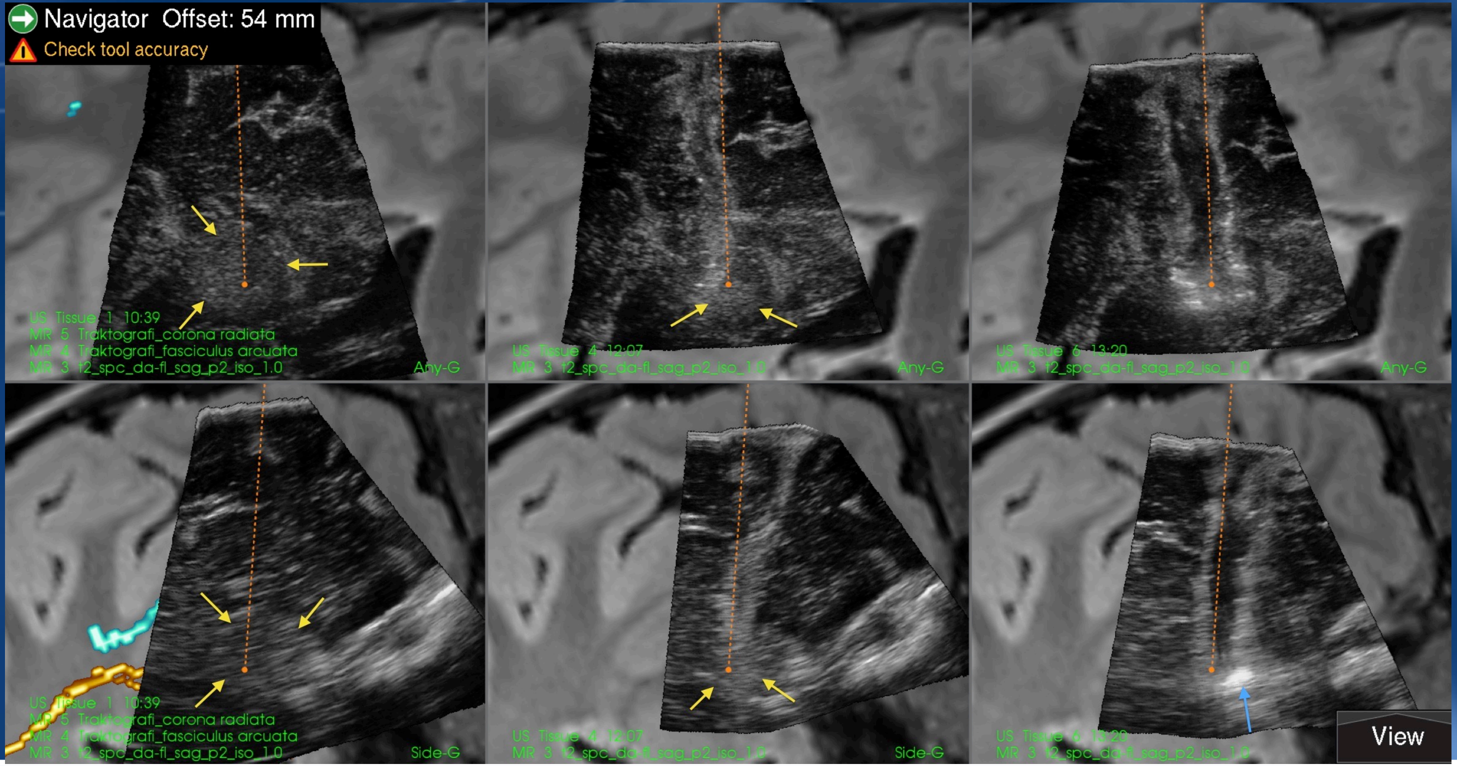




Transcortical access through temporal incision and craniotomy



Before start of resection | During resection | At the end of resection



Challenging for the surgeon to to fuse information from both the microscope and the navigation system

A possible future solution:

- Exoscope image (stereo) and 3D US navigation displayed side by side on a large monitor(4K or 8K)
- Many benefits:

-Increased information to the surgeon,
-Surgeon and assistant are released from the microscope
-Teaching will be much more effective

All my LGG operations were done with the patients asleep

Easy to combine navigated 3D US with wake operations

- Moiyadi, A and Shetty, P.: Early Experience with Combining Awake Craniotomy and Intraoperative Navigable Ultrasound for Resection of Eloquent Region Gliomas. J Neurol Surg A Cent Eur Neurosurg 2017
- Steno, A et al. : Navigated 3D-ultrasound versus conventional neuronavigation during awake resections of eloquent low-grade gliomas: a comparative study at a single institution. Acta Neurochir (Wien) 2018

Results of ultrasound guided LGG operations

ORIGINAL CONTRIBUTION

ONLINE FIRST

Comparison of a Strategy Favoring Early Surgical Resection vs a Strategy Favoring Watchful Waiting in Low-Grade Gliomas

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Kristin S. Myrmel, MD
Roar Kloster, MD
Sverre H. Torp, MD, PhD
Sigurd Lindal, MD, PhD
Geirmund Unsgård, MD, PhD
Ole Solheim, MD, PhD

Context There are no controlled studies on surgical treatment of diffuse low-grade gliomas (LGGs), and management is controversial.

Objective To examine survival in population-based parallel cohorts of LGGs from 2 Norwegian university hospitals with different surgical treatment strategies.

Design, Setting, and Patients Both neurosurgical departments are exclusive providers in adjacent geographical regions with regional referral practices. In hospital A diagnostic biopsies followed by a "wait and scan" approach has been favored (biopsy and watchful waiting), while early resections have been advocated in hospital B (early resection). Thus, the treatment strategy in individual patients has been highly dependent on the patient's residential address. Histopathology specimens from all adult patients diagnosed with LGG from 1998 through 2009 underwent a blinded histopathological review to ensure uniform classification and inclusion. Follow-up ended April 11, 2011. There were 153 patients (66 from the center favoring biopsy and watchful waiting and 87 from the center favoring early resection) with diffuse LGGs included.

Main Outcome Measure The prespecified primary end point was overall survival based on regional comparisons without adjusting for administered treatment.

Results Initial biopsy alone was carried out in 47 (71%) patients served by the center favoring biopsy and watchful waiting and in 12 (14%) patients served by the center favoring early resection ($P<.001$). Median follow-up was 7.0 years (interquartile range, 4.5-10.9) at the center favoring biopsy and watchful waiting and 7.1 years (interquartile range, 4.2-9.9) at the center favoring early resection ($P=.95$). The 2 groups were comparable with respect to baseline parameters. Overall survival was significantly better with early surgical resection ($P=.01$). Median survival was 5.9 years (95% CI, 4.5-7.3) with the approach favoring biopsy only while median survival was not reached with the approach favoring early resection. Estimated 5-year survival was 60% (95% CI, 48%-72%) and 74% (95% CI, 64%-84%) for biopsy and watchful waiting and early resection, respectively. In an adjusted multivariable analysis the relative hazard ratio was 1.8 (95% CI, 1.1-2.9, $P=.03$) when treated at the center favoring biopsy and watchful waiting.

Conclusions For patients in Norway with LGG, treatment at a center that favored early surgical resection was associated with better overall survival than treatment at a center that favored biopsy and watchful waiting. This survival benefit remained after adjusting for validated prognostic factors.

JAMA. 2012;308(18):doi:10.1001/jama.2012.12807 www.jama.com

The diffuse low-grade gliomas (LGGs) include World Health Organization (WHO) grade II astrocytomas, oligodendrogliomas, and oligoastrocytomas.[1] Due to diffuse brain infiltration, LGGs are usually not considered surgically curable.[2] In fact, the effect of surgery on survival remains unclear because current evidence relies on uncontrolled surgical series alone.[3,4] Such series can be much affected by selection bias since patients with favorable outcomes may fare better regardless of treatment.[5,6] For example, watchful waiting until progression has been reported safe,[7,8] while others report improved survival and delayed time to malignant transformation if total resection of the tumor is achieved.[9-13] Due to lack of better evidence, management of suspected LGGs has remained one of the major controversies in neuro-oncology[3,14,15] and treatment strategies often differ considerably between neurosurgical centers.[16]

See related article.

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JAMA®
The Journal of the American Medical Association

AS Jakola and coauthors

Comparison of a Strategy Favoring Early Surgical Resection vs a Strategy Favoring Watchful Waiting in Low-Grade Gliomas

Published online October 25, 2012

Available at www.jama.com

LGG material 1998-2009

Survival

- Free healthcare in Norway, regional organization
- All patients referred to their "own" university clinic

"Randomization by post code"

- All patients with astrocytoma grade II, (incl patients with gliomatosis cerebri, contrast enhancement, or poor functional status)
- 3D US guided operation , asleep patients
- Survival published in JAMA 2012 and Annals of Oncology 2017
- Median survival 14,4 years

(median survival at the other hospital 5,8 years)

No difference in adverse events!!

EOR in LGG material 2008-2015

Intraoperative 3D ultrasound-guided resection of diffuse low-grade gliomas: radiological and clinical results. Bø et al. J Neurosurgery 2019, Feb 1: 1-12

- 47 patients
- A few of them with large diffusely infiltrating tumors in eloquent areas with low intensity on US
- Asleep operations guided by 3D US

- Median resection grade 93,4%
- GTR 30%
- Median residual tumor volume 1 ml
- Quality of life maintained/improved: 86%

Conclusion:

3D US guided LGG resections under general anesthesia are safe, with EOR consistent with published studies using other advanced neurosurgical tools

Thank you!