ROBOTIC and NEUROSURGERY
Present and Future

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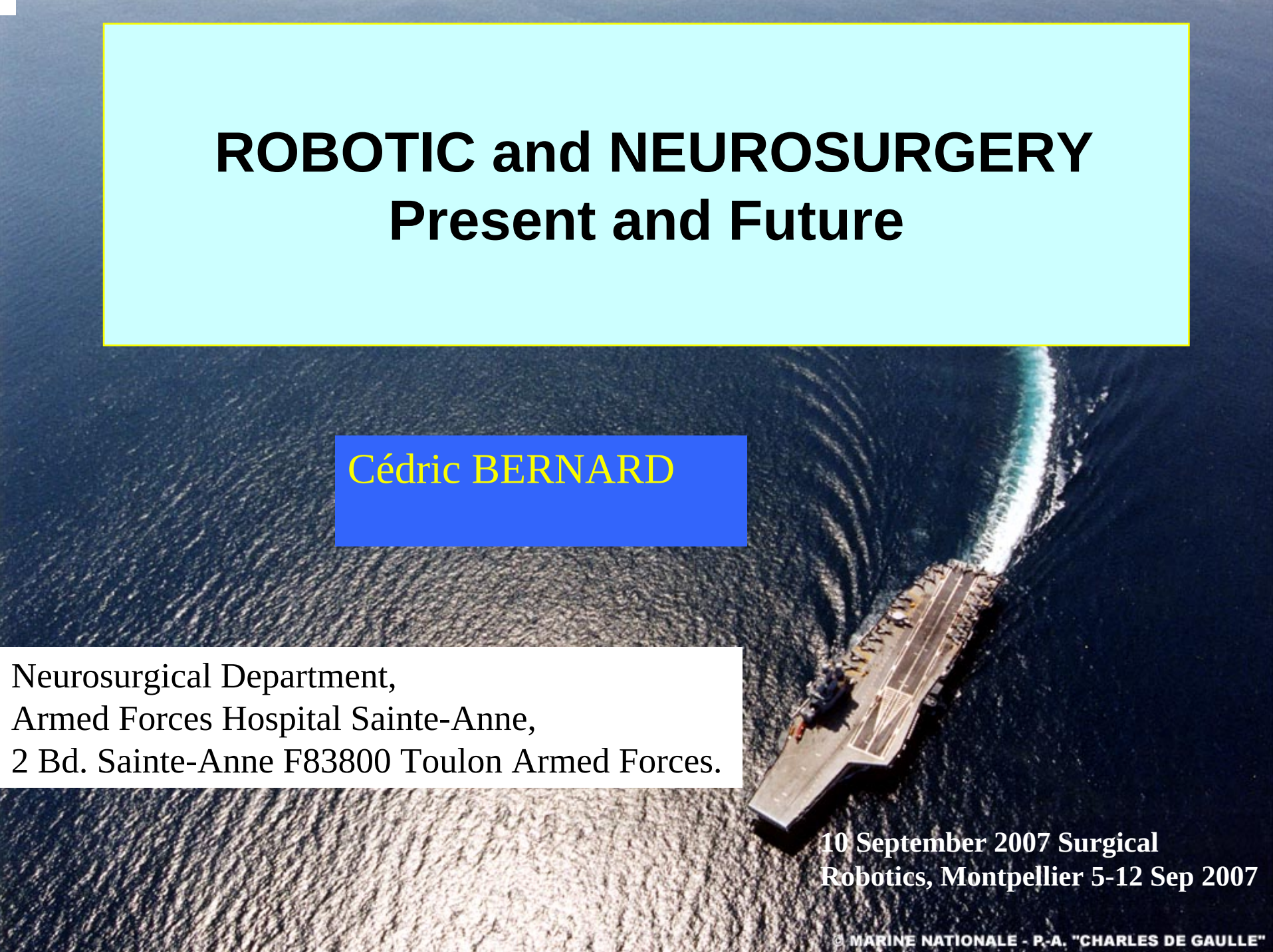
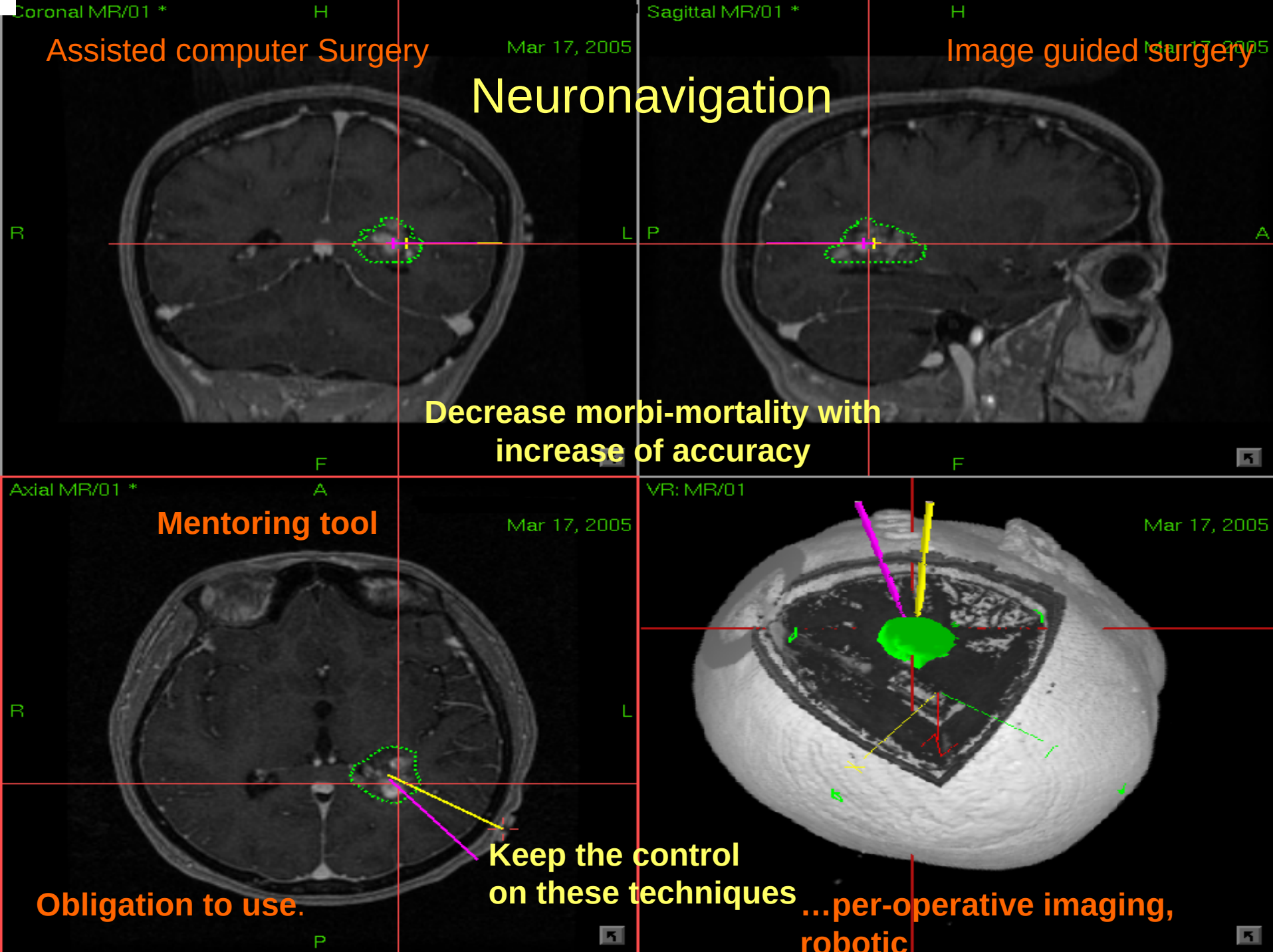


10 September 2007 Surgical Robotics, Montpellier 5-12 Sep 2007

© MARINE NATIONALE - P.-A. "CHARLES DE GAULLE"



Neuronavigation

Assisted computer Surgery

Image guided surgery

Decrease morbi-mortality with increase of accuracy

Mentoring tool

Keep the control on these techniques

Obligation to use.

…per-operative imaging, robotic

INTRODUCTION:

Robotic in Neurosurgery is one more step in our practice:

Microscope

CT-scan, MRI, MRA

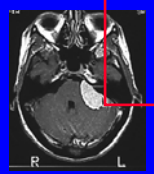
Neuronavigation (MKM (Zeiss) Val de Grâce, Paris, 1994 : Pr. Michel DESGEORGES, Toulon NOVEMBER 1999). In 199.'s it looked like « Star Wars » in France

Endoscope

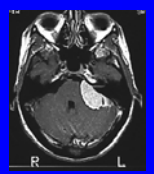
Minimal invasive neurosurgery

Robotic

Summer 2005: New system Stealth Station (Treon + Axiem) : MEDTRONIC



History



- Evolution of Knowledge

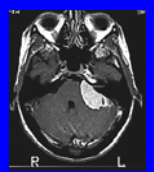
- *Anatomical step*

Middle of The XIX century with reports of cadaver dissections.

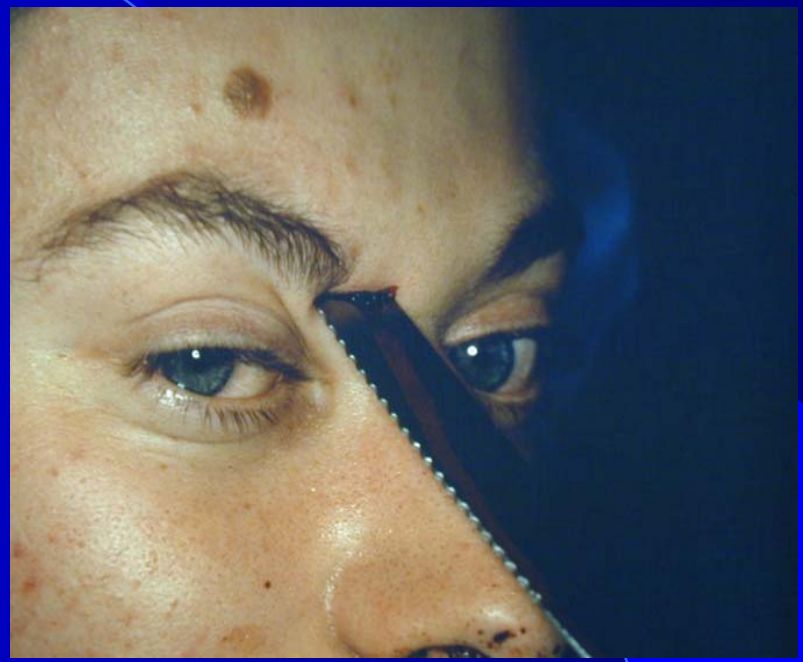
- *Therapeutic step*

First middle of the XX century

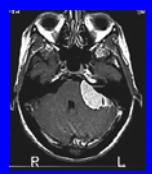
⟶ Mortality = 50 %



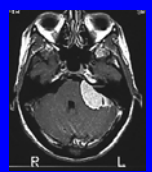
Simplified view of the surgeon: hand and knife



Truth is elsewhere !!!!



In very old times, craniotomy, yet!

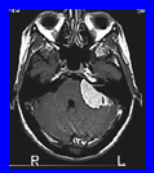


- *Therapeutic step*

- Development due to progresses of neuroradiology

  - Air, and contrast enhanced Ventriculogaphy
  - Air Encephalography
  - Carotid and Vertebral artery Angiography

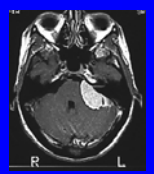
→ Invasive investigations released at intracranial hypertension status.



- *Microscope step*

- 1970… → operative mortality < 10 % — Operative microscope

- 1980… → Earlier diagnosis — CT-Scan and MRI



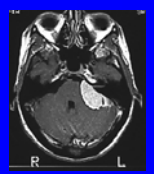
- Image guided surgery step

- 1990… → Neuronavigation

Aims: mortality 0%
or accidental
morbidity equal to pre-op.

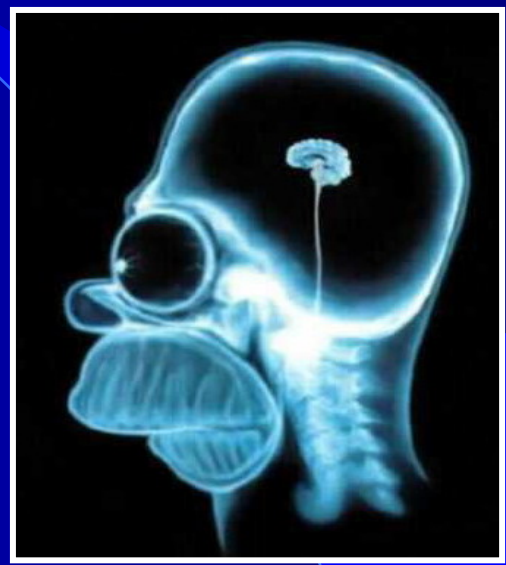
<1970
Surgery to « stay alive »

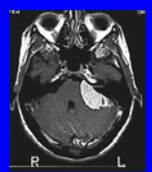
>1990
« preventive » surgery



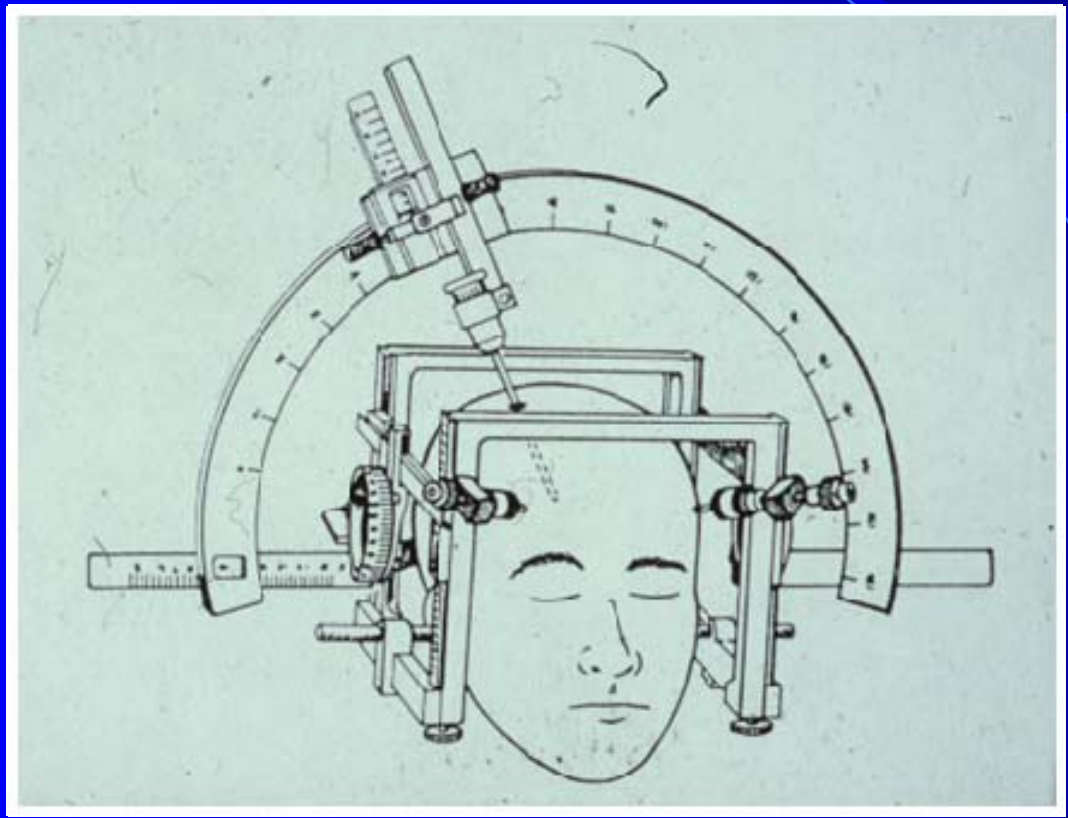
The challenges in neurosurgery

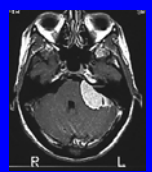
- To define the borders between tumour and brain
- Localize risks and functional area
- Confirmed the quality of resection
- To free from anatomical changes during surgery (brain shift)
- To have the better accuracy as possible (stereotactic procedures)
- To have guide-tools (biopsy-needle, DBS electrode,…)





Integration of pioneers' Brain stereotatctic atlases in softwares.





Steps of a navigated procedure

Imaging Department

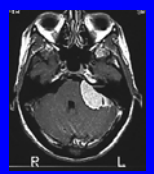
Images Acquisition

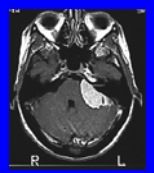
Neurosurgical Department

Operative Planning

Operating Room

(Operative Planning)
Mapping
Image Guided Surgery
Microscope with Robotic arm




R
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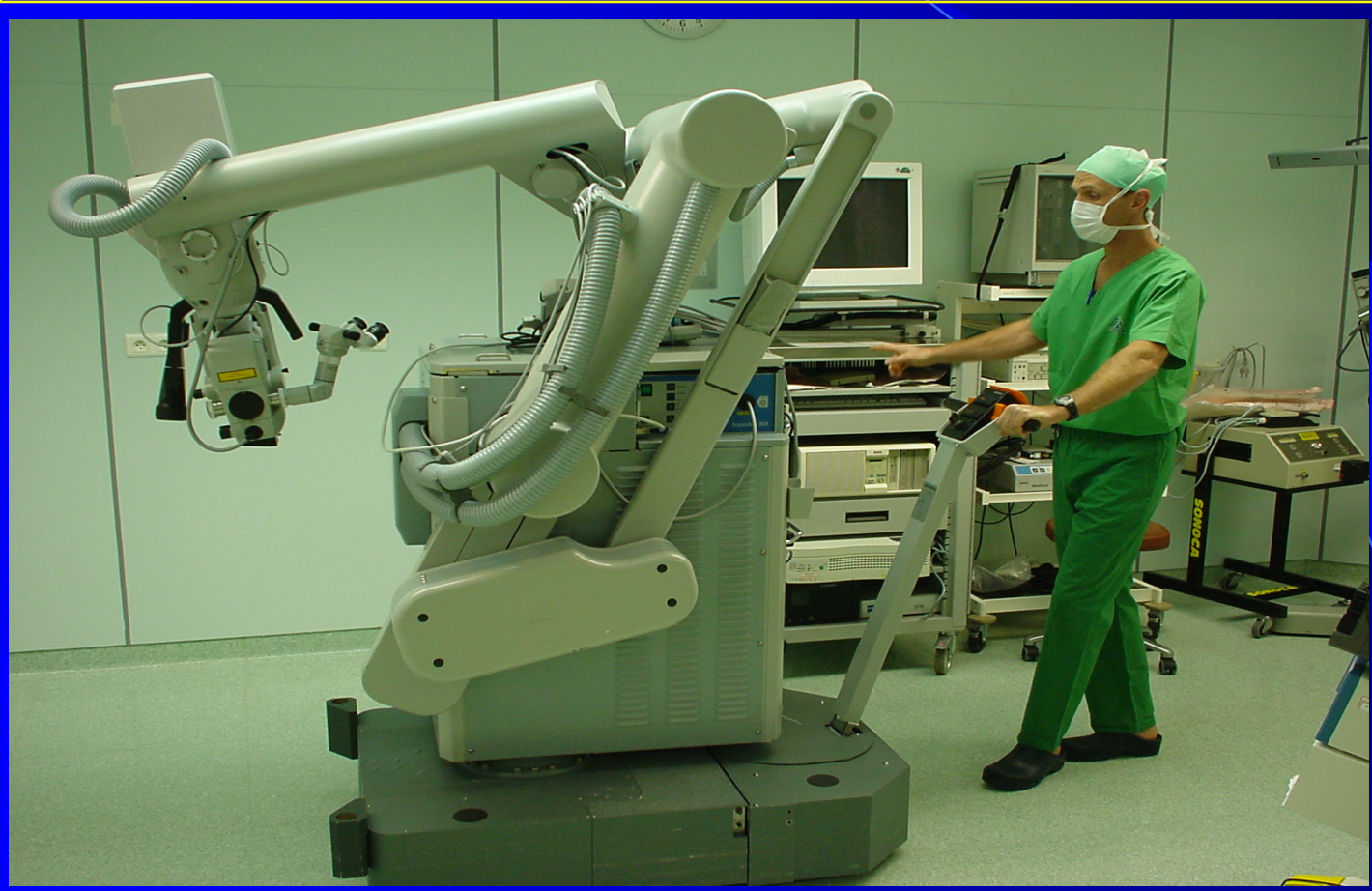
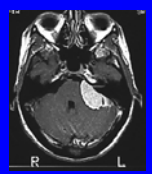
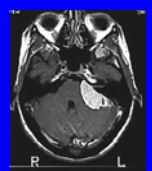
TOOLS: MKM (ZEISS®)

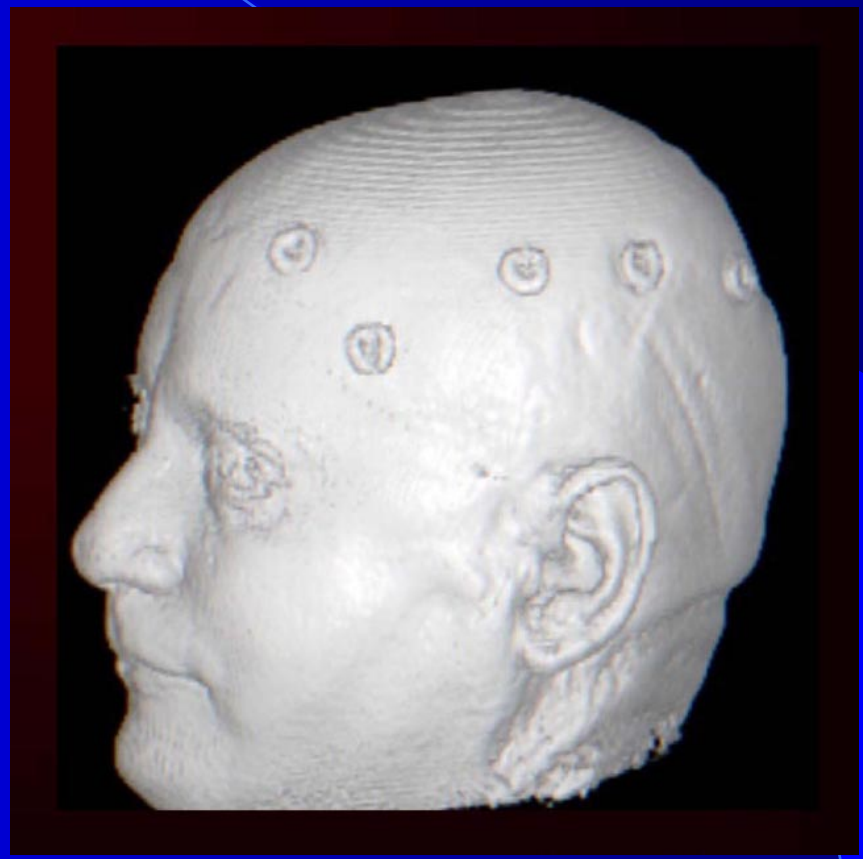


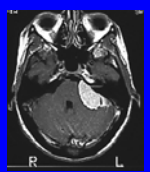


TOOLS: Station Treon MEDTRONIC®

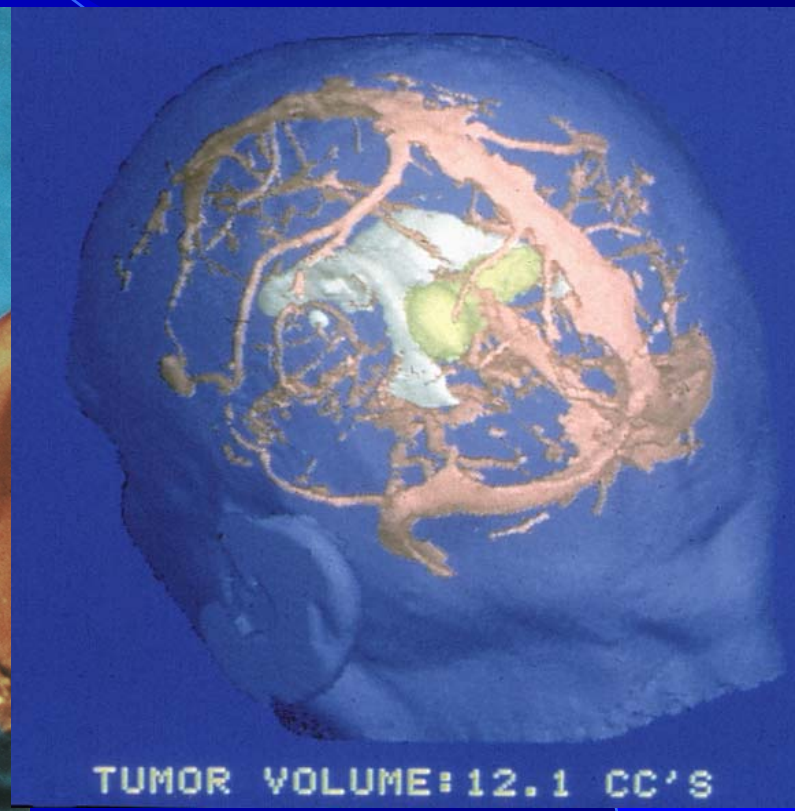


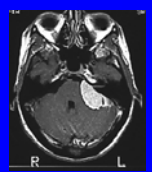
Fiducials for mapping

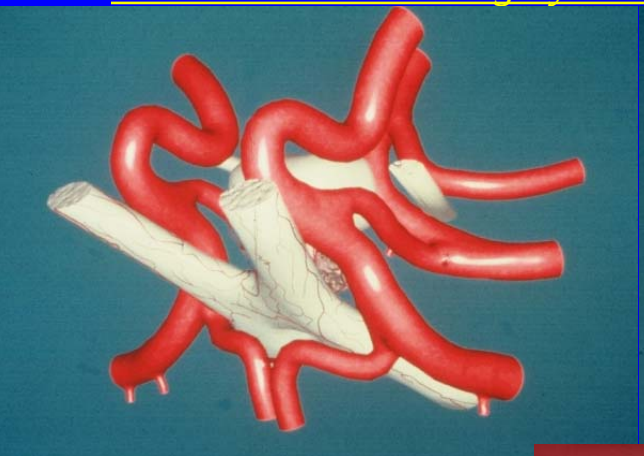


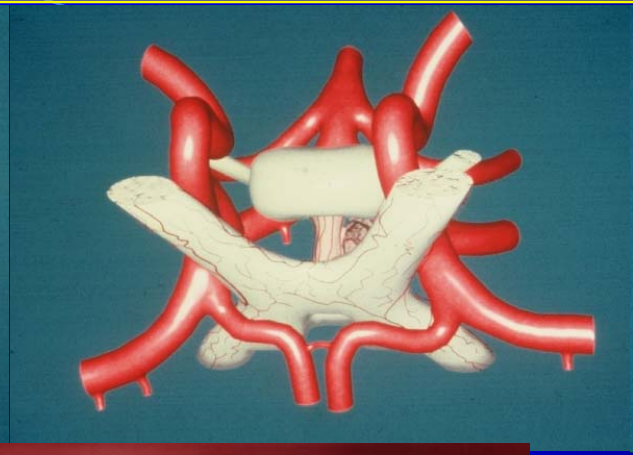


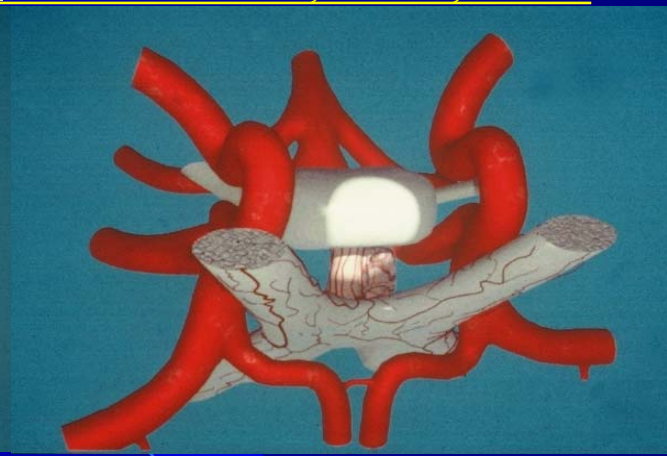
The revolution around Neurosurgery: Neuroimaging



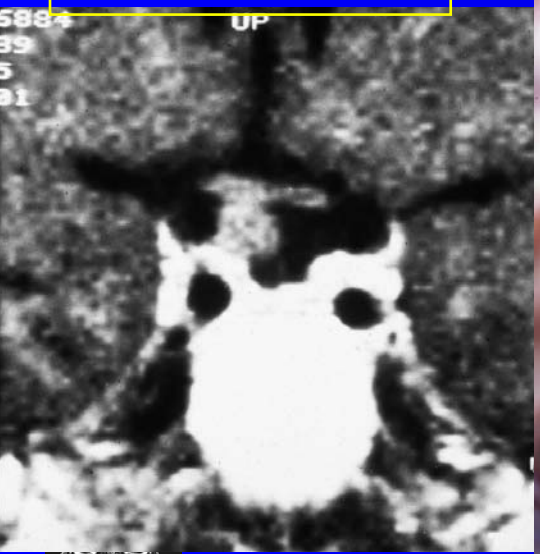


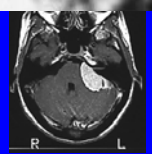






Planning





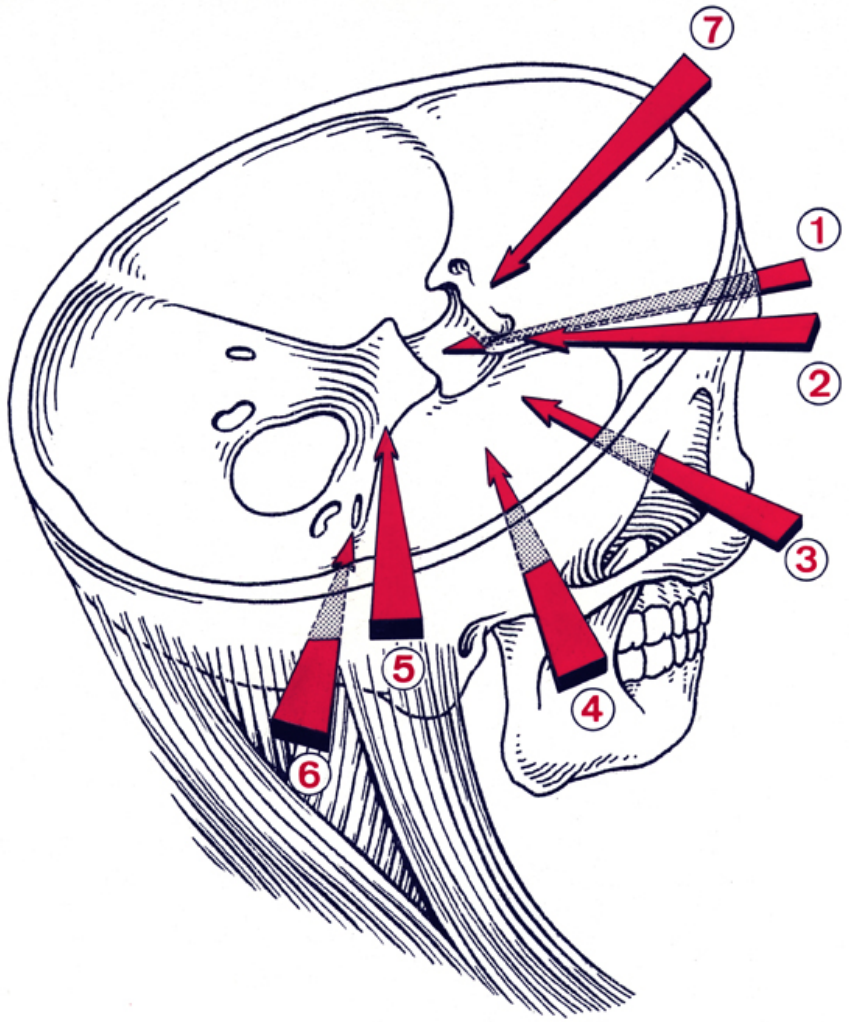
Cédric BERNARD, 10 September 2007

Planning

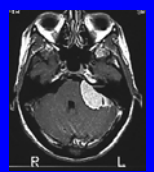
Aim: find anatomically preformed spaces on the way to the pathology by preoperative Imaging:

INDIVIDUAL ANATOMY OF THE PATIENT

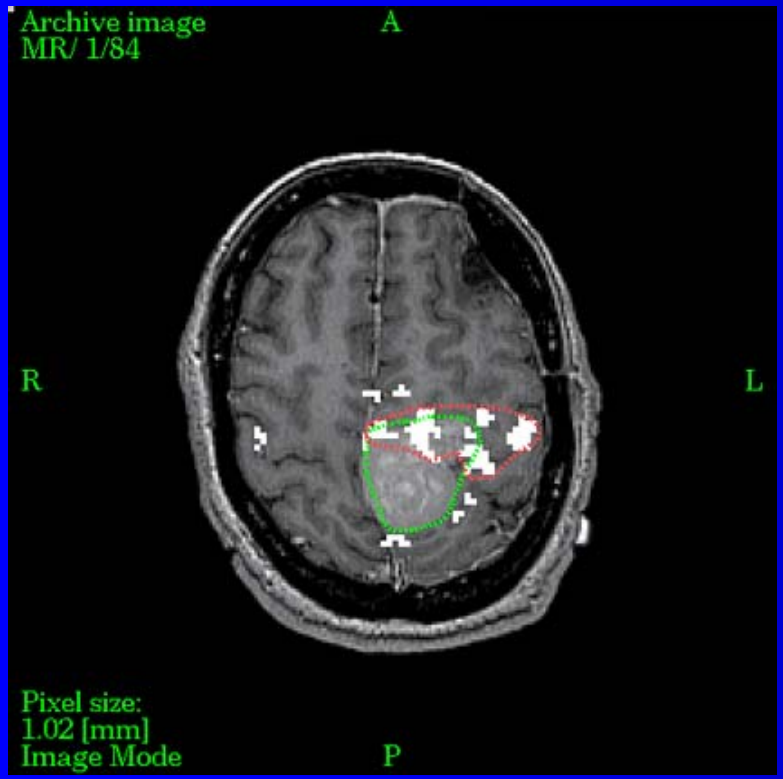
INDIVIDUAL ANATOMY

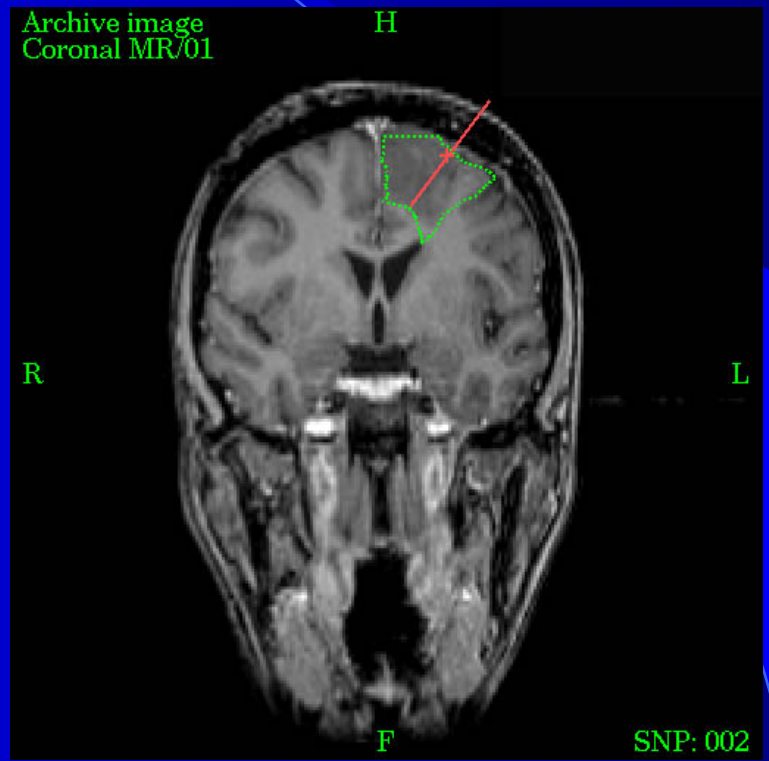


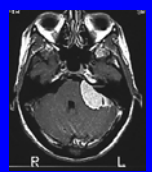
INDIVIDUAL APPROACH



Operative Planning

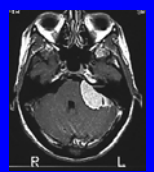






Operative Planning

- Images fusion (fMRI, Brain scintigraphy, MRI, Pet-scan, CT-Scan, MRA, DTI sequences,…)
- Definition of tumour borders, risks areas, functional areas,…
- Three-dimensional reconstruction,
- Definition of a trajectory,
- Simulation of surgical access in different plans



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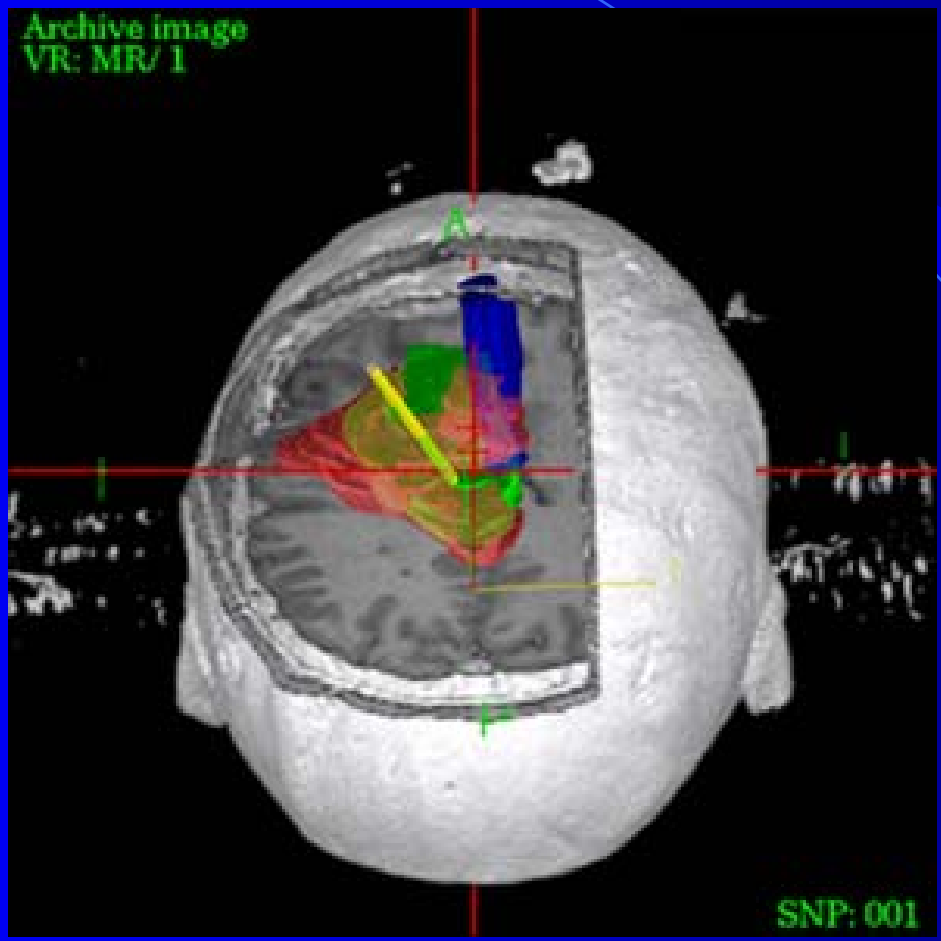
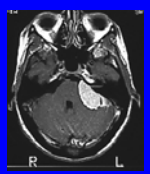
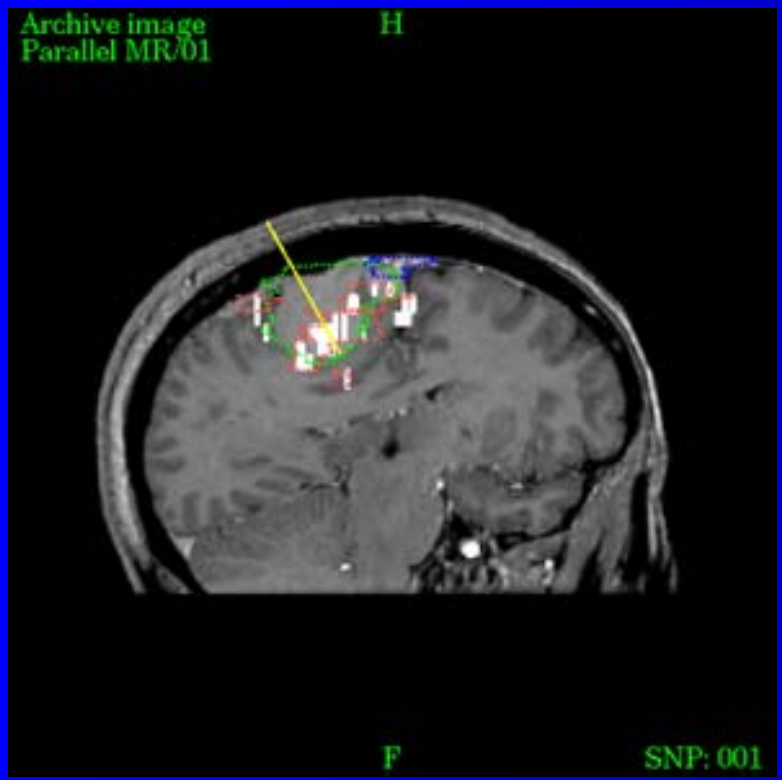
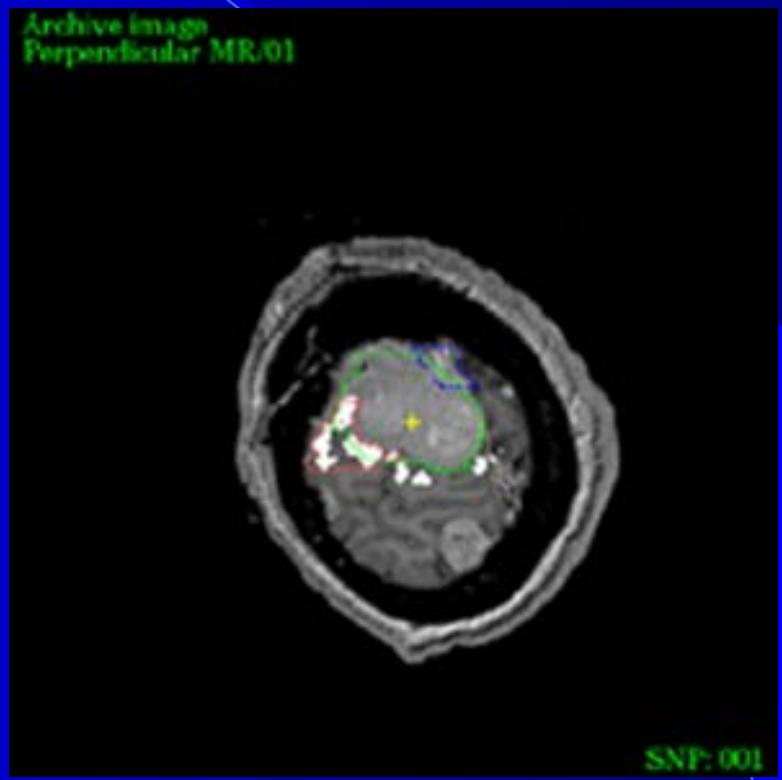
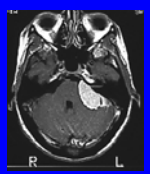




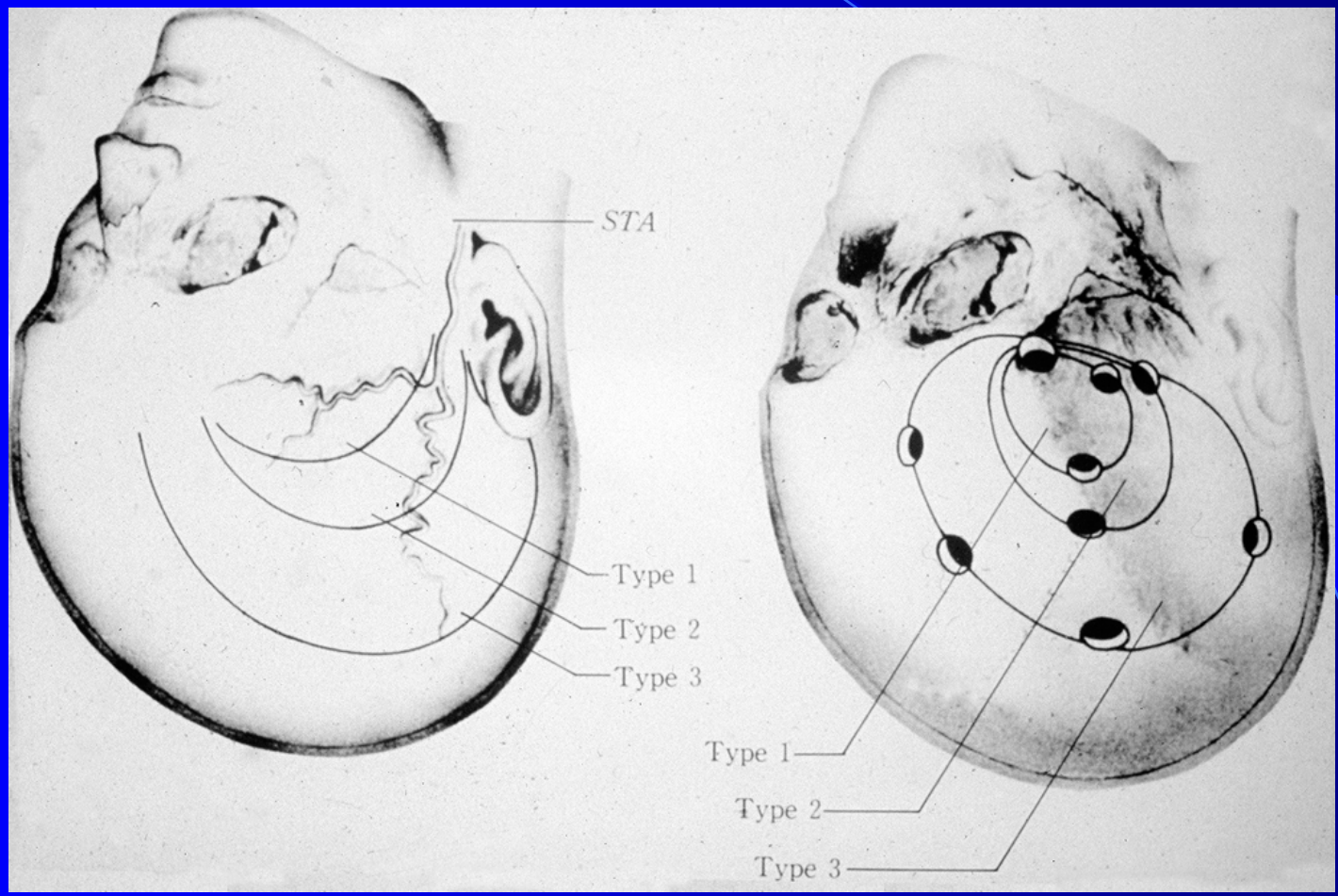
Operative Planning

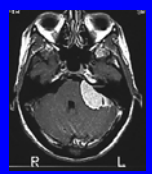


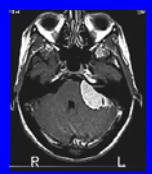




Size of craniotomy: just what is needed



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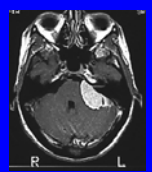
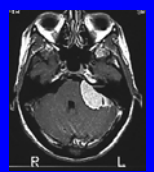
Volumes mapping
« Patient head » and « MRI volume »
Now: surface mapping with pointer

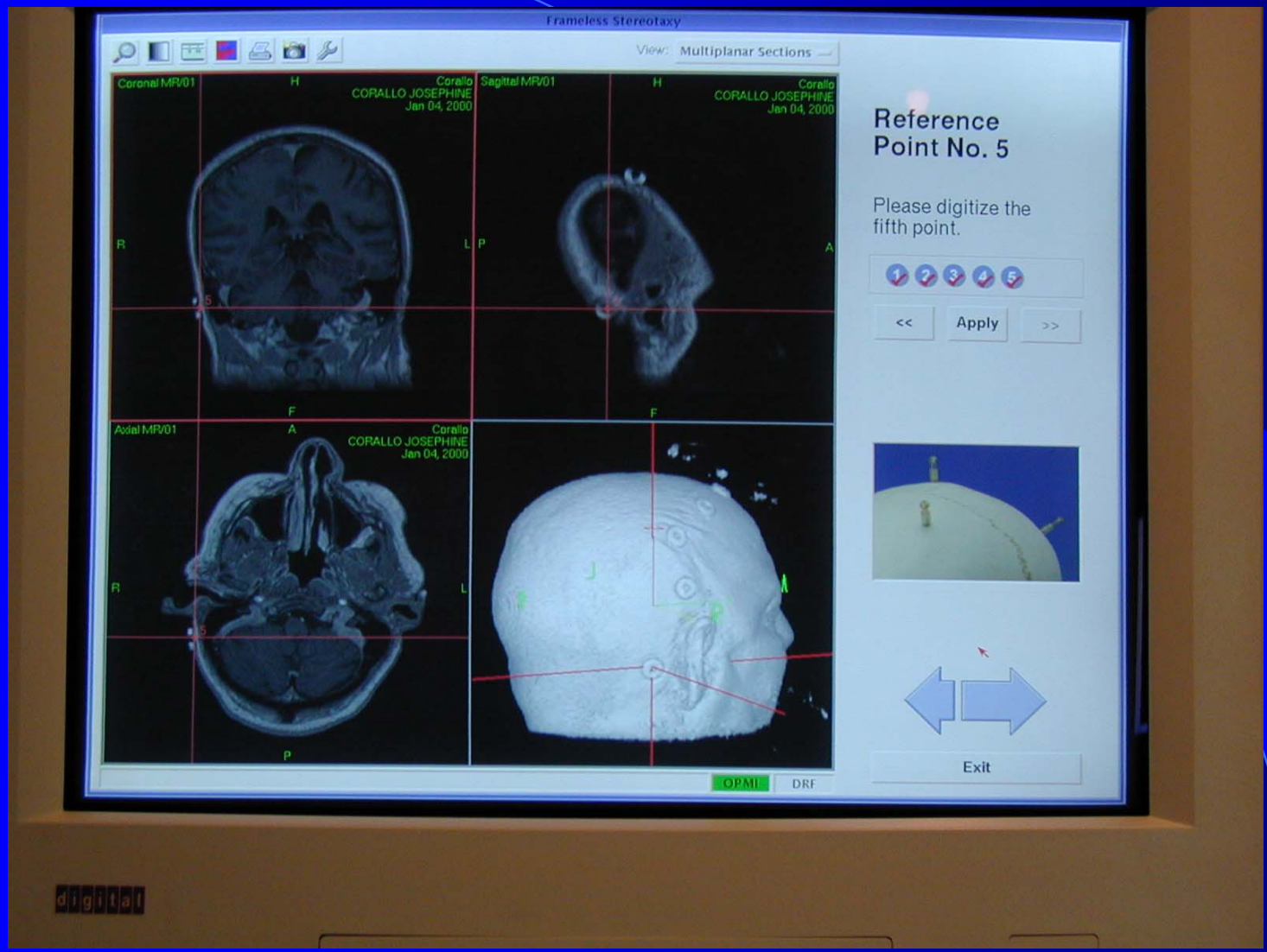


Mapping

- surface mapping
- optical(laser) on microscope
- Infra-red ou Electromagnetic

Notion of accuracy of correlation




Frameless Stereotaxy
View: Multiplanar Sections
Coronal MR/01
Corallo
CORALLO JOSEPHINE
Jan 04, 2000
Sagittal MR/01
Corallo
CORALLO JOSEPHINE
Jan 04, 2000
Axial MR/01
Corallo
CORALLO JOSEPHINE
Jan 04, 2000
Reference Point No. 5
Please digitize the fifth point.
<<
Apply
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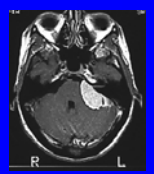
Exit
OPMI
DRF




Frameless Stereotaxy
View: Multiplanar Sections
Coronal MR/01
Sagittal MR/01
Axial MR/01
Perpendicular MR/01
Corallo
CORALLO JOSEPHINE
Jan 04, 2000
Operation
Microscope
DRF
ptr_135
Patient Coordinates: (x, y, z) =
18.9
35.8
52.7
Tip Zoom:
0.0
mm
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RESET
[+] >>
Freeze ON/OFF
Exit
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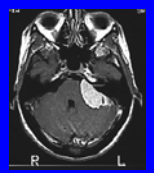


Concept of Minimally Invasive Neurosurgery

PRIMUM NON NOCERE

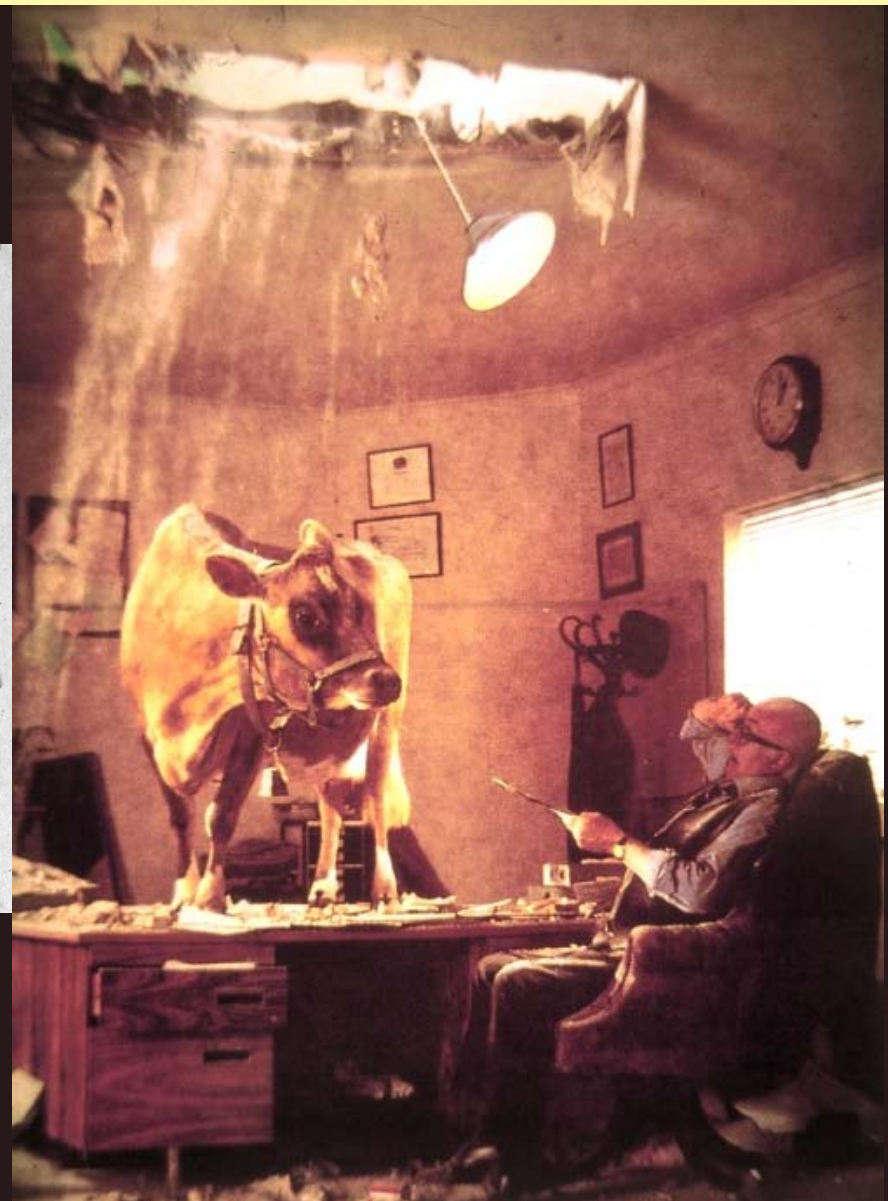
("Firstly, do not harm the patient")

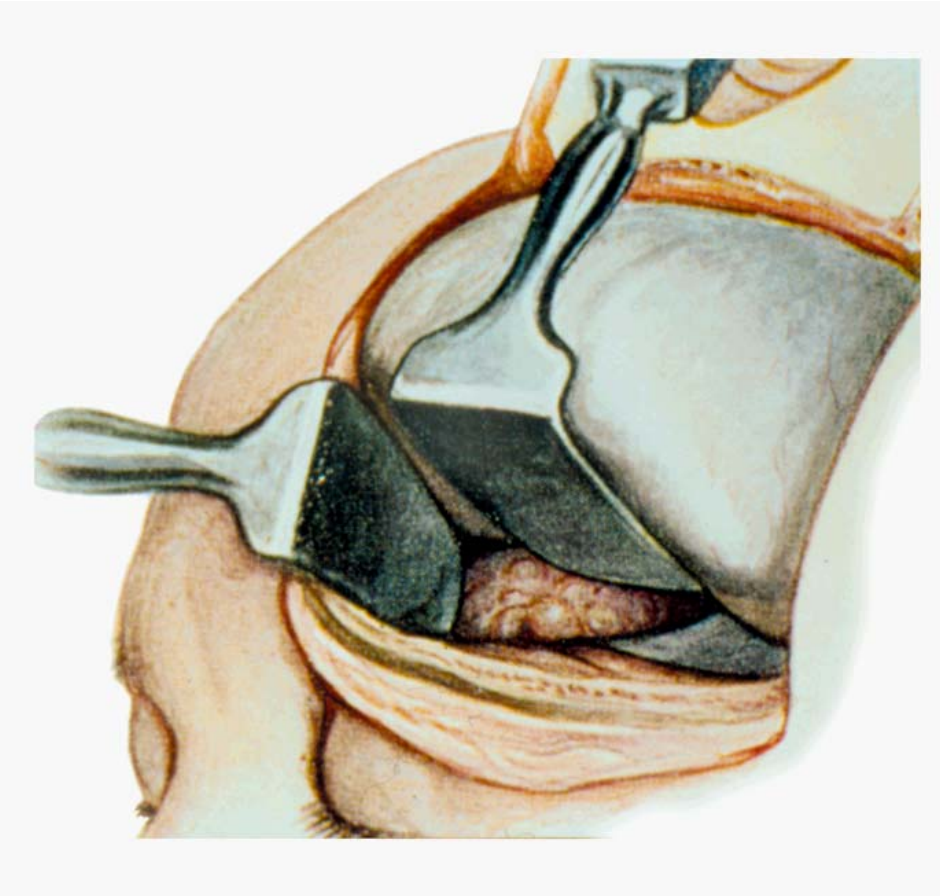
HIPPOCRATES

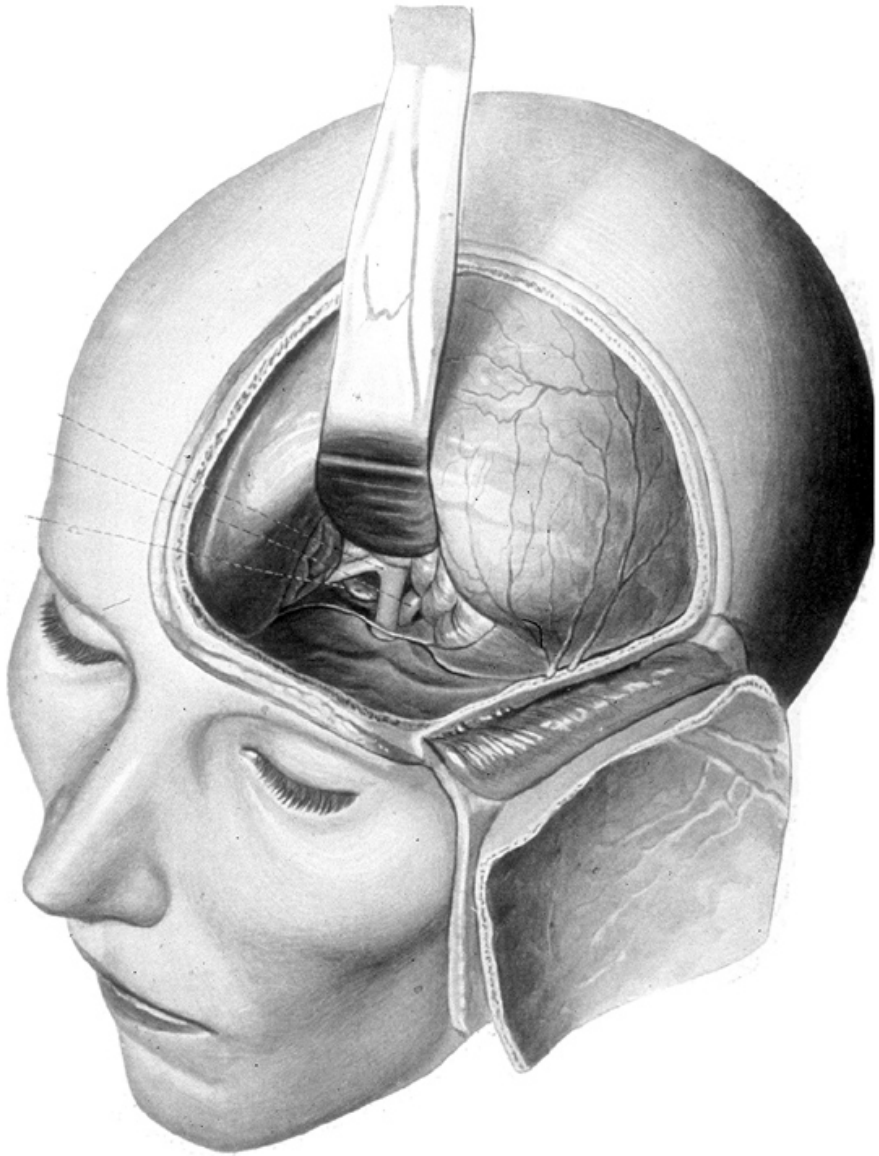
Definition of Minimally Invasive:

The lowest medical traumatization combined with the highest therapeutic effect

Doors and Windows



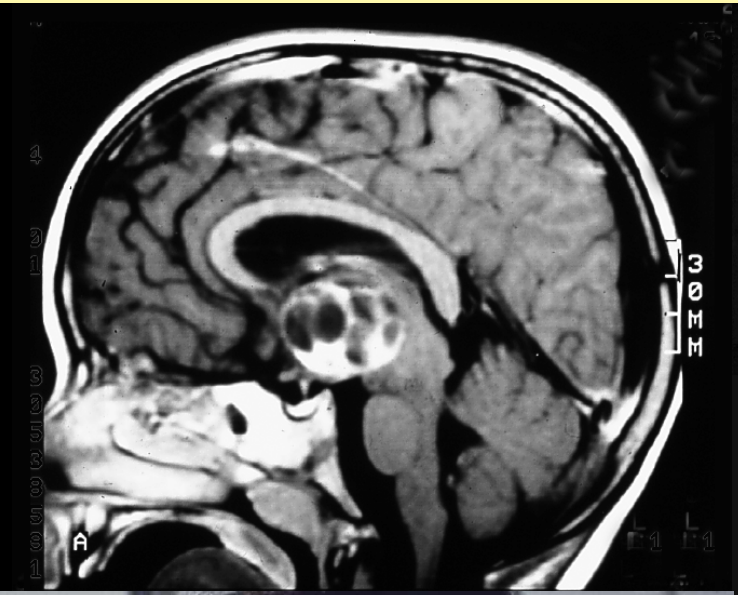




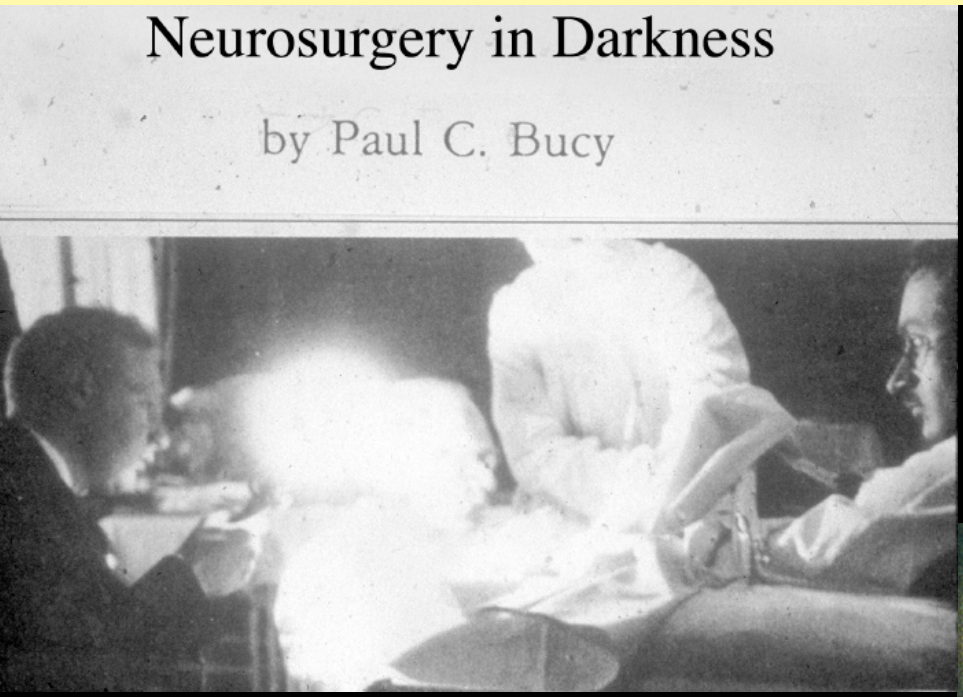
F. Krause (1908)

Tandler -Ranzi (1932)

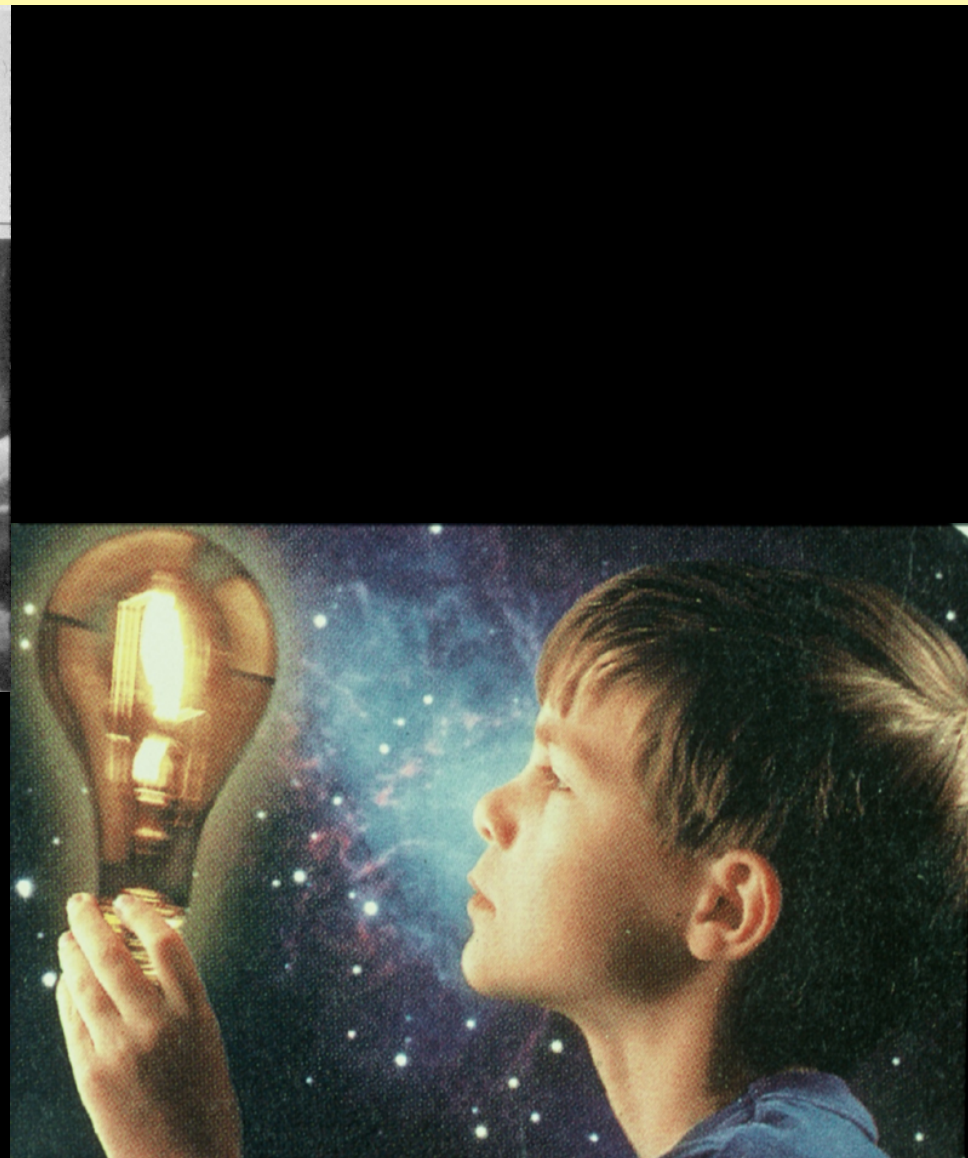
Craniopharyngioma
Supraorbital Approach



Visualisation and Light

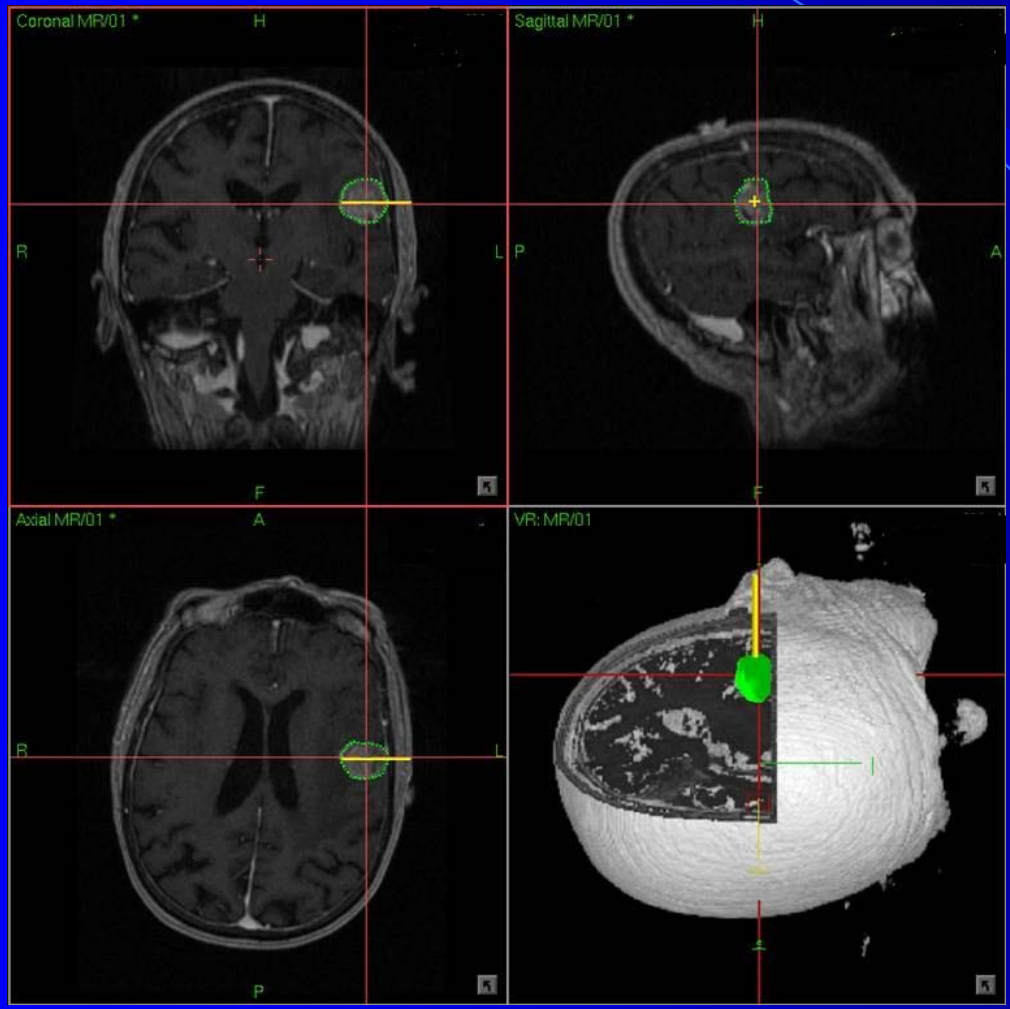


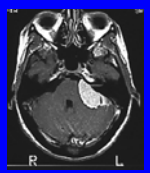
P. Bucy, O. Foerster



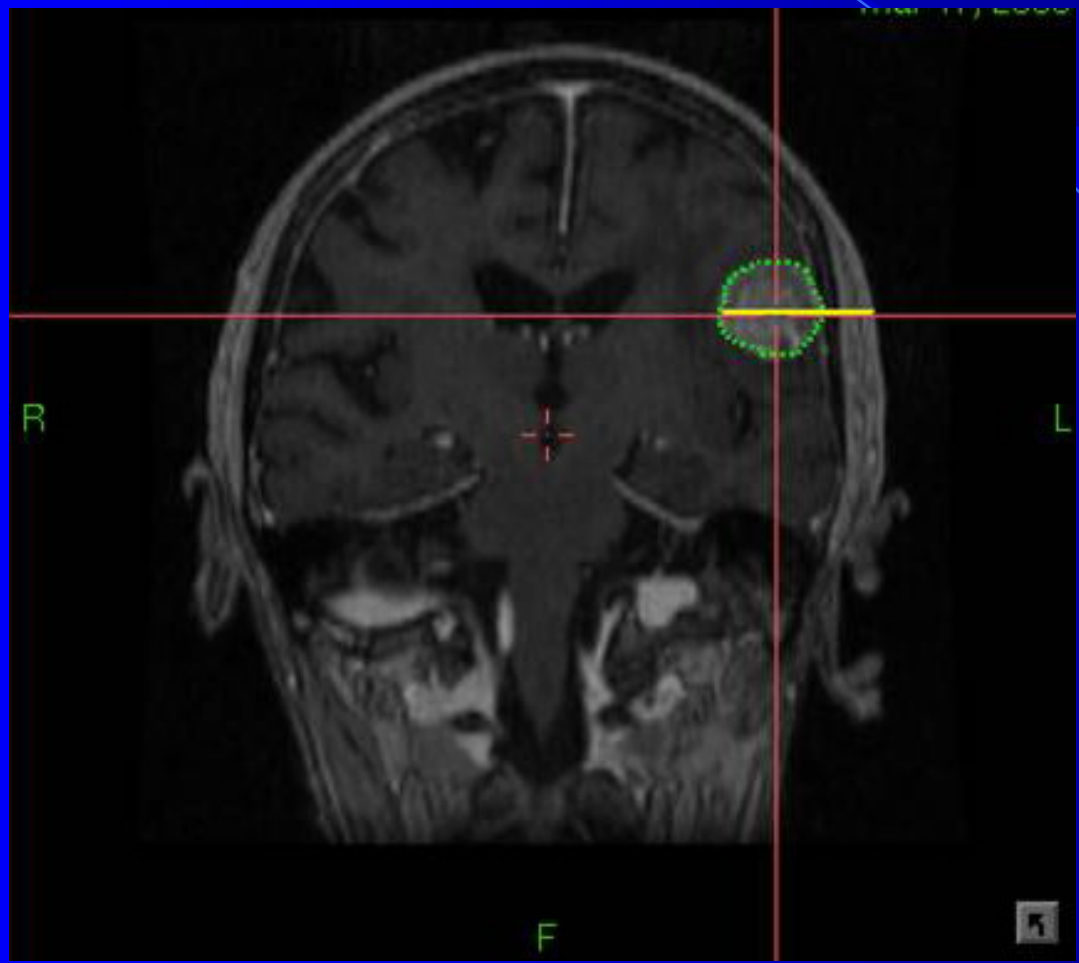

MKM: Microscope + Navigation + Robotic Arm

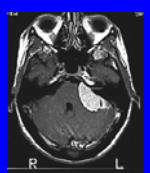
Frontal metastasis February 2001

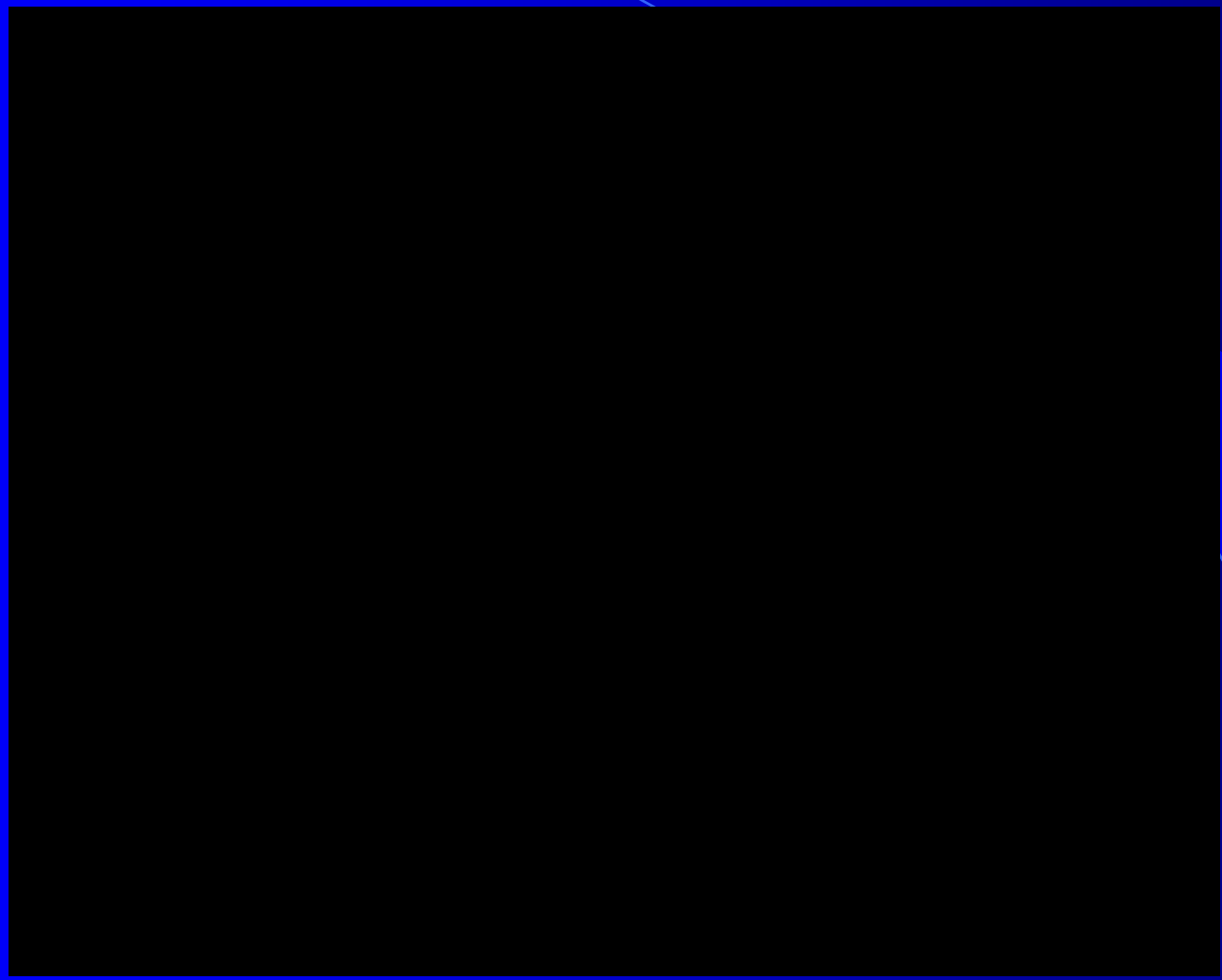


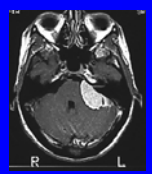


Frontal metastasis February 2001





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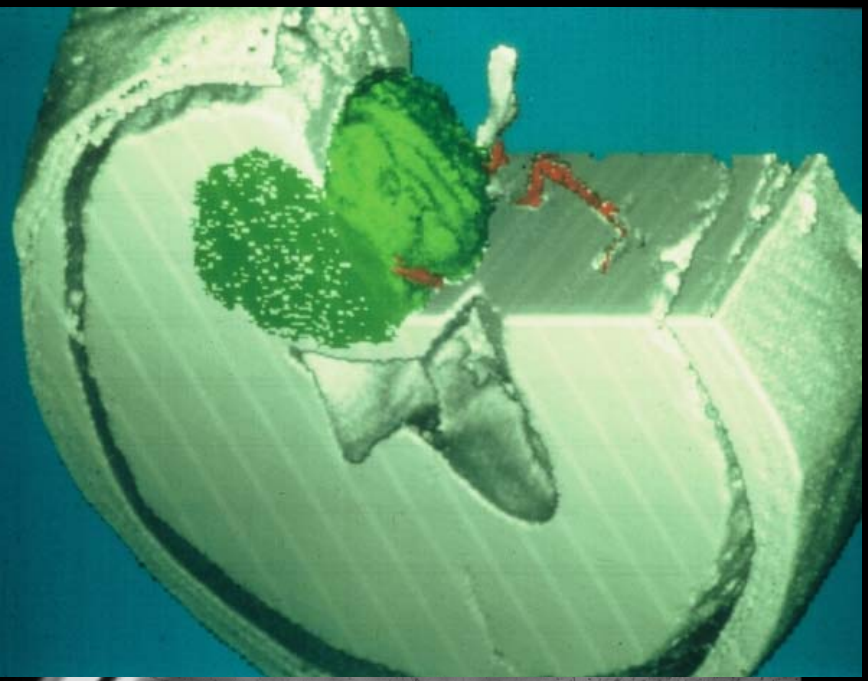
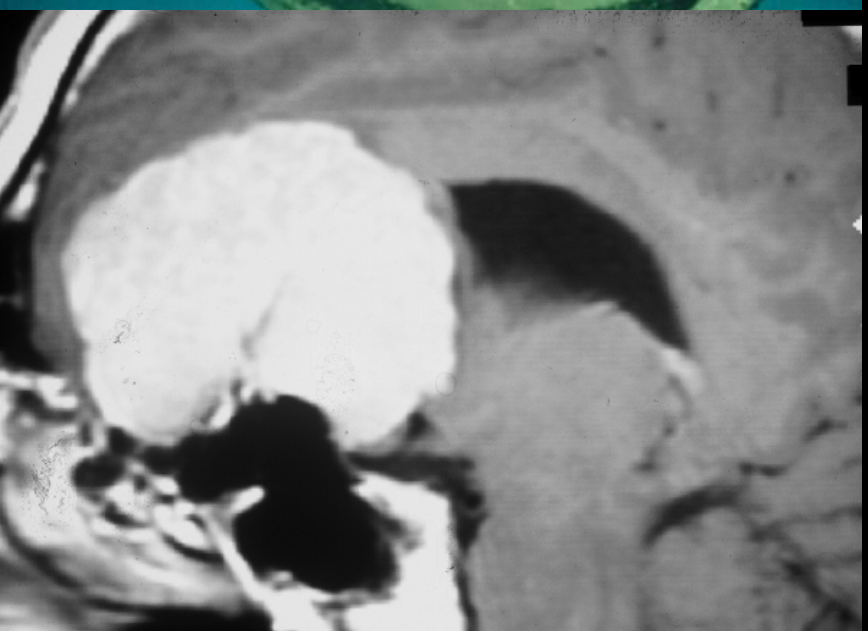
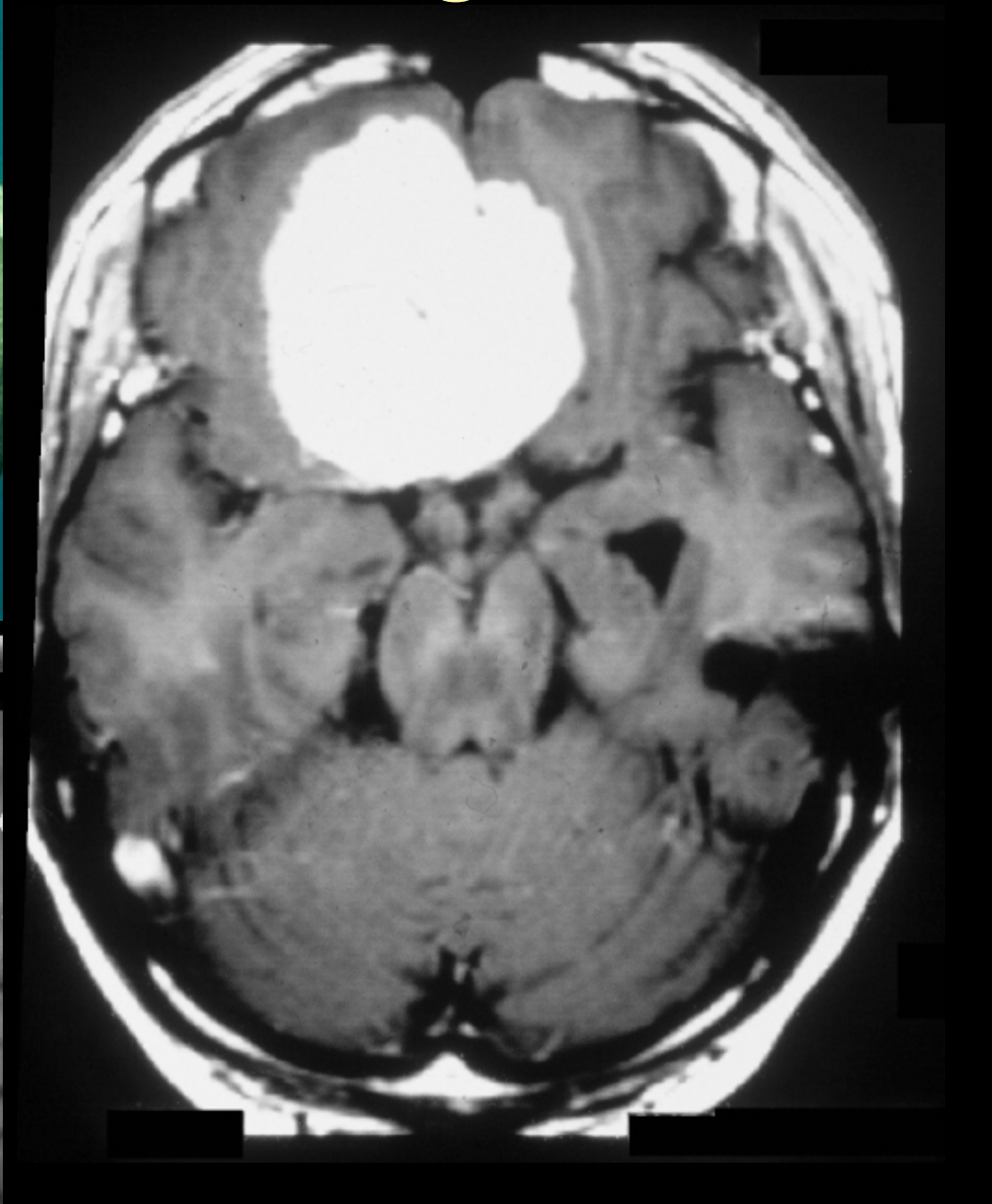
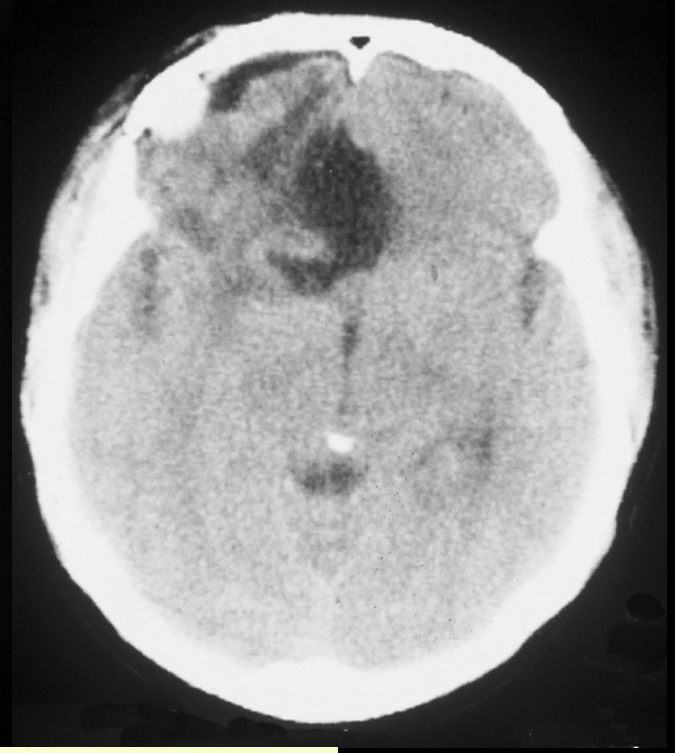
Frontobasal meningioma



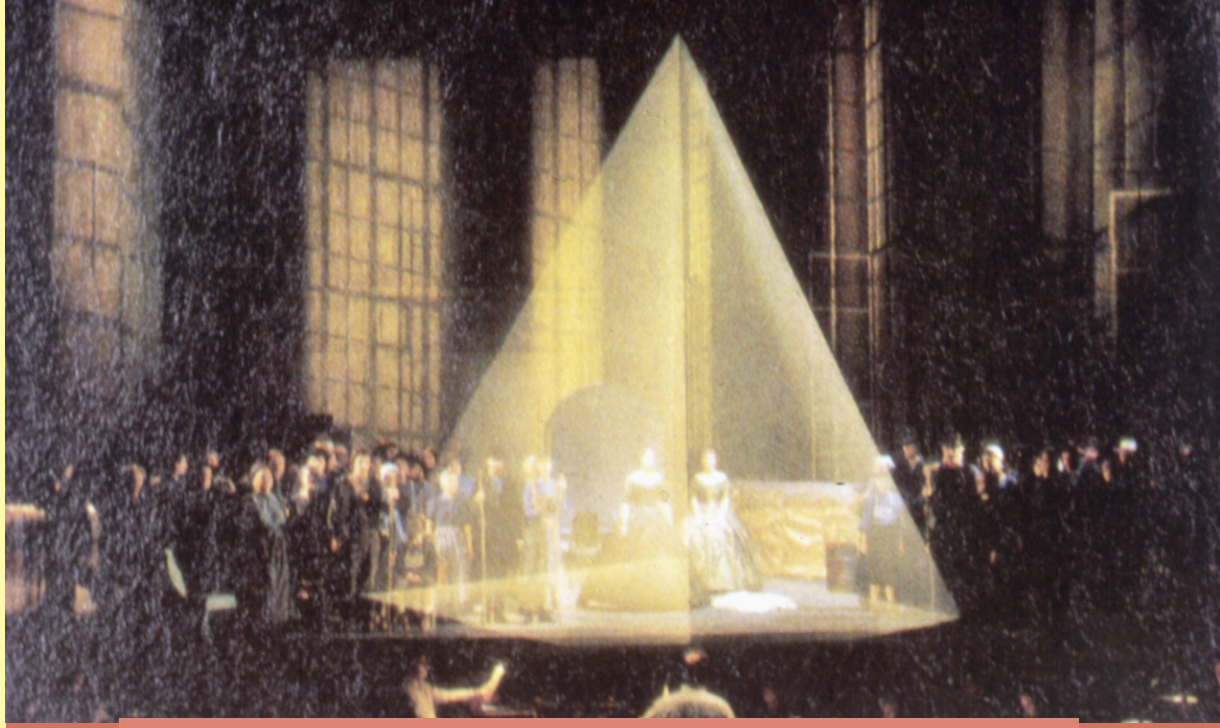


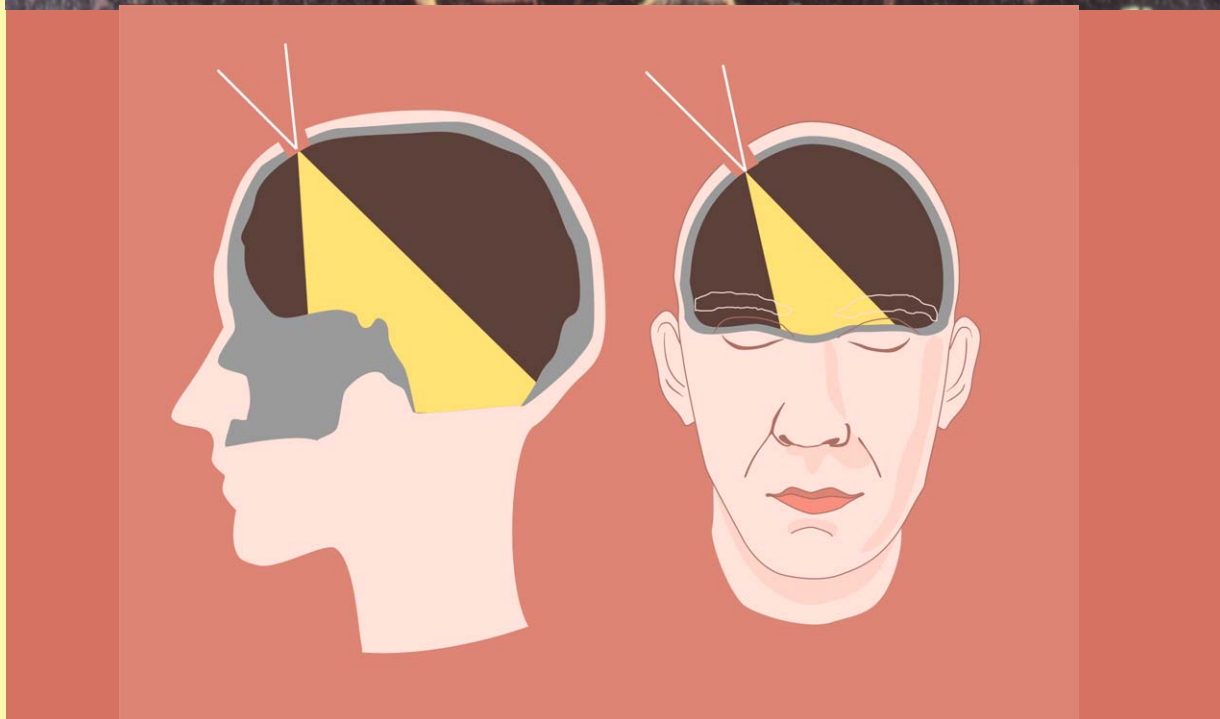




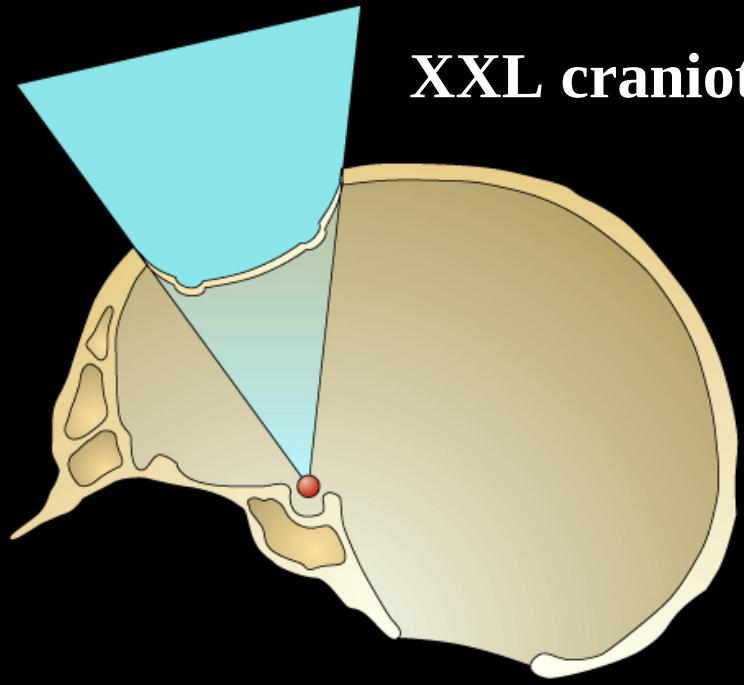
The Key-hole Concept in Neurosurgery

Sector-like widening of the visual field



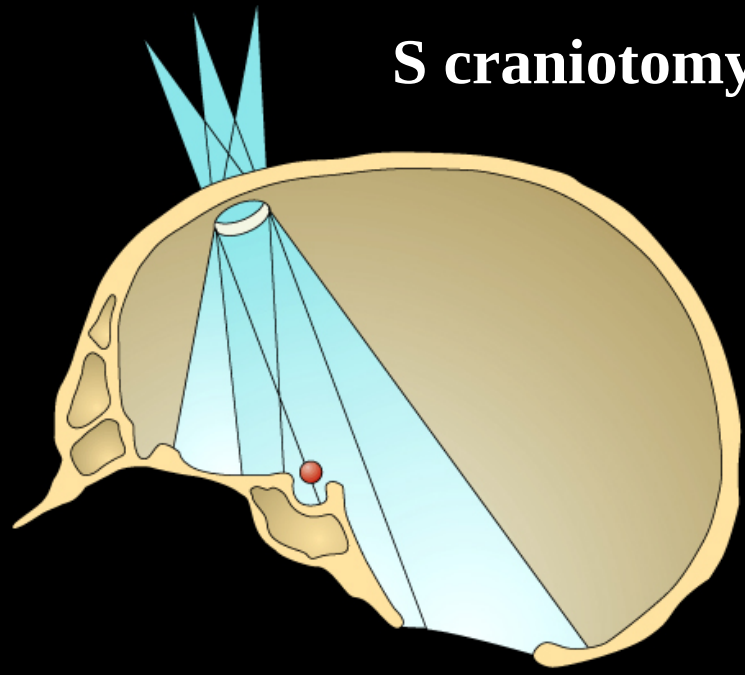


XXL craniotomy

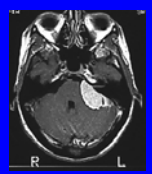


old surgical concept

S craniotomy



keyhole concept



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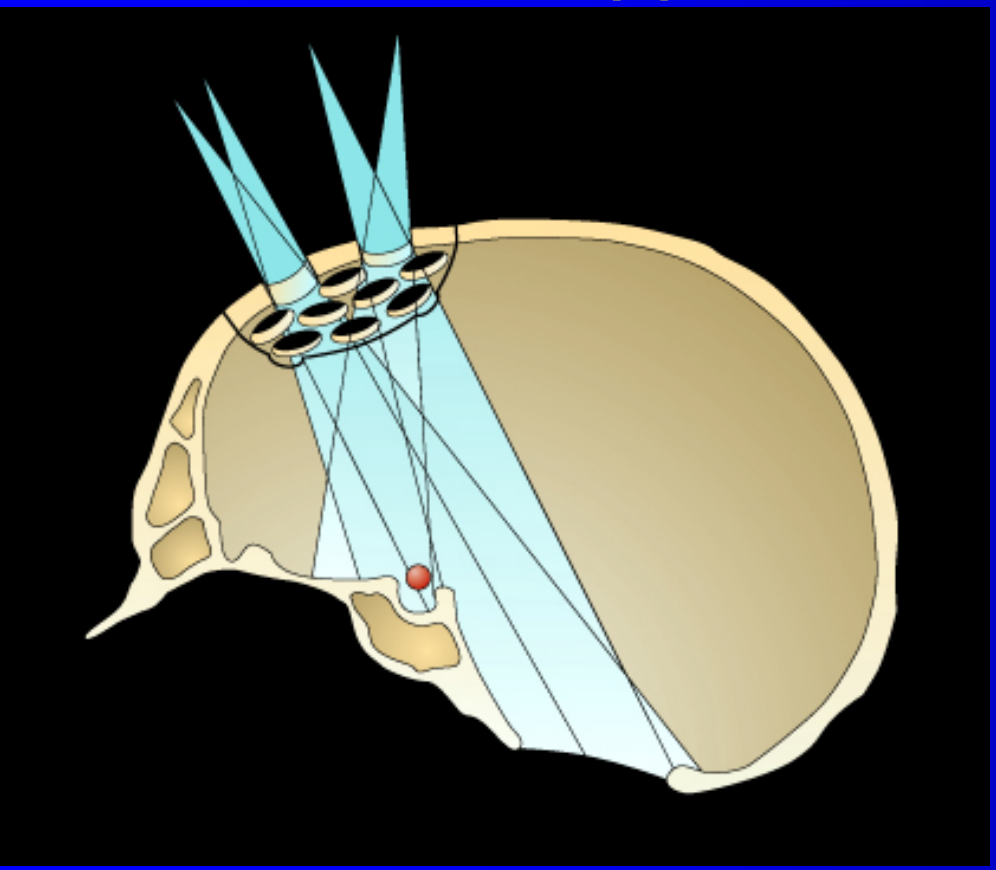
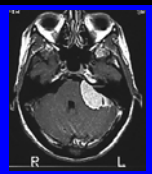
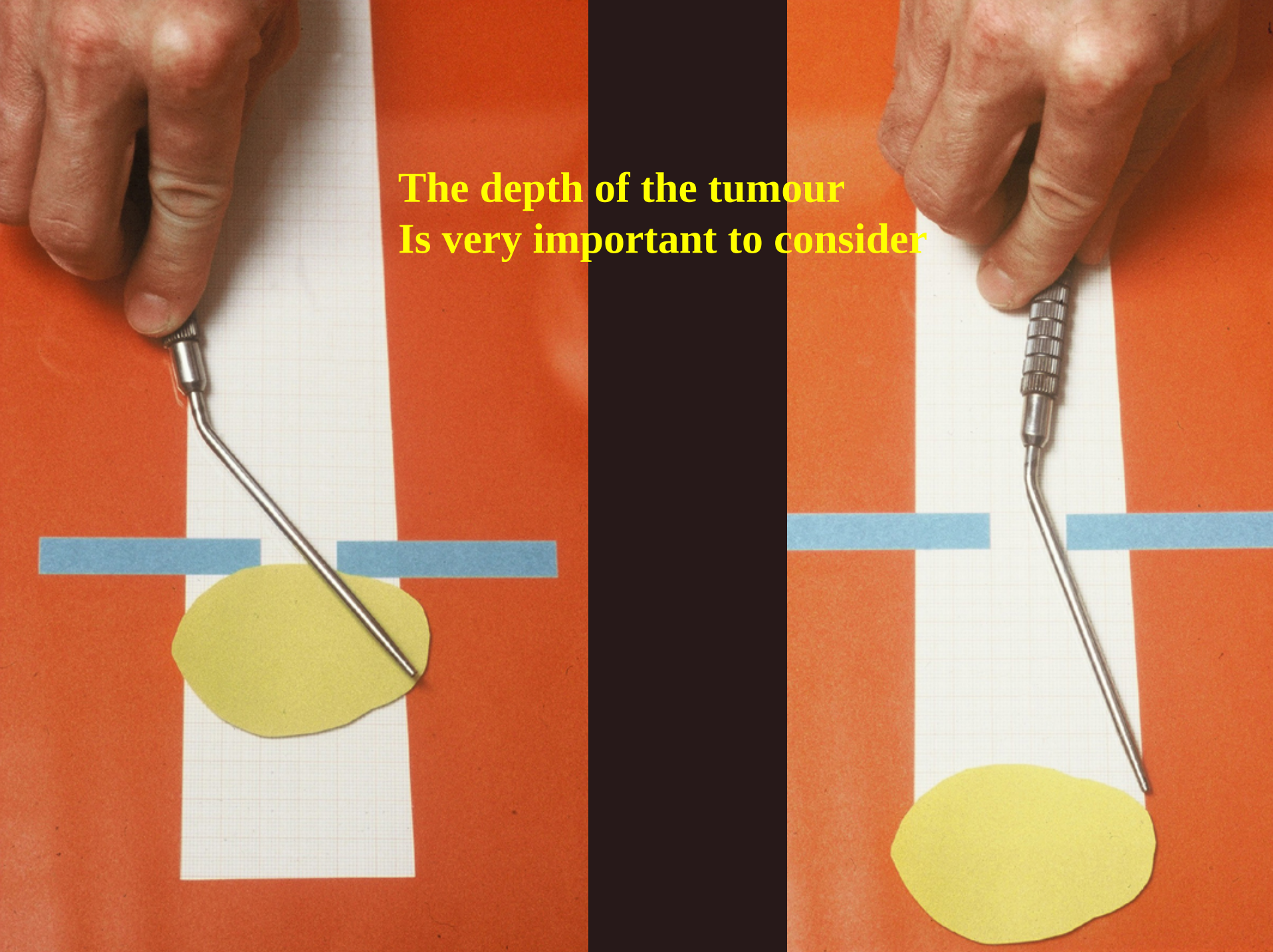
Standard approach = collection of keyhole approaches

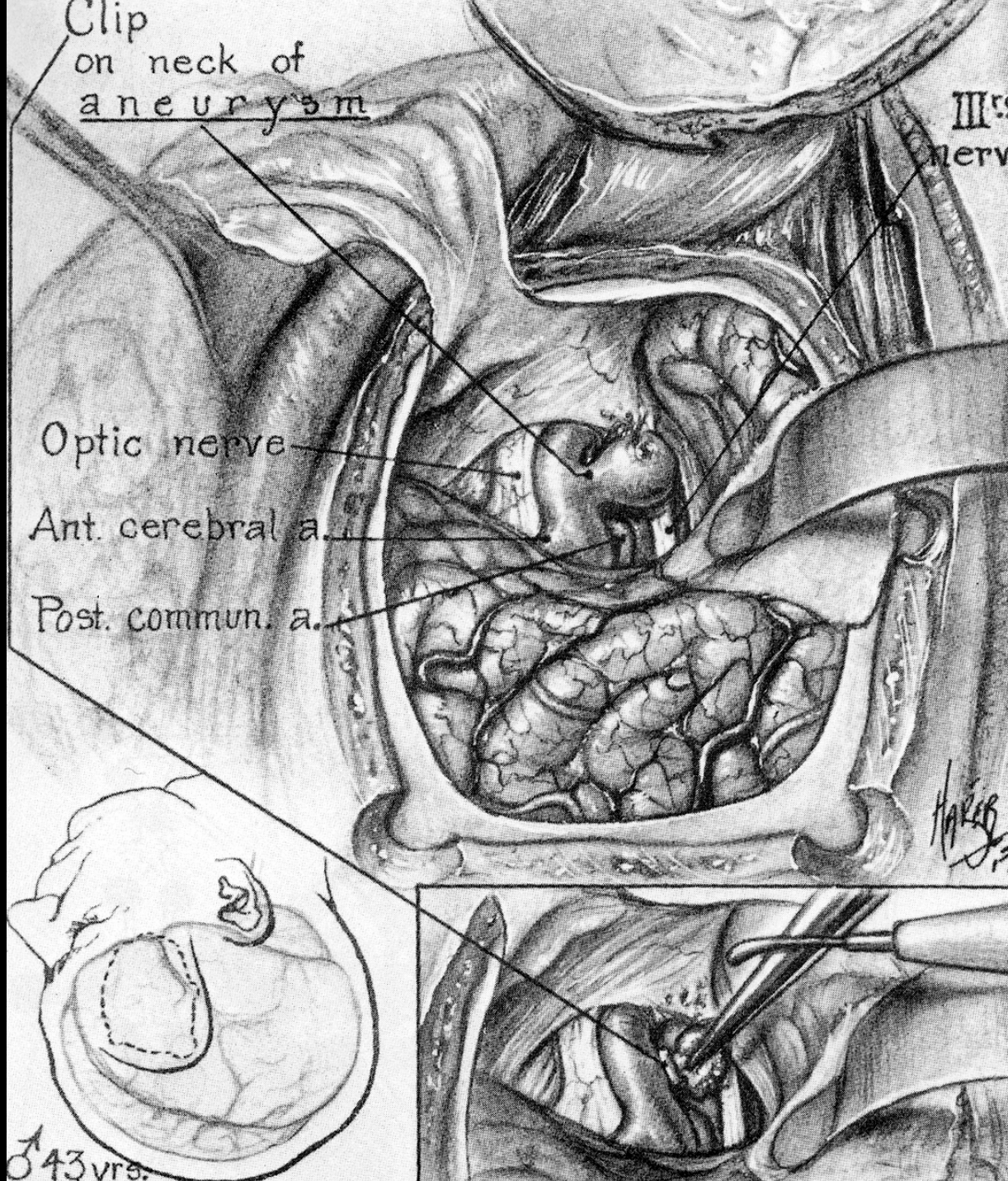


Individual choice of combination of key-holes according to the individual planning.

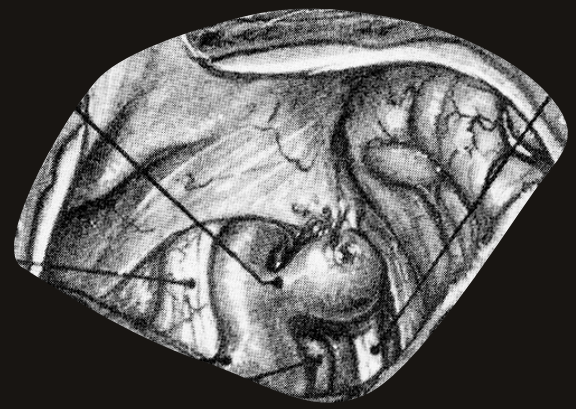



The depth of the tumour
Is very important to consider

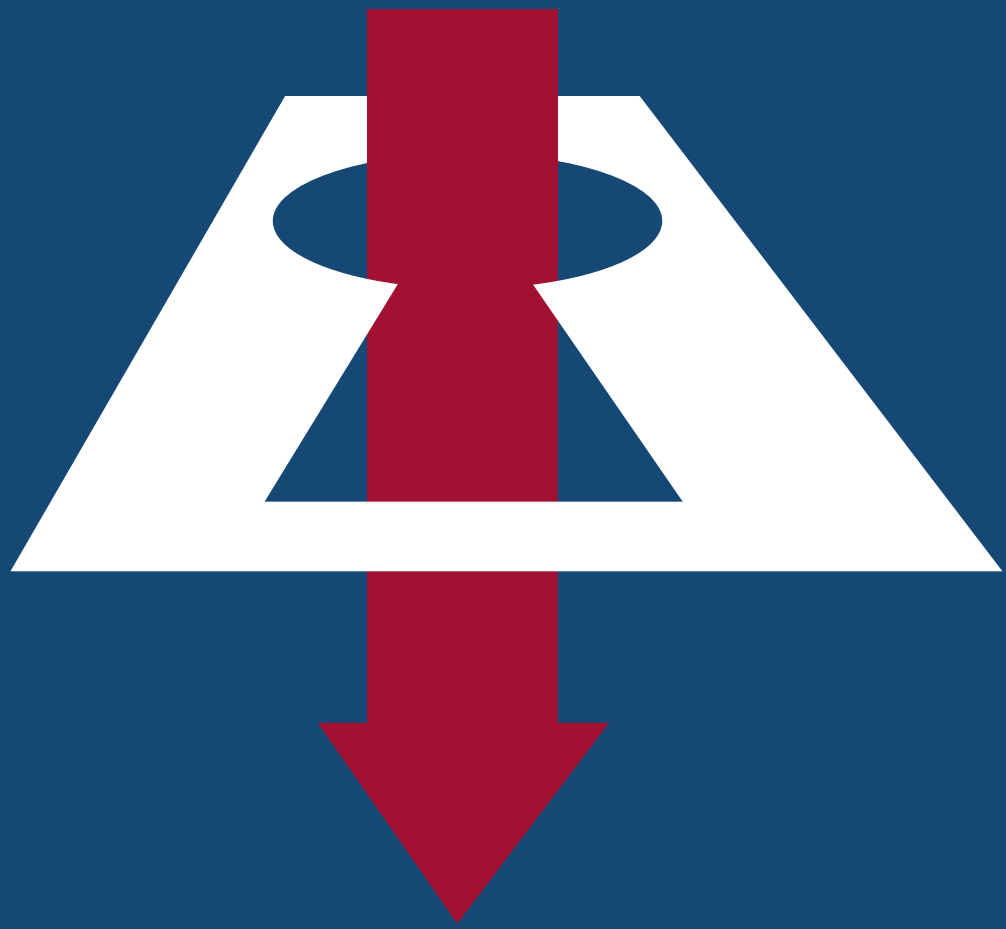
Which part was needed for the exposure?



Which part was needed for the exposure?



Key-hole

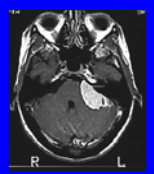


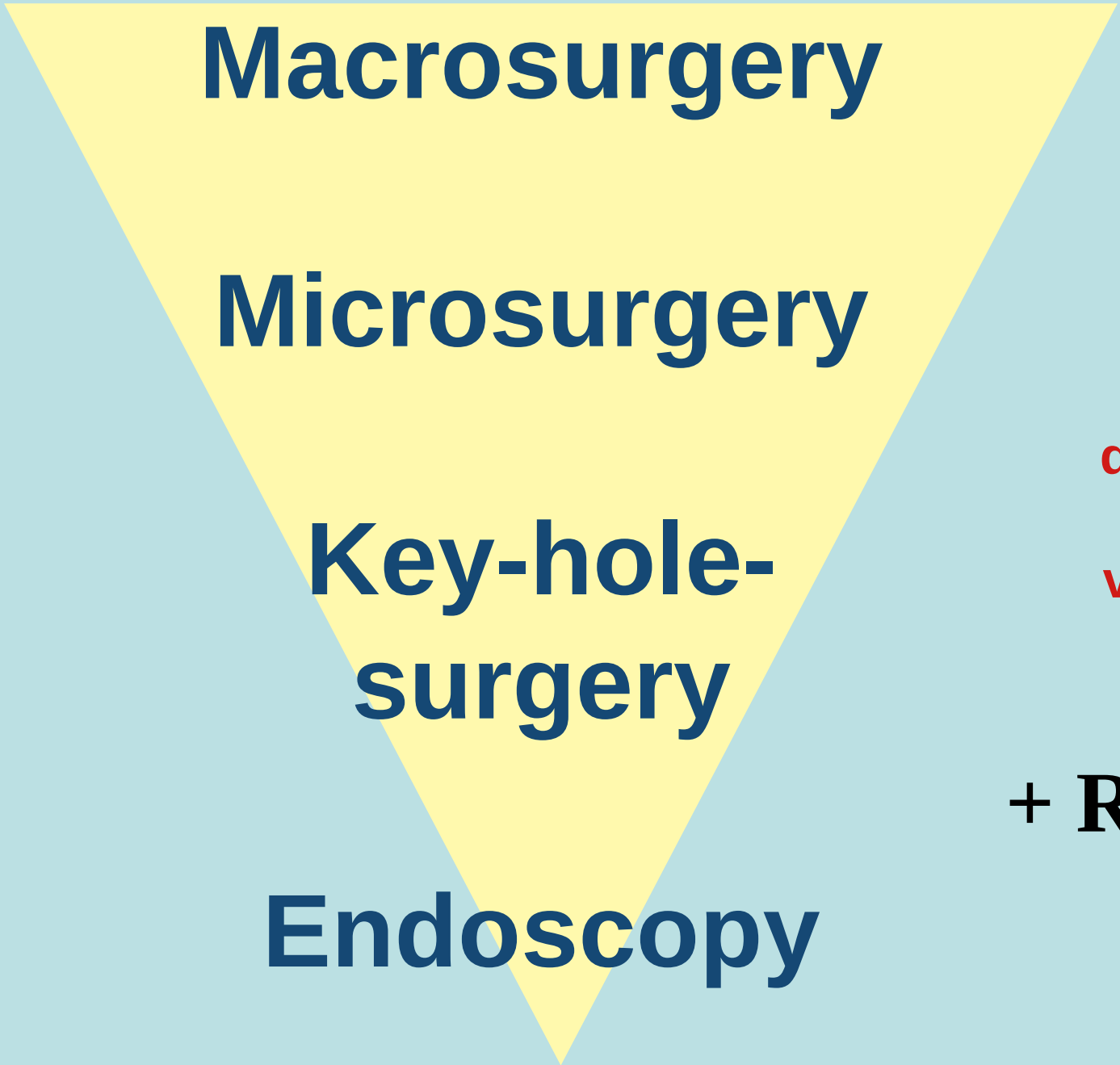
Contra lateral approaches

Most important part
of keyhole surgery

Surgical-anatomical

PLANNING





development of light and visualisation

+ Robotic

Neuroendoscopy new dimension

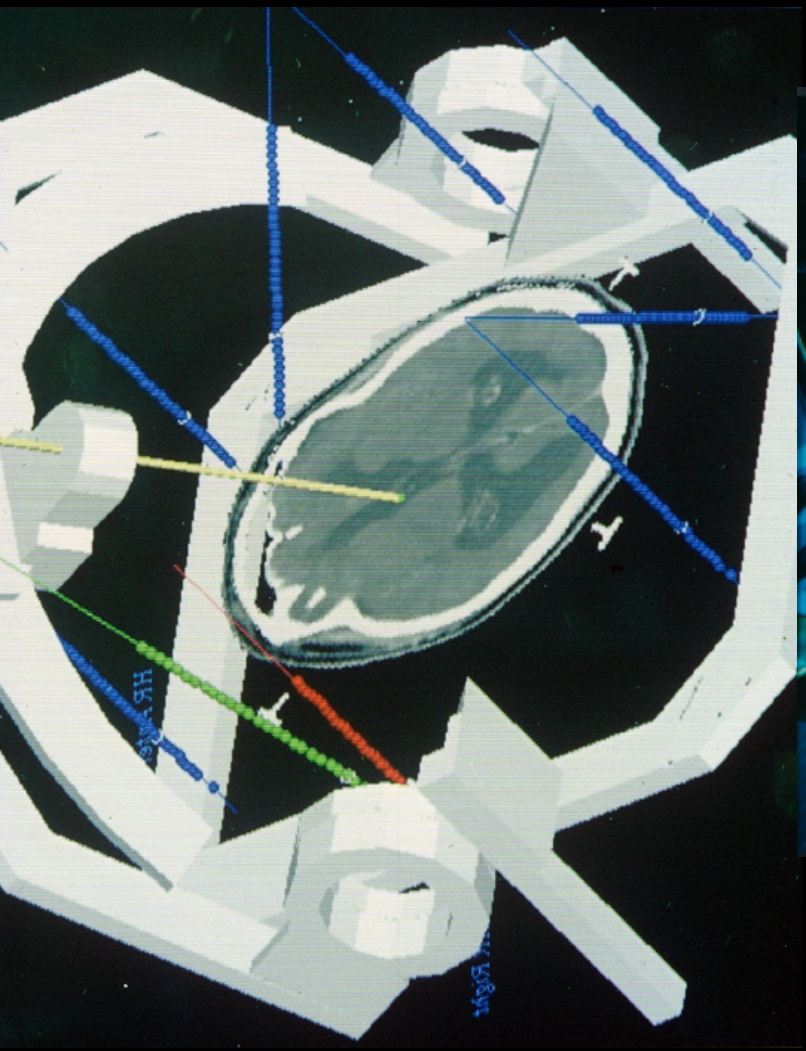
Neuroendoscope Can be hold and guided In the trajectory By robot.

New topographic anatomy

Approach the sick tree without touching the healthy one

our forest

Neuronavigation



„real navigation“ needs „real time imaging“

Intraoperative imaging

- fluoroscopy
- ultrasound

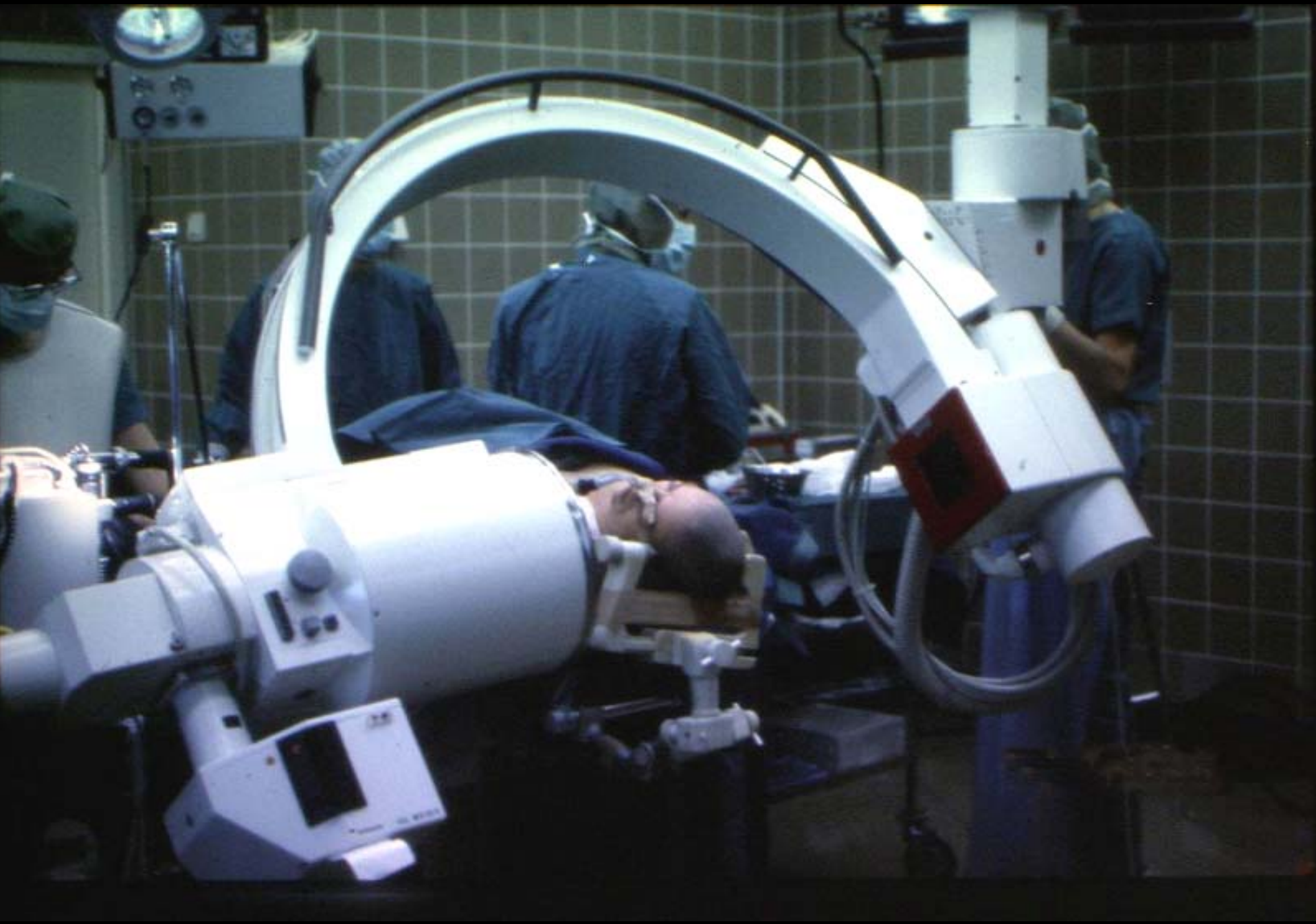
} real time imaging

- CT
- MR

Intraoperative Imaging

X-ray

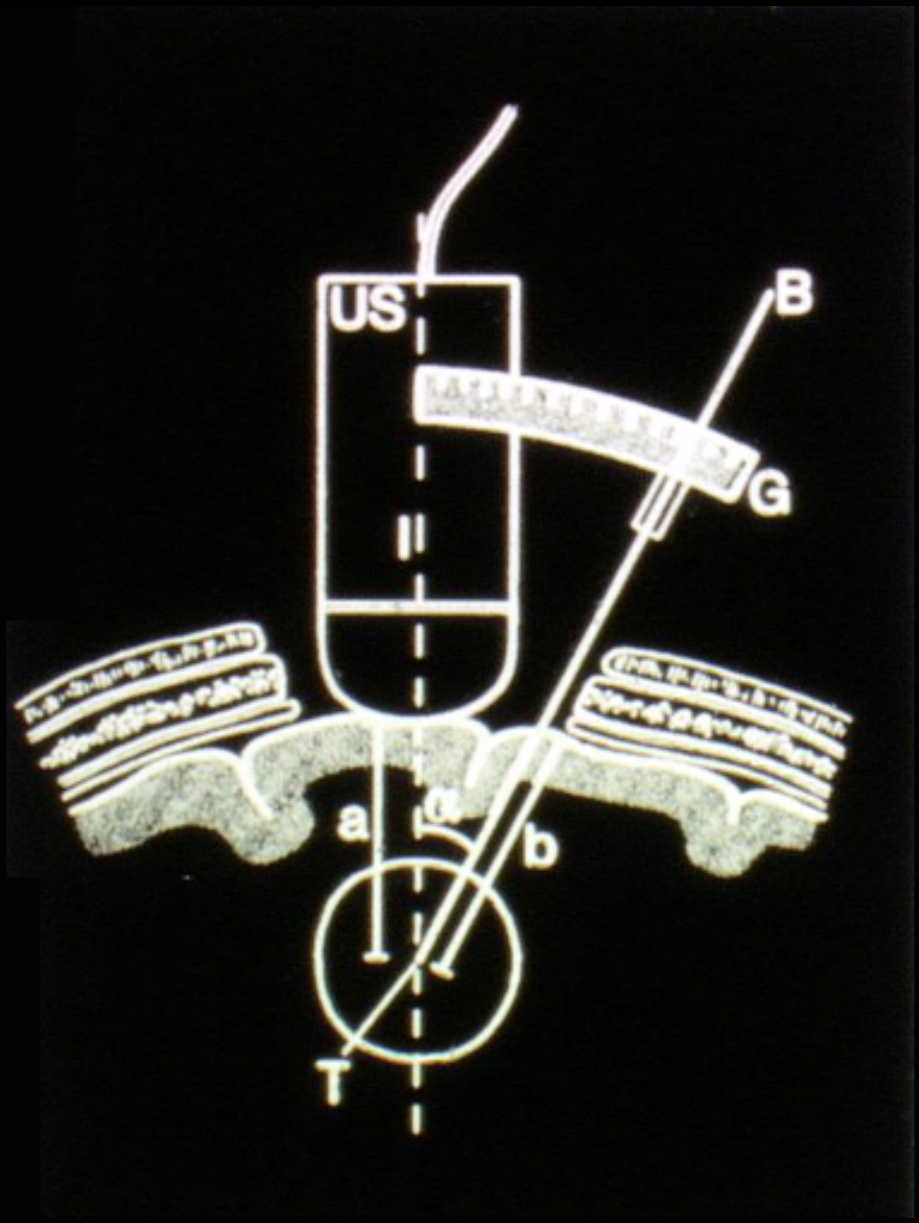
- simple
- no special construction needed
- traditional, standard
- everywhere possible
- real time imaging
- contrast medium: intra-operative angiography
- mobile: intra-operative cavity presentation
- navigation, traditional stereotaxy



Intra-operative Imaging

Ultrasound

- simple
- everywhere possible
- no special construction needed
- Doppler
- 3-D imaging
- navigation
- mobile
- real time imaging


US
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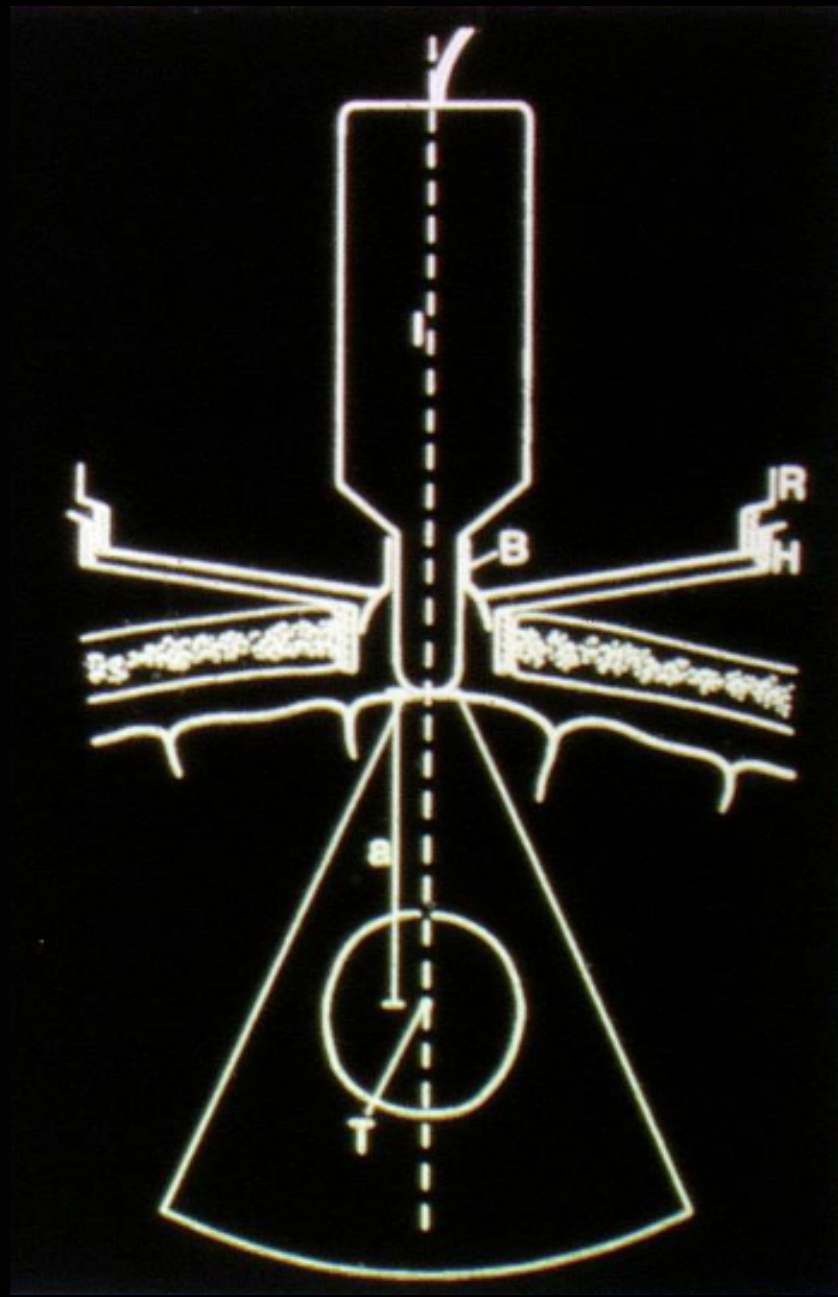
R
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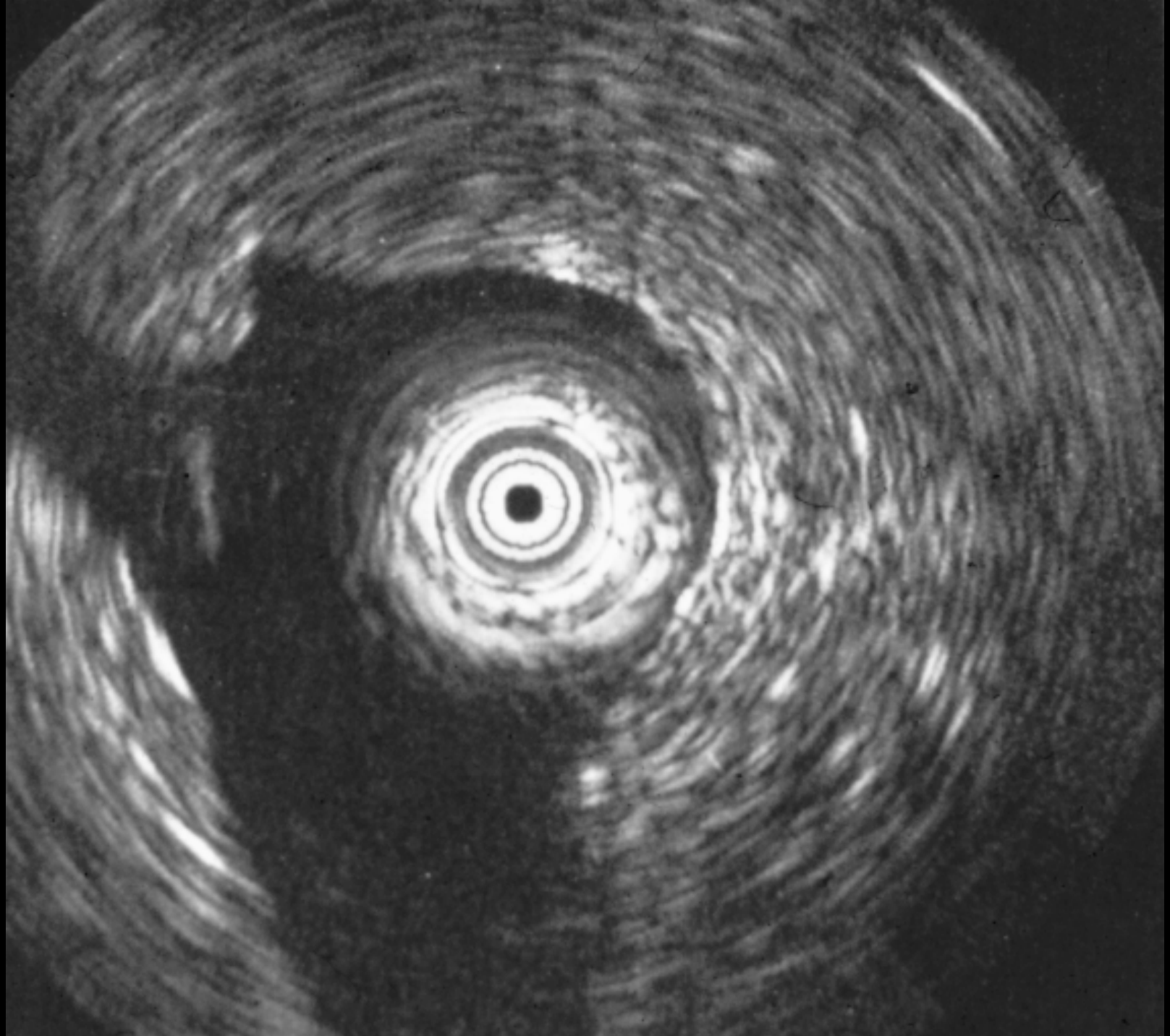
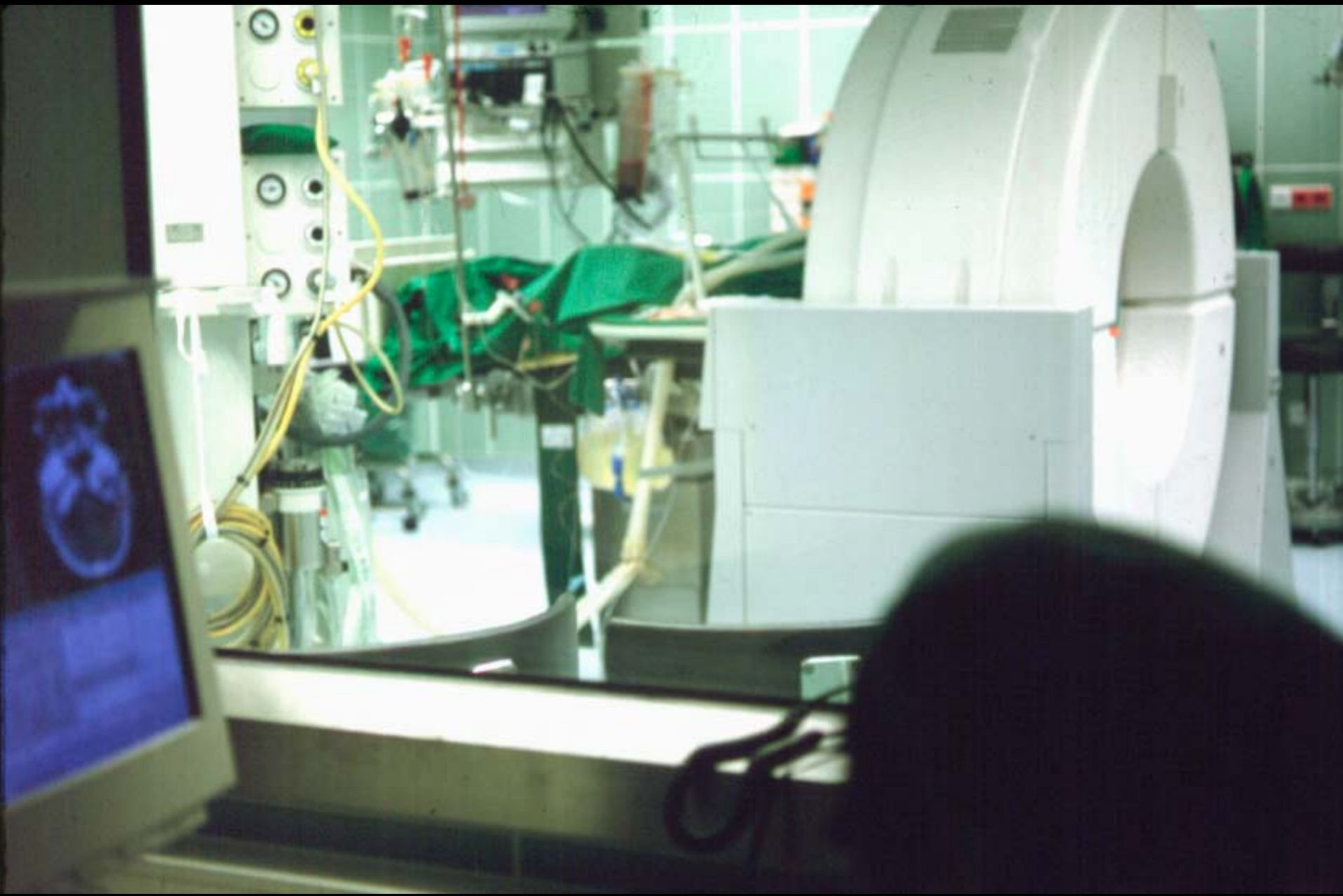


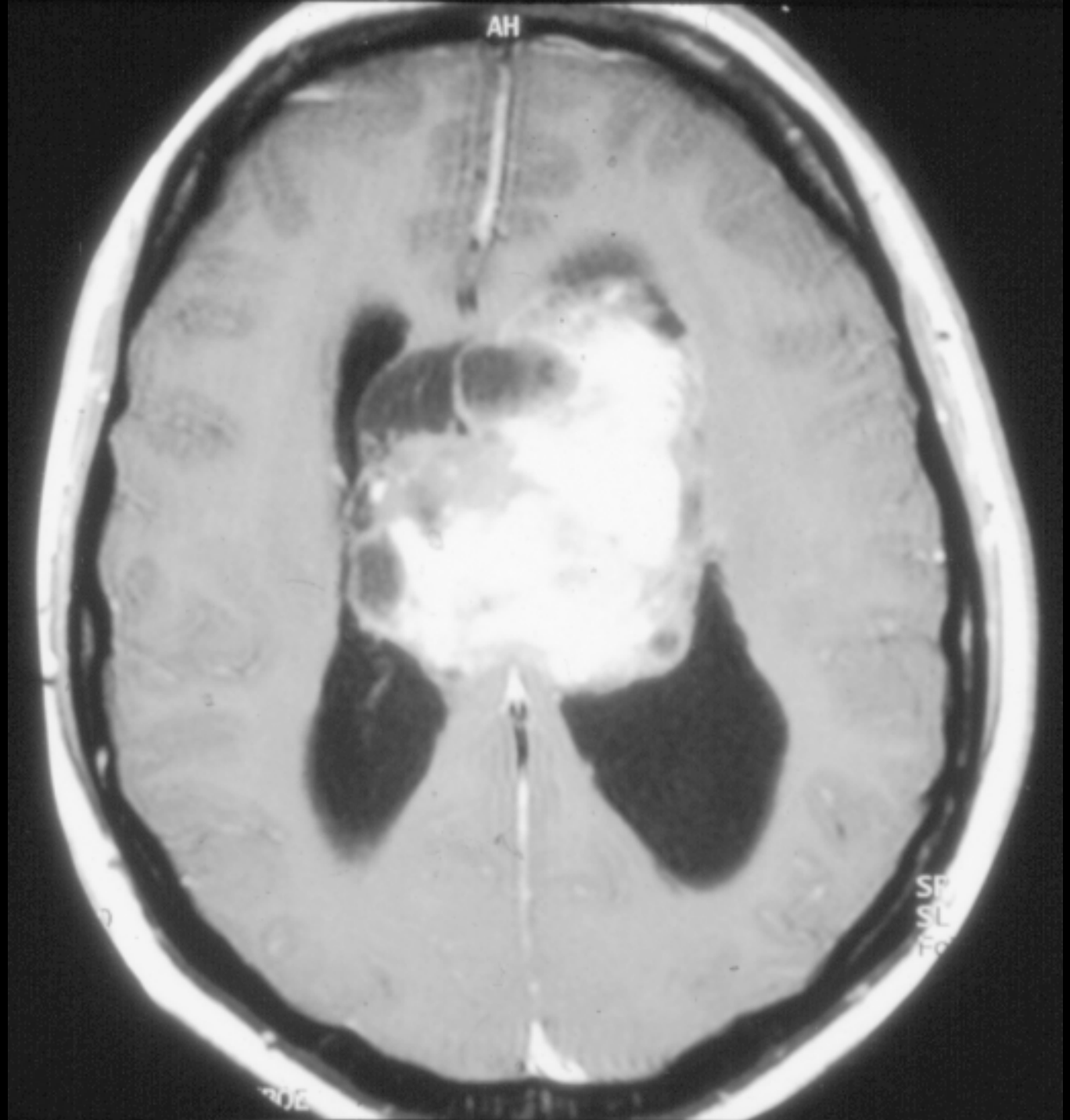
Intra-operative Imaging

special personal needed

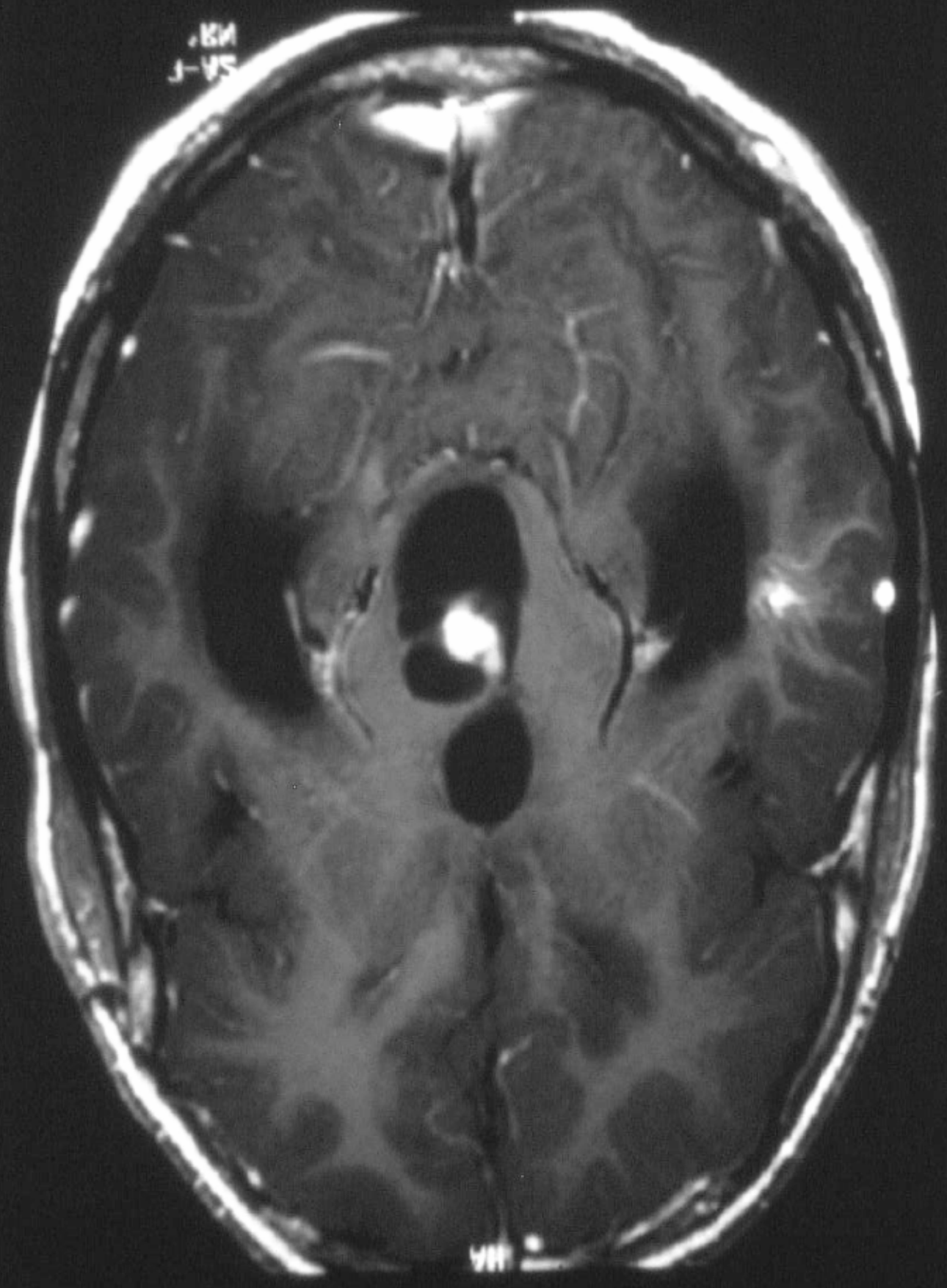
CT

– mobile
– no special construction needed
– no special isolation needed
– spinal mode
– CT angiography intra-operatively
– navigation
– stereotaxy
– no real time imaging




AH


Zoo.



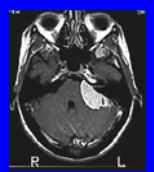
Intra-operative Imaging

special personal needed

– special construction needed
– special isolation needed
– new instruments, new OR-equipment needed
– best quality of imaging
– no real time imaging navigation
– functional imaging time consuming space occupying

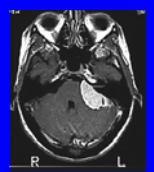
Operative time

- Put in trajectory,
- Point to point localisation,
- Following of trajectory,
- Virtual tip,
- Images injection in the binocular.



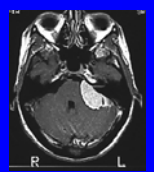
Objective advantages of navigation
benefit for the patient

- Safety and comfort :
  - Decrease of the time of hospitalisation +++
    - Mean: 5 to 6 days
  - Operative time equal or increased of 20 mn.
  - Morbidity decreased.



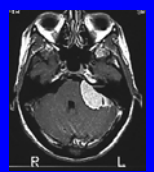
Subjective advantages of navigation : Its technical capacities

- Safety and comfort for the neurosurgeon
- Accuracy



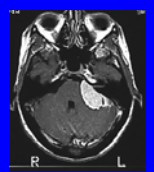
Disadvantages of robotic navigation with MKM

- The bulk and weight, (MKM)
- Mind to placement of referential and infra-red camera/ advantage with Axiem
- Incidents: necessity of maintenance contract and to form all kinds of users (operating room nurses, surgeons, anaesthesiologists,...)

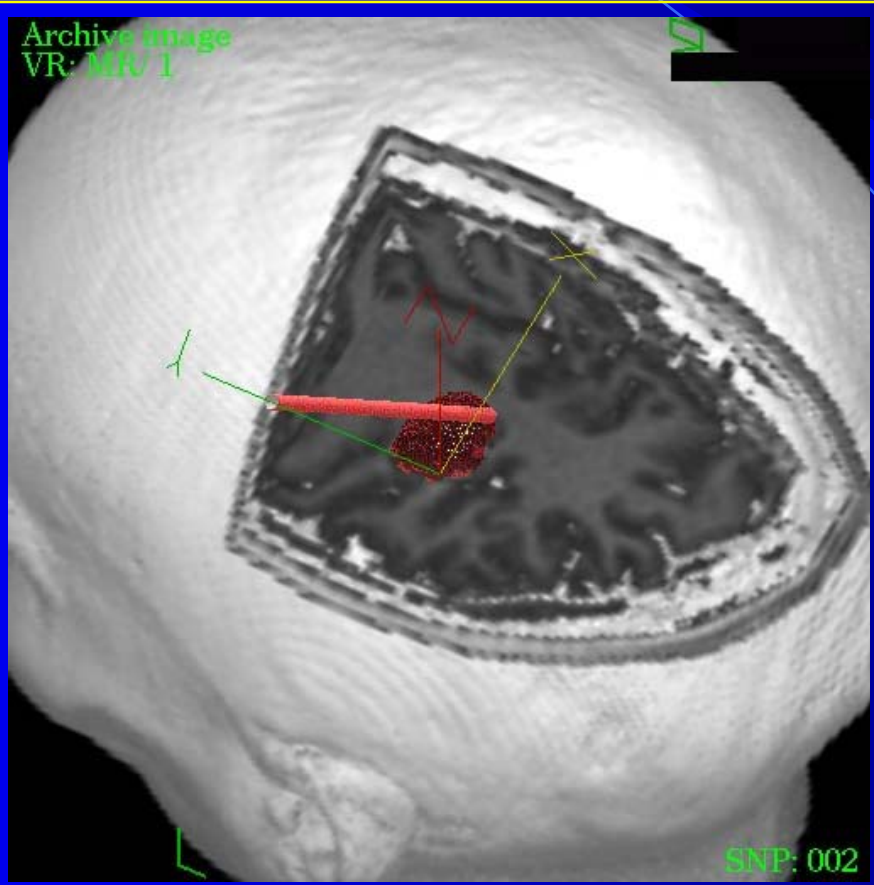


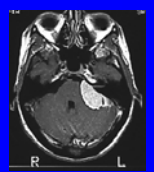
Imperative indications

- Small deep lesion: cavernoma of the insula,…
- « Invisible » lesion: Low grade glioma,…
- Proximity of risk area: meningioma closed to skull-base arteries,…

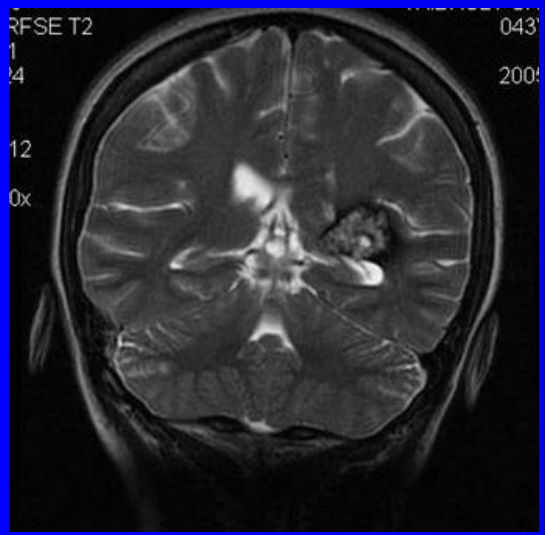


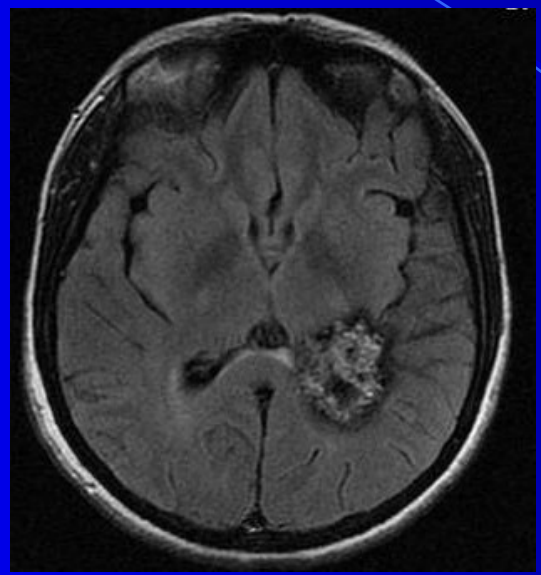
Small deep lesion *ex : parietal cavernoma*

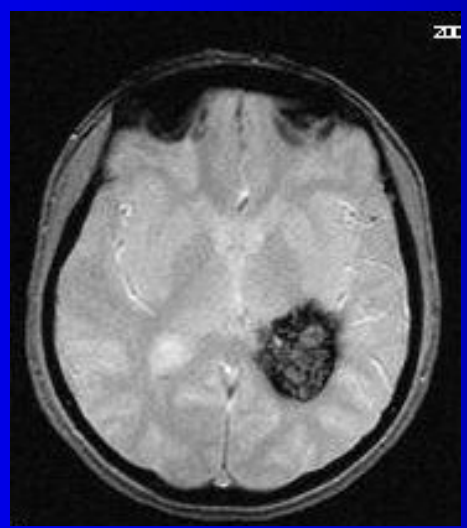


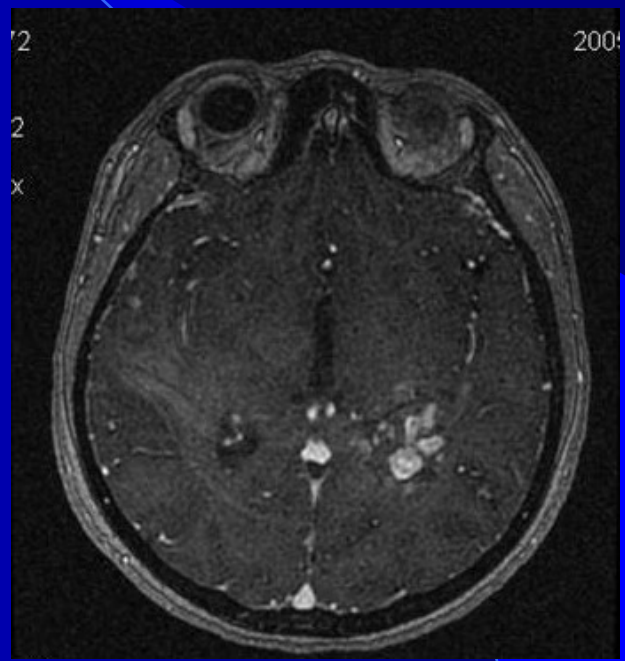


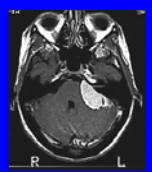
Giant cavernoma of left anatomical crossroads 11 march 2005











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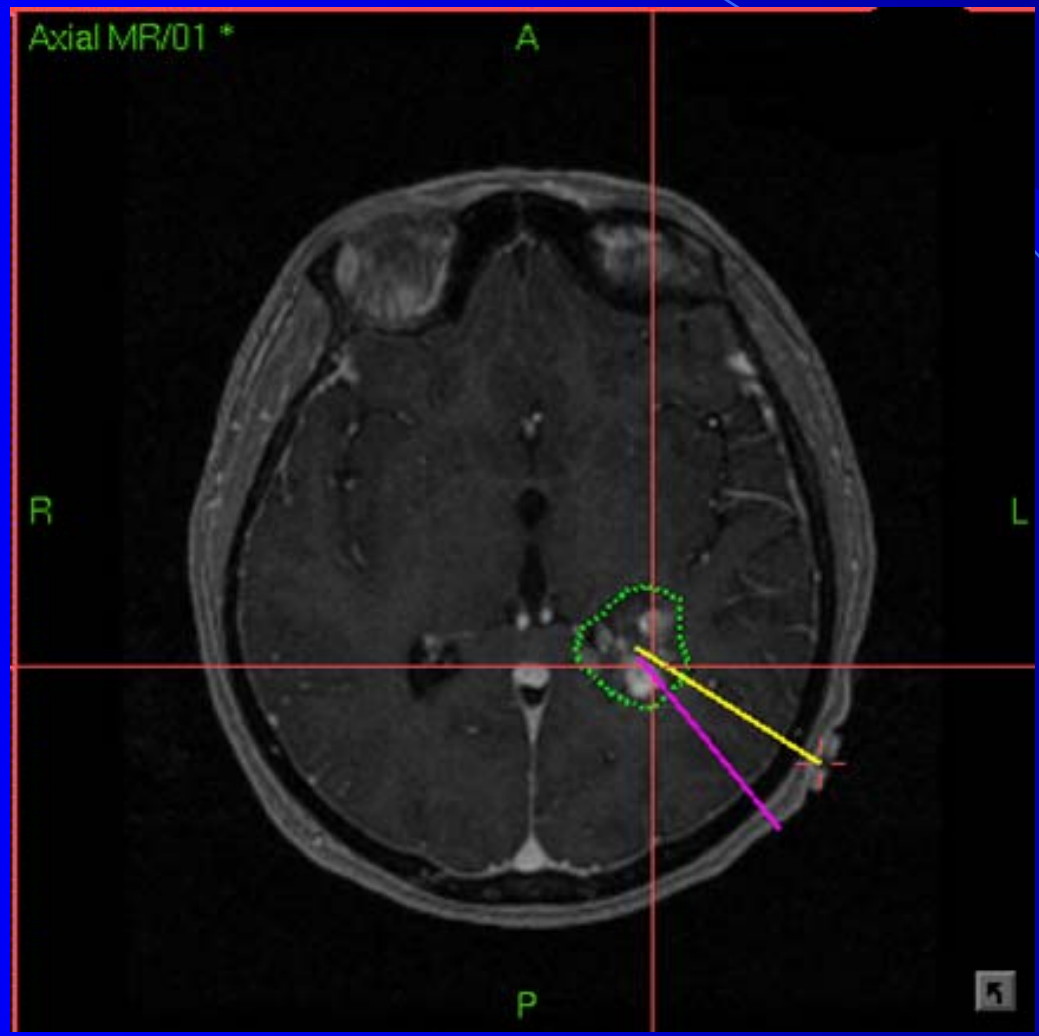
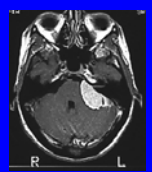
Giant cavernoma of left anatomical crossroads 11 march 2005 Planning





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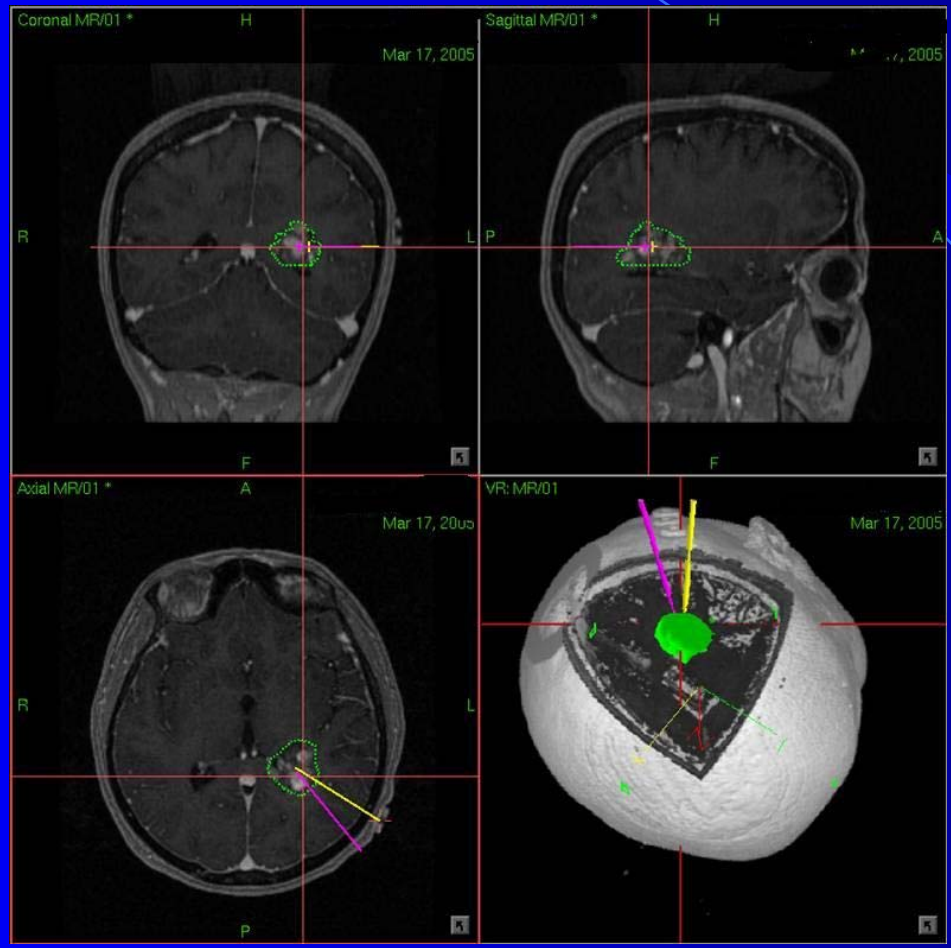
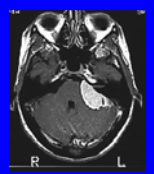
Giant cavernoma of left anatomical crossroads 11 march 2005 Planning





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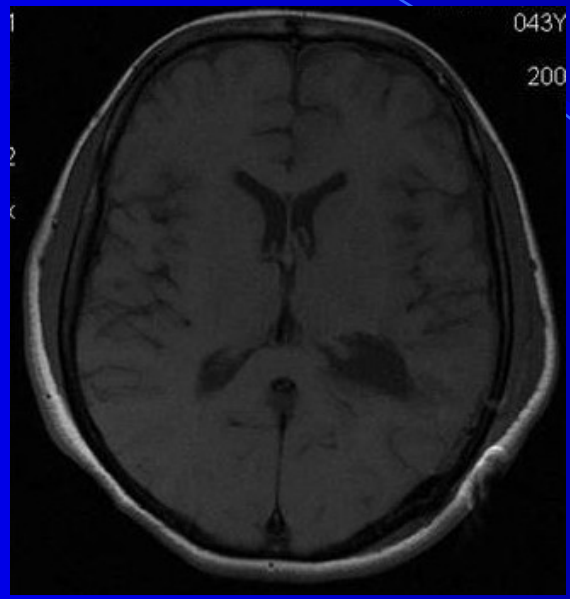
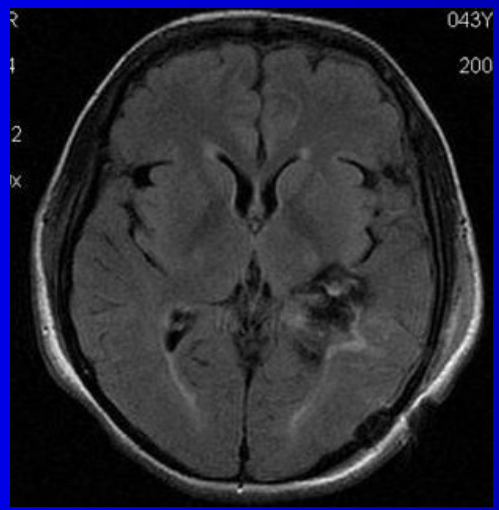
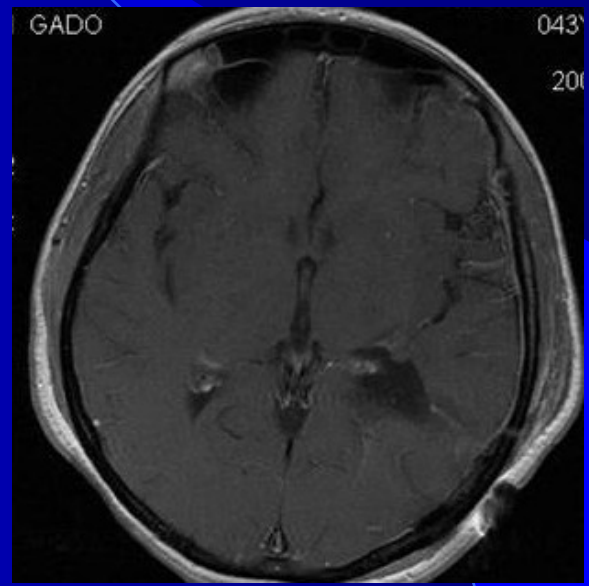
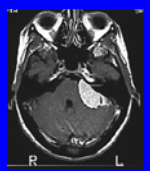
Giant cavernoma of left anatomical crossroads 11 march 2005, post-op MRI at D1 Back Home at D5.









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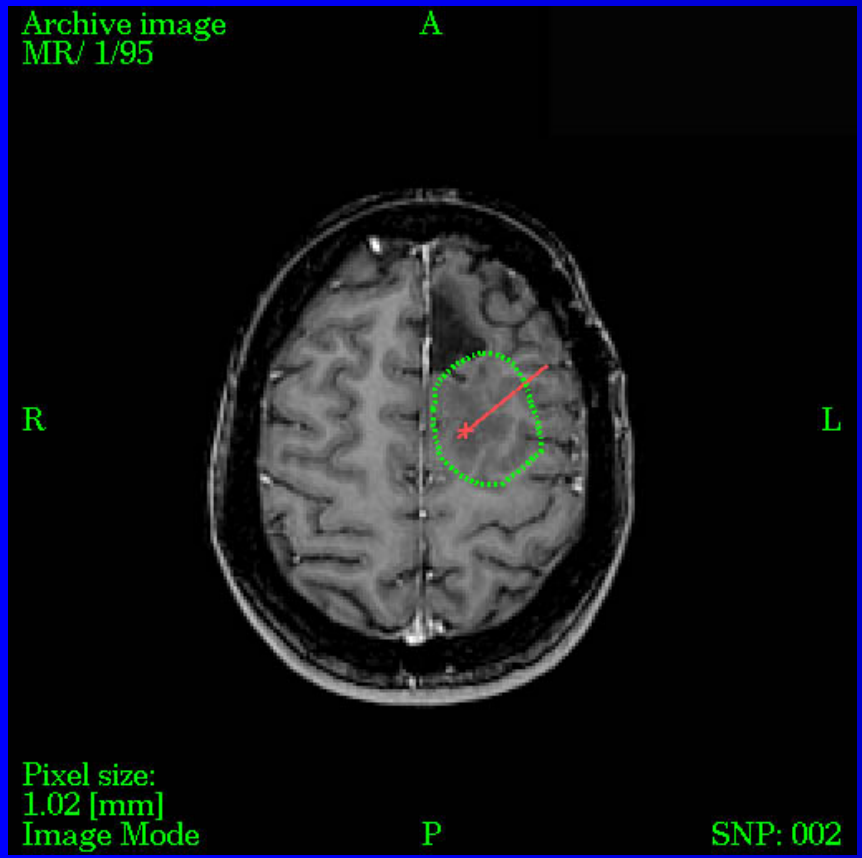
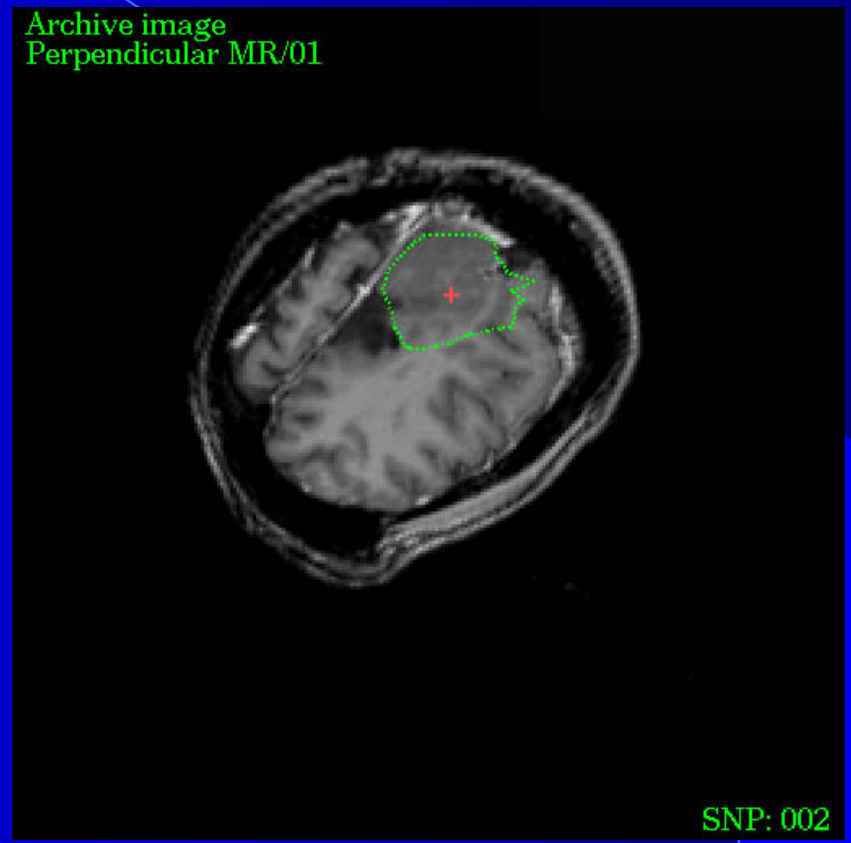
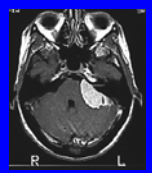
Invisible lesion

ex : oligodendroglioma of Rolando area

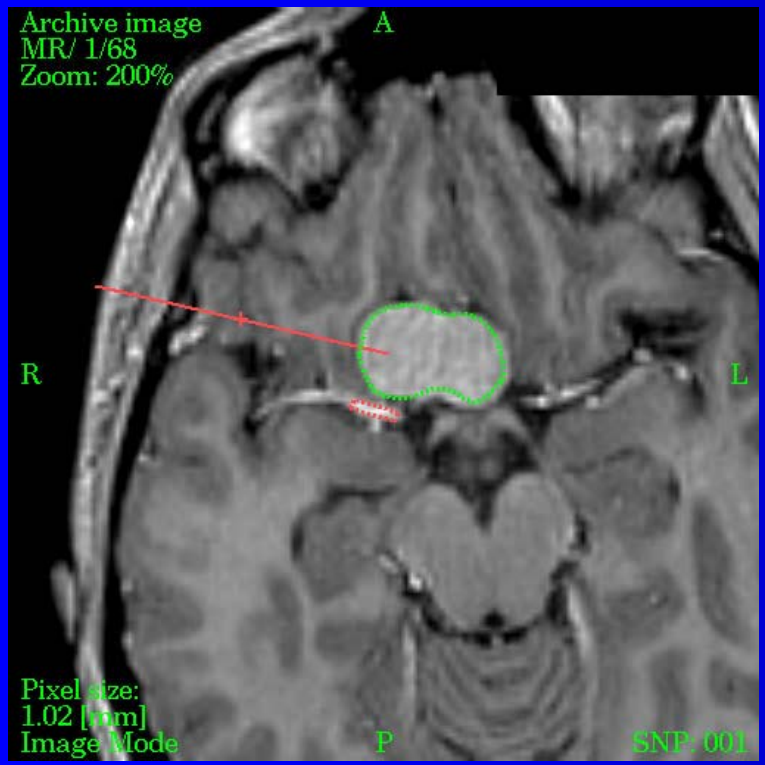


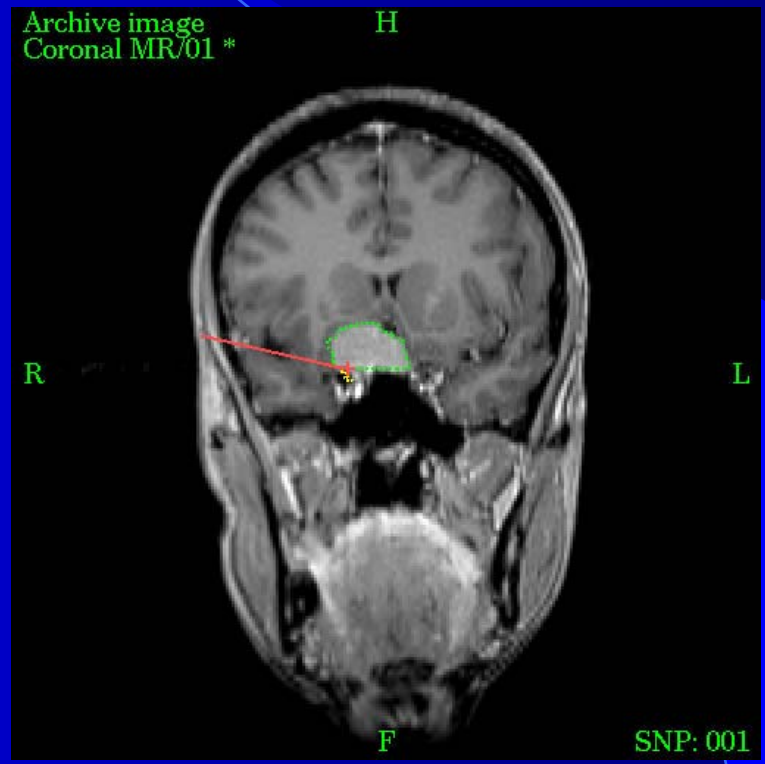


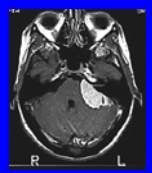


Risk area

ex : meningioma of the du tuberculum sellae

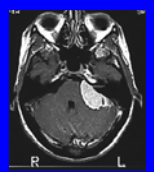




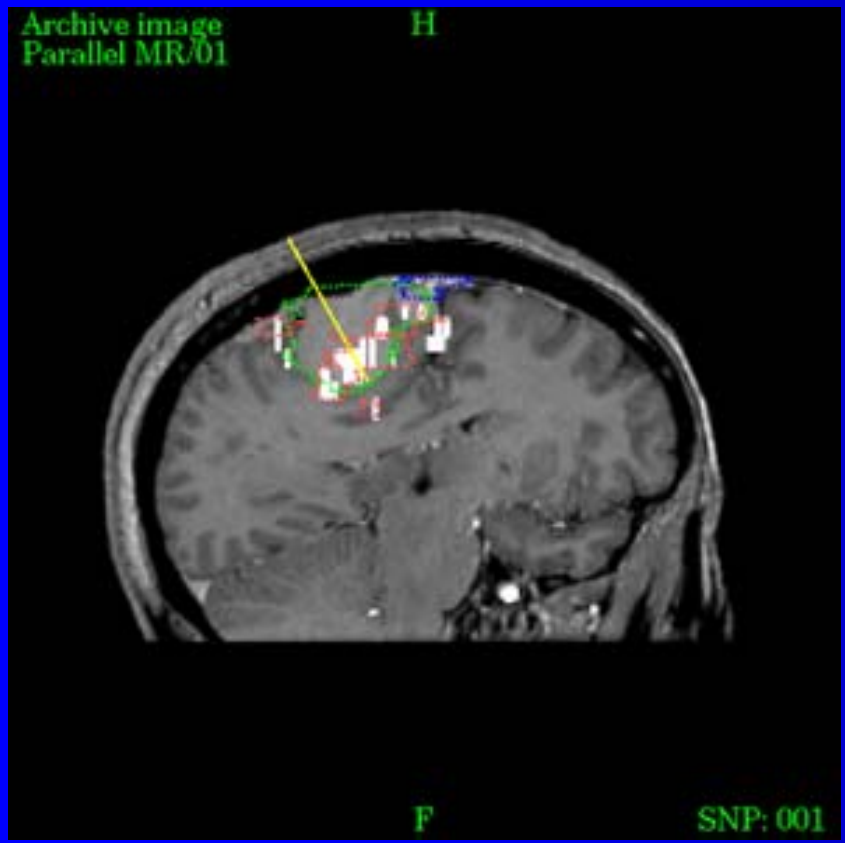


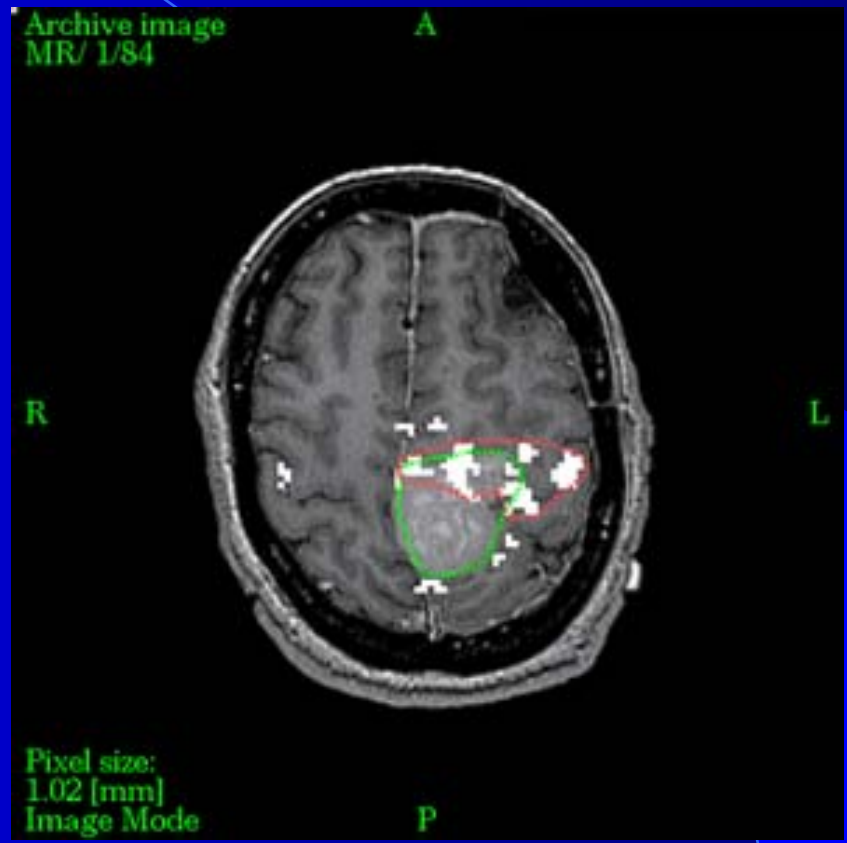
Non imperative indications

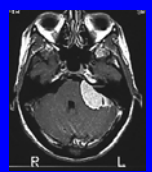
- Superficial tumour
- Extra-parenchymatous tumour
- Big tumour
- Second look



Superficial Tumour: Important interest for study of the venous drainage before craniotomy *ex : meningioma of Rolando*

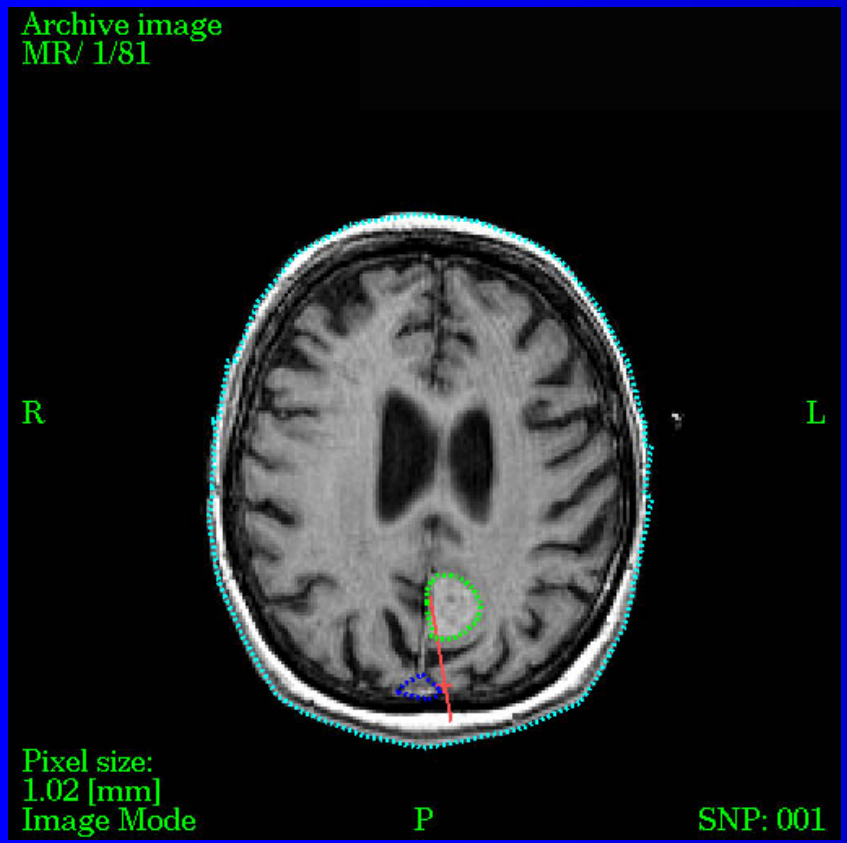


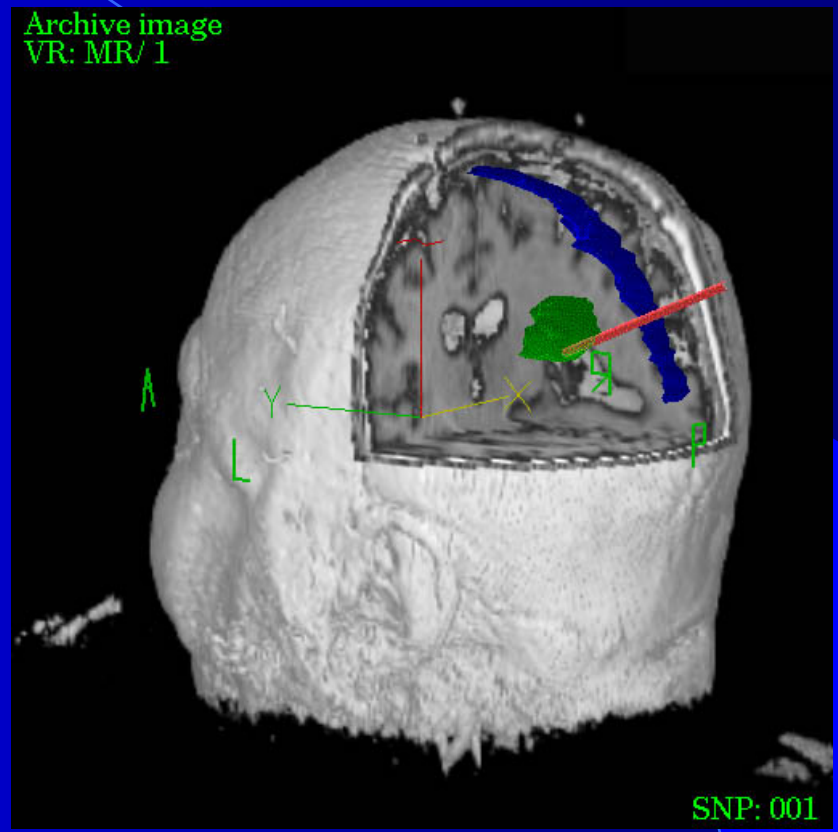


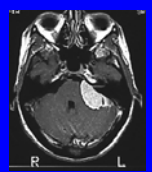


Deep Tumour

ex : Falx cerebri meningioma







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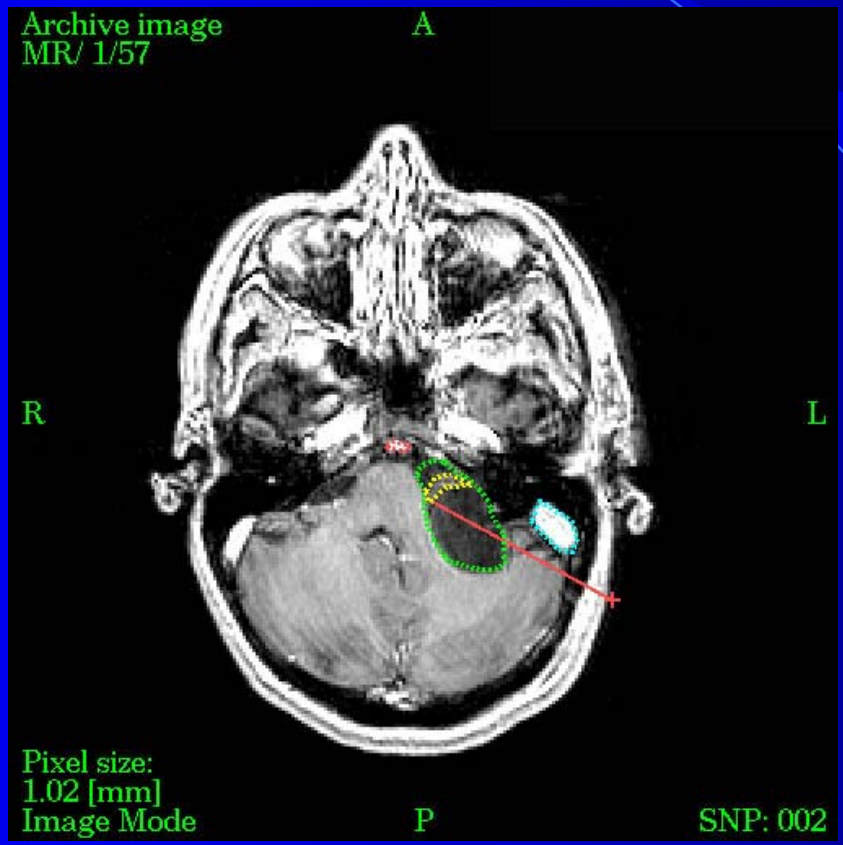
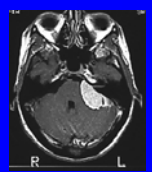
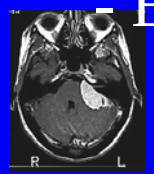
Extra-parenchymatous tumour

ex : cholesteatoma of CPA

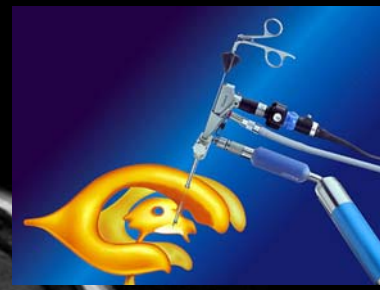


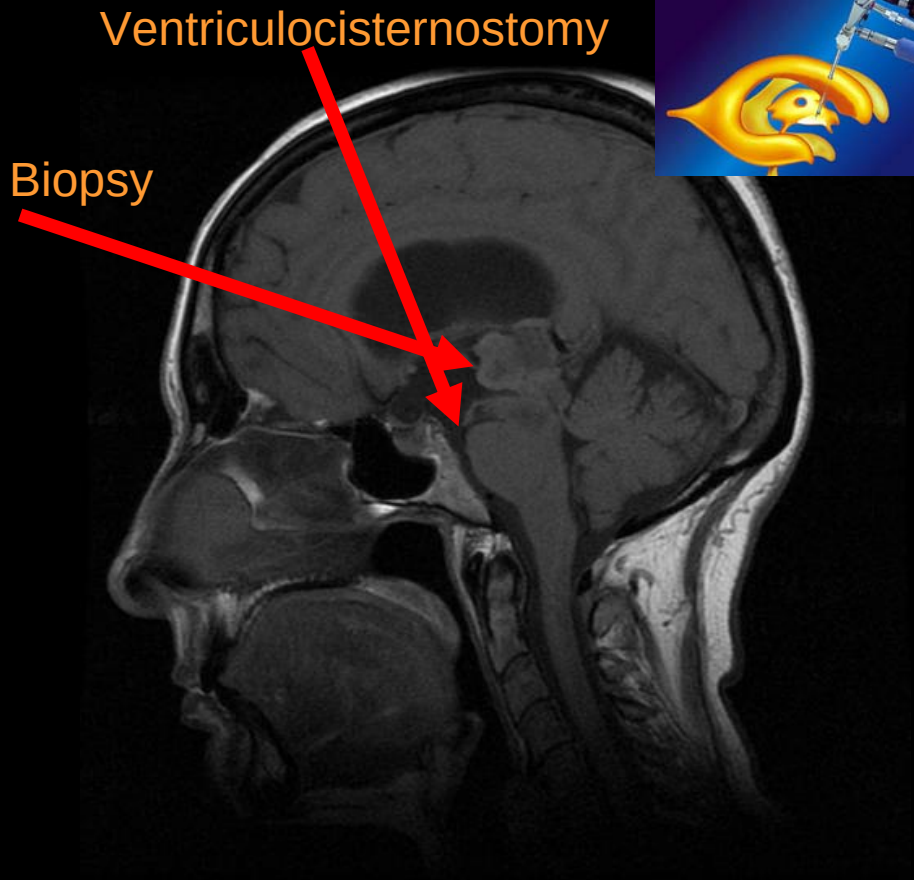


- Stereotactic Biopsies
frameless with MKM or TREON
- Navigation for Spine.
-Images fusion with fMRI, cerebral Thallium scintigraphy, sequences of DTi FiberTract, PETscan.
-Coupled with CO2 laser, per-operative Neuroendoscopy
-Robotic Microsurgery assisted by endoscope and image guidance
-Interstitial per-operative radiotherapy : Acubeam.
-Awaked surgery for functional area tumours, coupled with per-operative brain stimulation.
- ENT applications.



Neuroendoscopy and microsurgery assisted by endoscopy

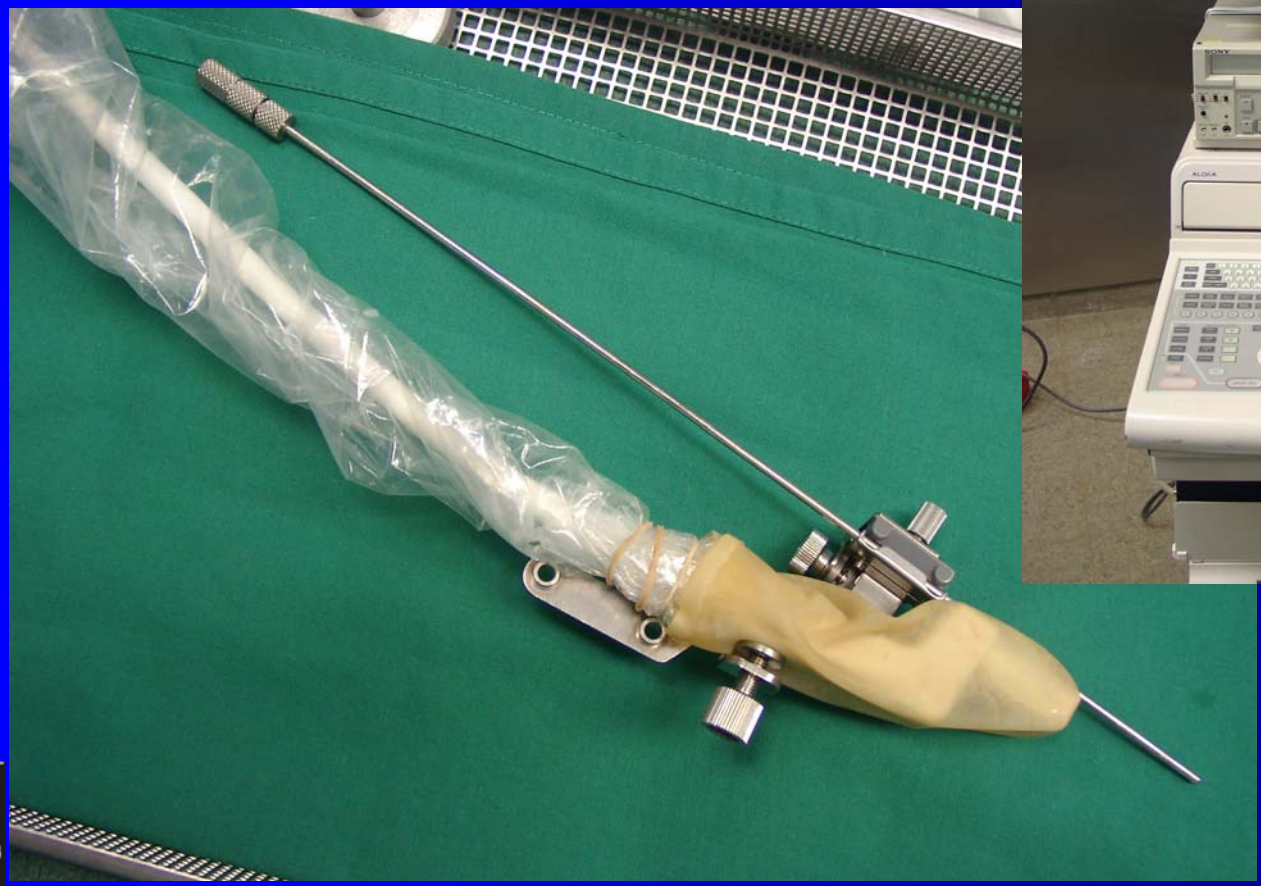


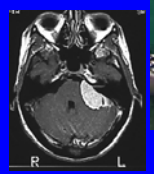


For intra-ventricular or pineal tumours.

Robotic arm can help to guide, fix and micro-movement of endoscope, or biopsy-needle

Biopsy coupled with ultra-sounds
Robotic arm can hold and guide
US probe and biopsy needle





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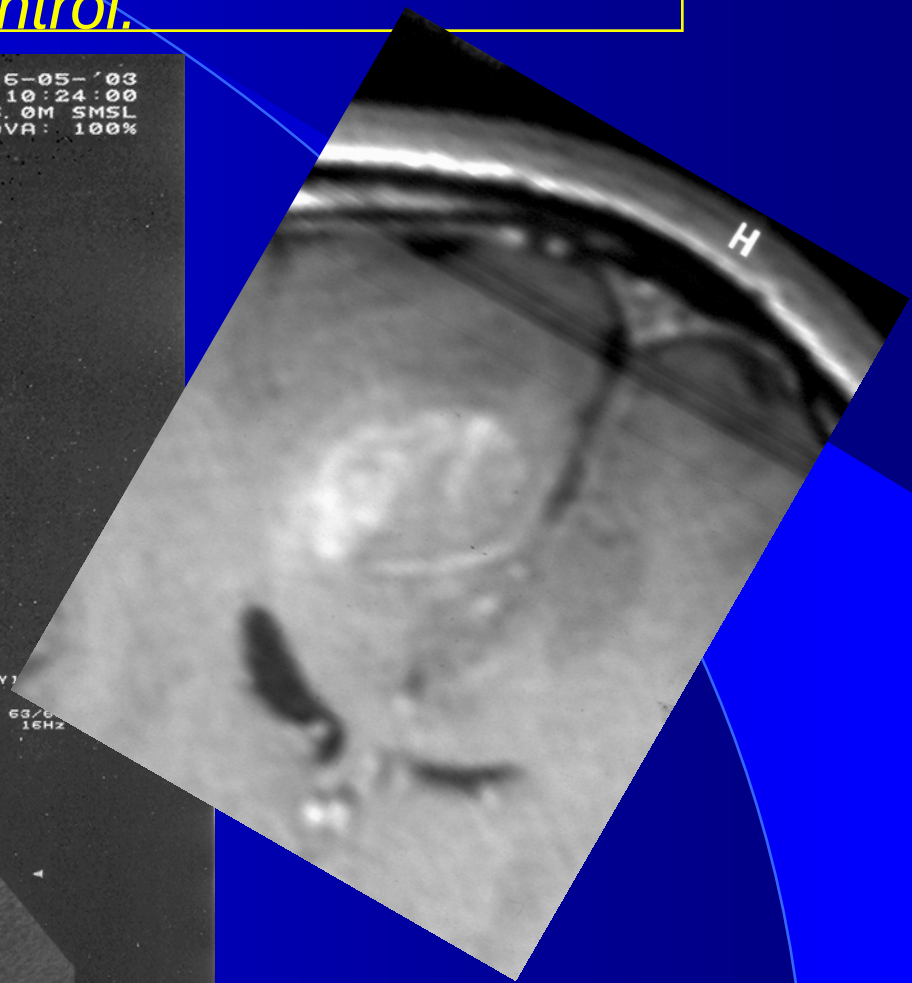
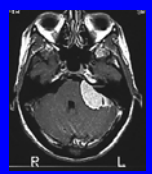
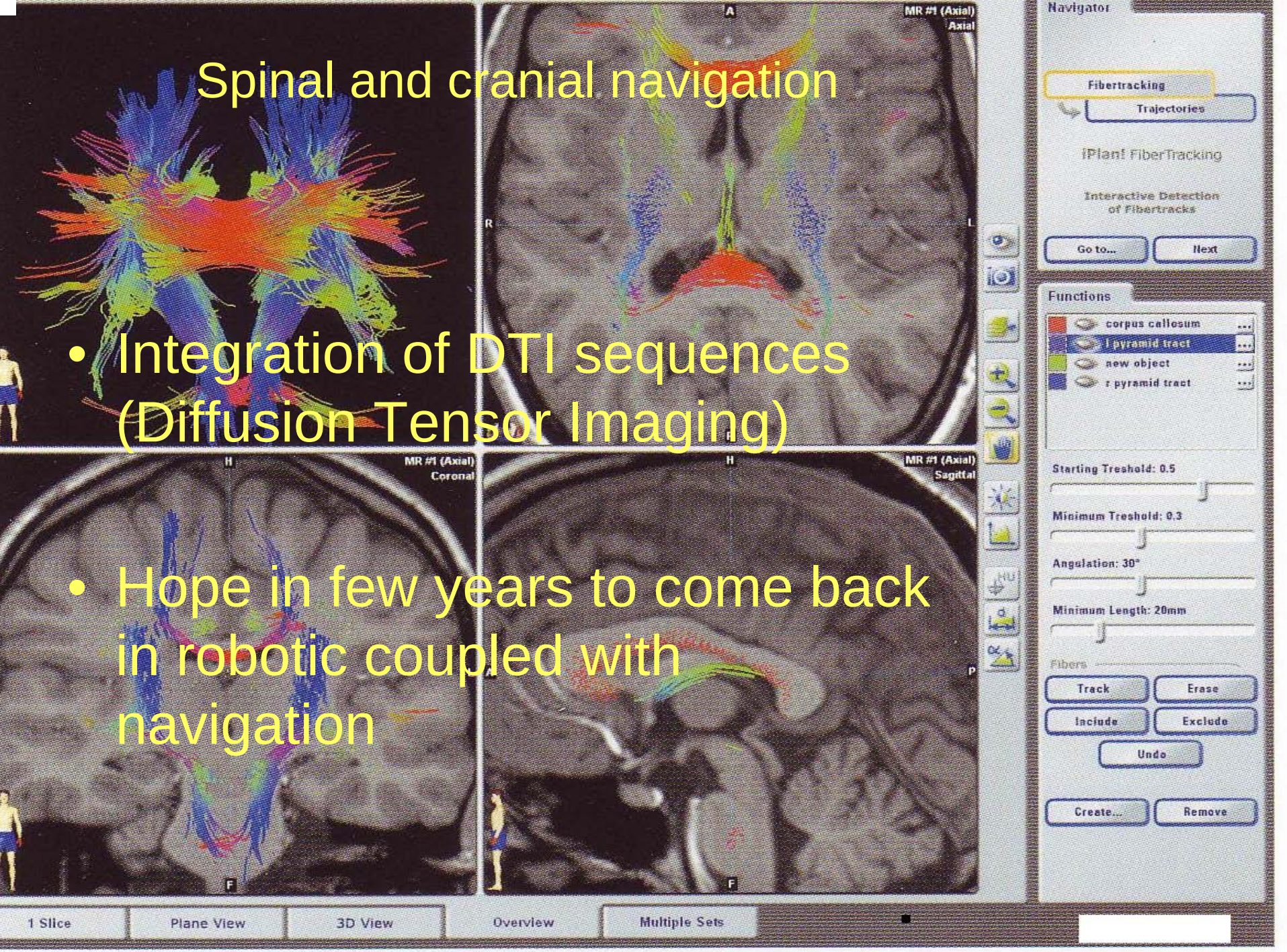
Biopsy coupled with ultra-sound: real time per-operative control.



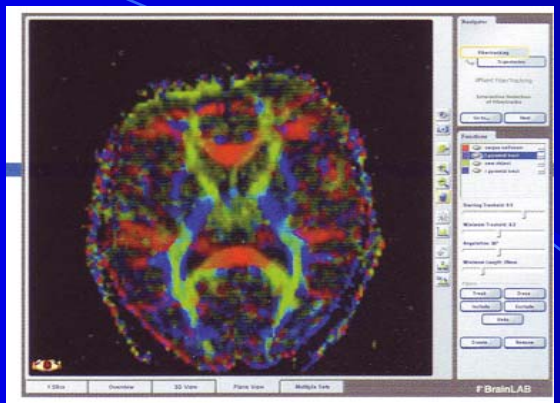


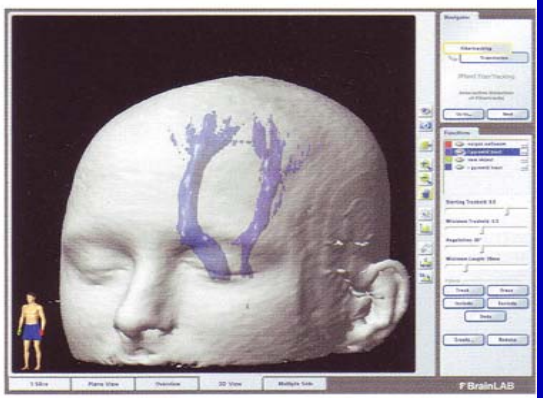
Spinal and cranial navigation

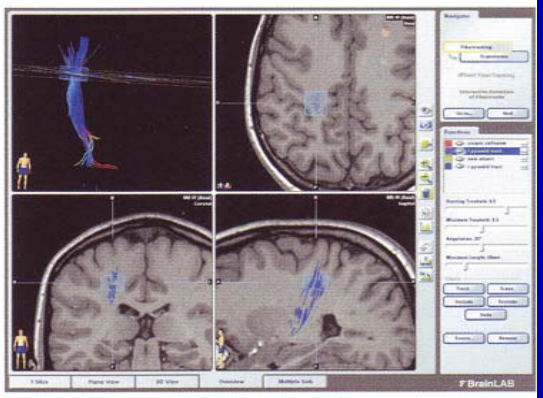


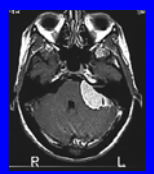
- Integration of DTI sequences (Diffusion Tensor Imaging)
- Hope in few years to come back in robotic coupled with navigation

FiberTracking









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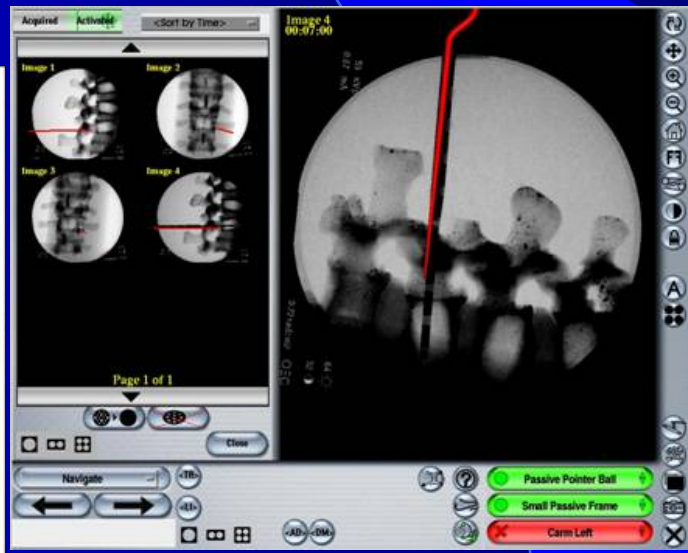
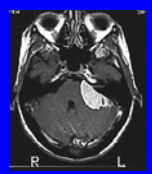
Spine surgery: 2D Fluoronav

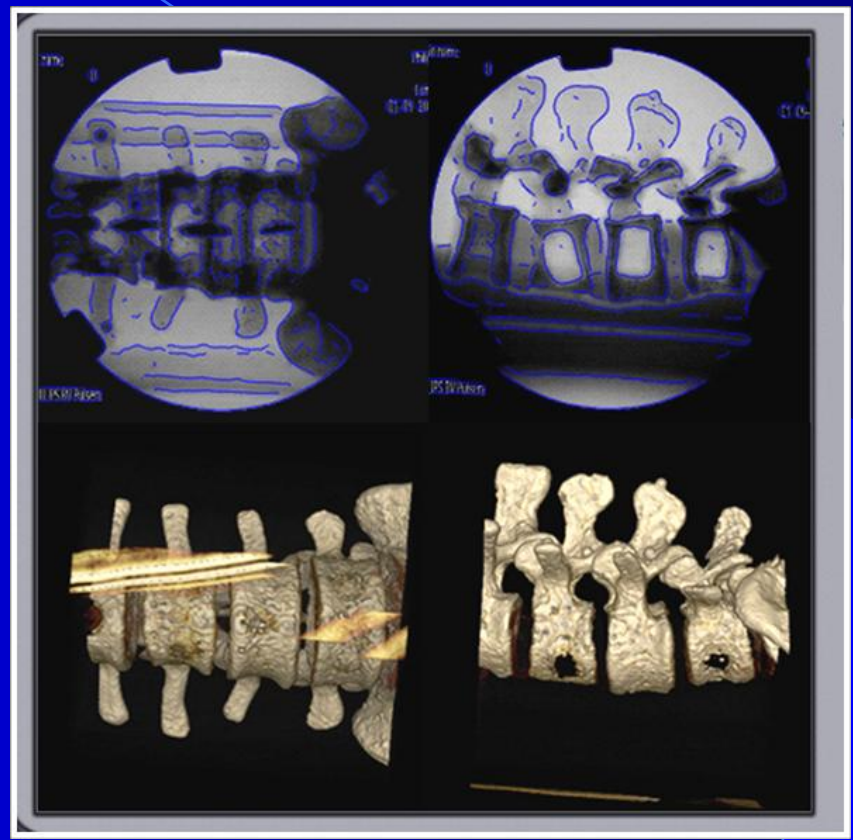
- Easy positioning of screws
- Visualisation of perpendicular plans to screws (Verification of right positioning of the screws)
- Definition of screw size
- Robotic arm can help to put the guide in the right trajectory define by navigation
- 15 % of wrong positioning

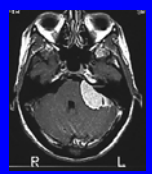




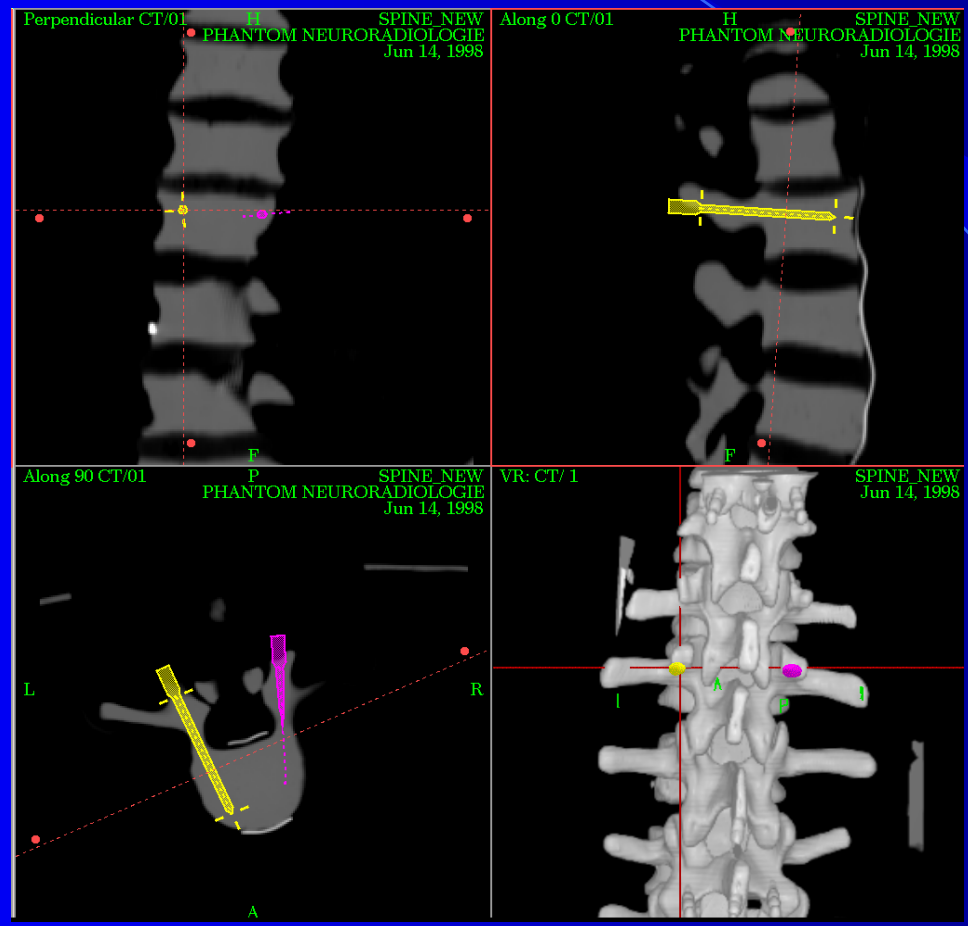
Spine surgery: 3D FluoroMerge

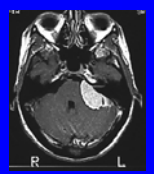
- Accuracy of pedicles screw positioning
- Definition of areas to drill (Vertebral tumours, arthrosis…)
- Help to put disc-prosthesis





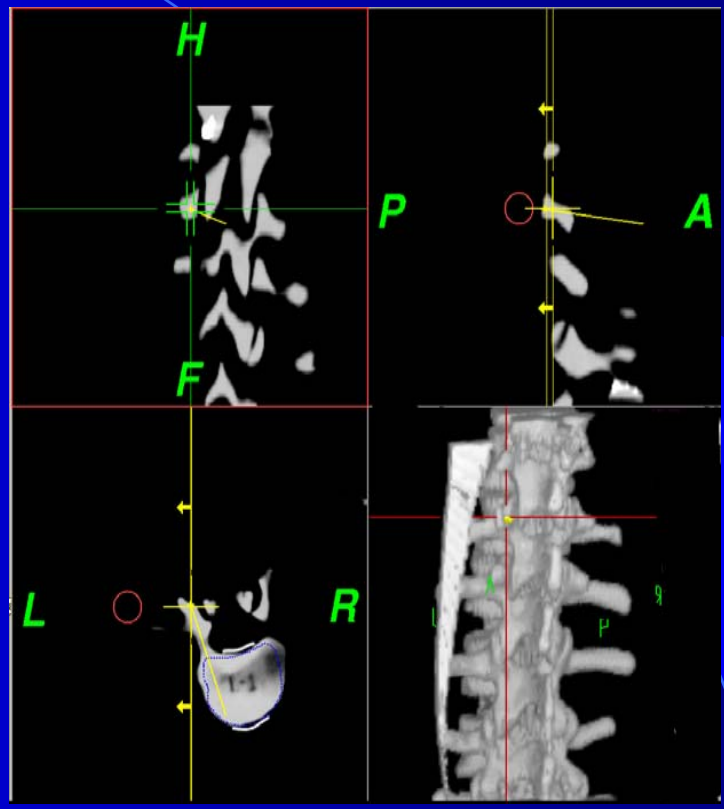
Pedicles screw positioning

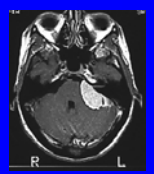




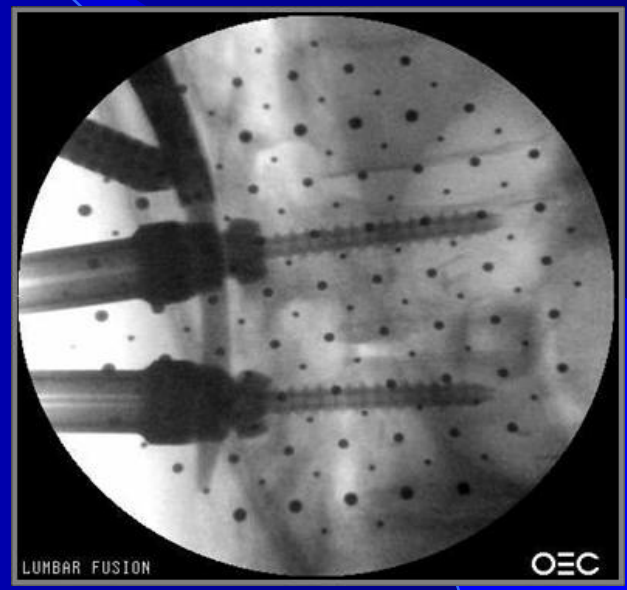
per-operative

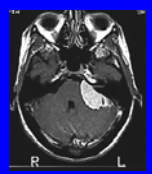
- Guidance mode to help for positioning the screw



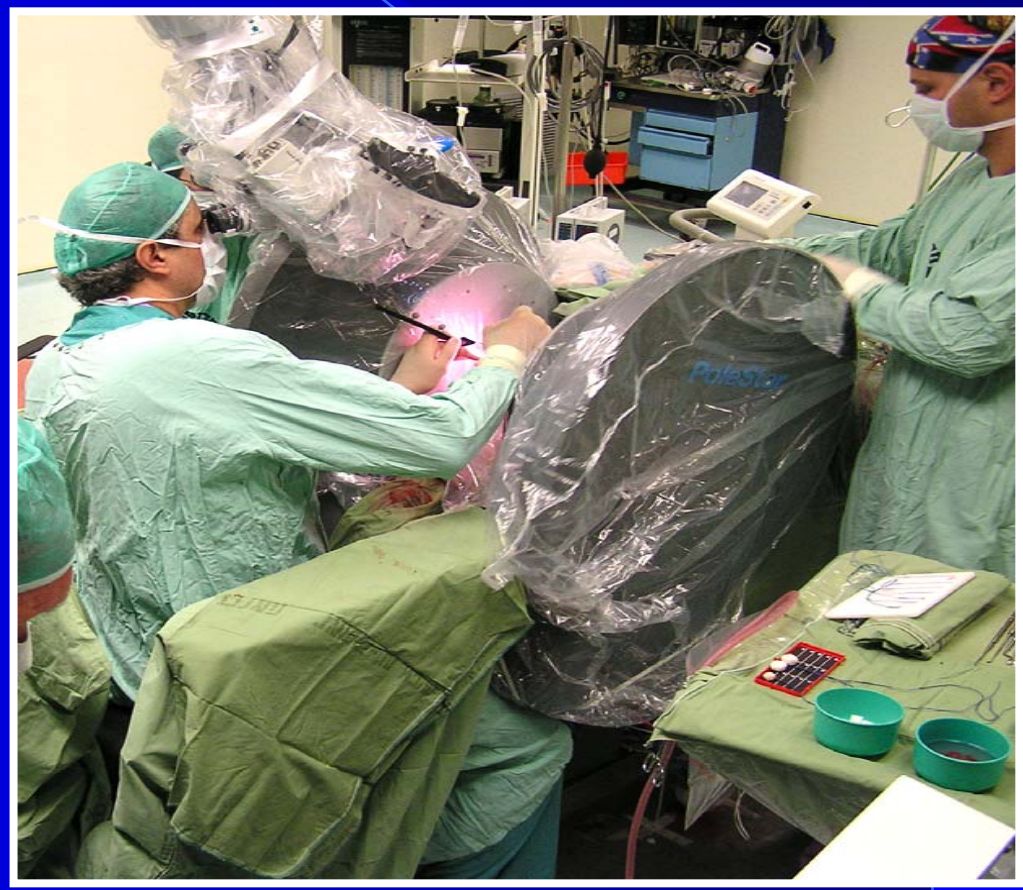


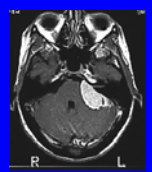
Spine surgery: Percutaneous technique under navigation- Sextan -



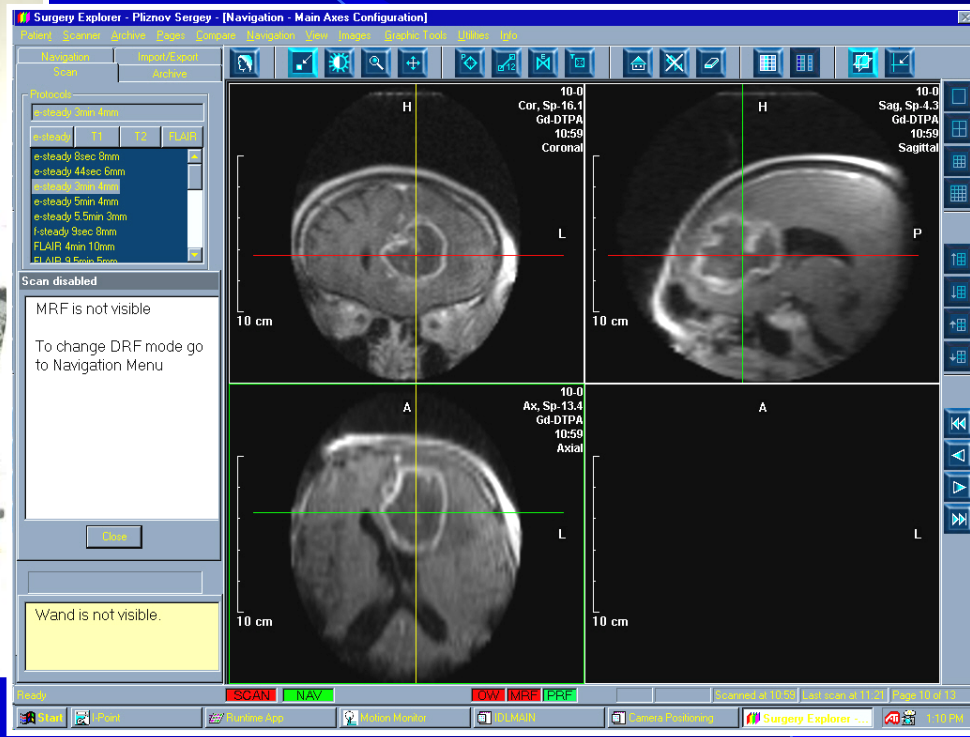


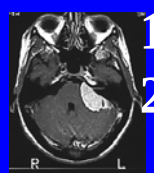
Low field intra-operative MRI: 0,12 T and 0,20 T





Per-operative low field MRI coupled with neuronavigation





1. **To update navigated images (actually SonoNav)**
2. **To verify per-operatively the quality of tumour resection**

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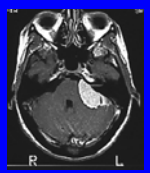
Per-operative low field MRI *Mobile Faraday cage*



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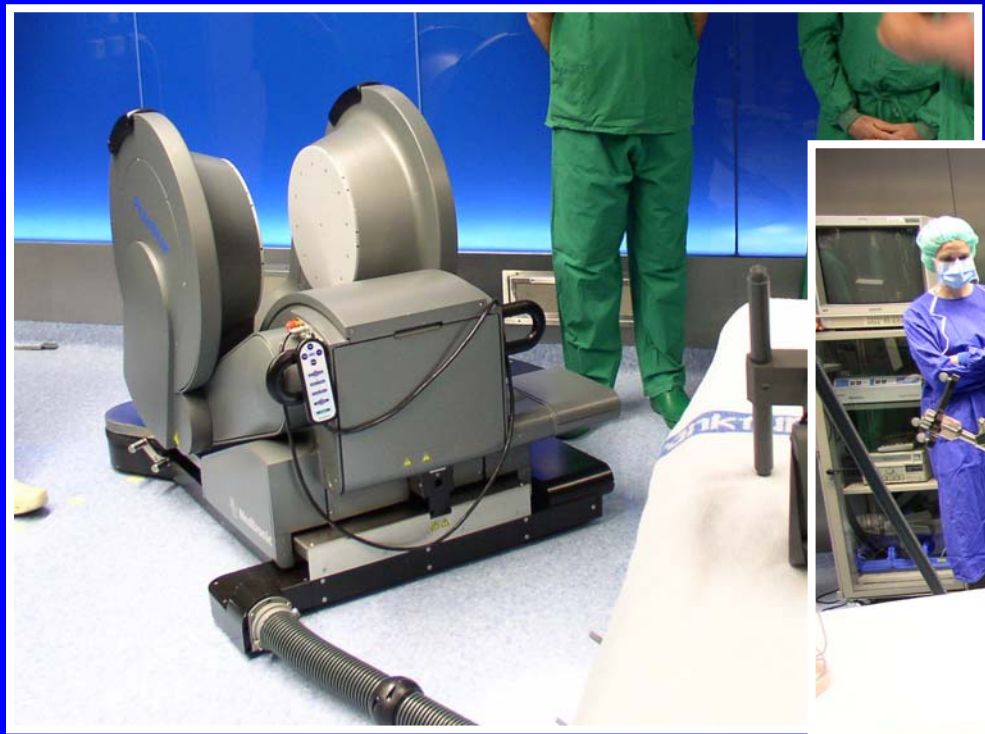
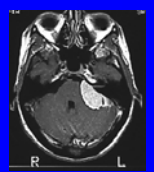
Per-operative low field MRI « OR » Faraday cage





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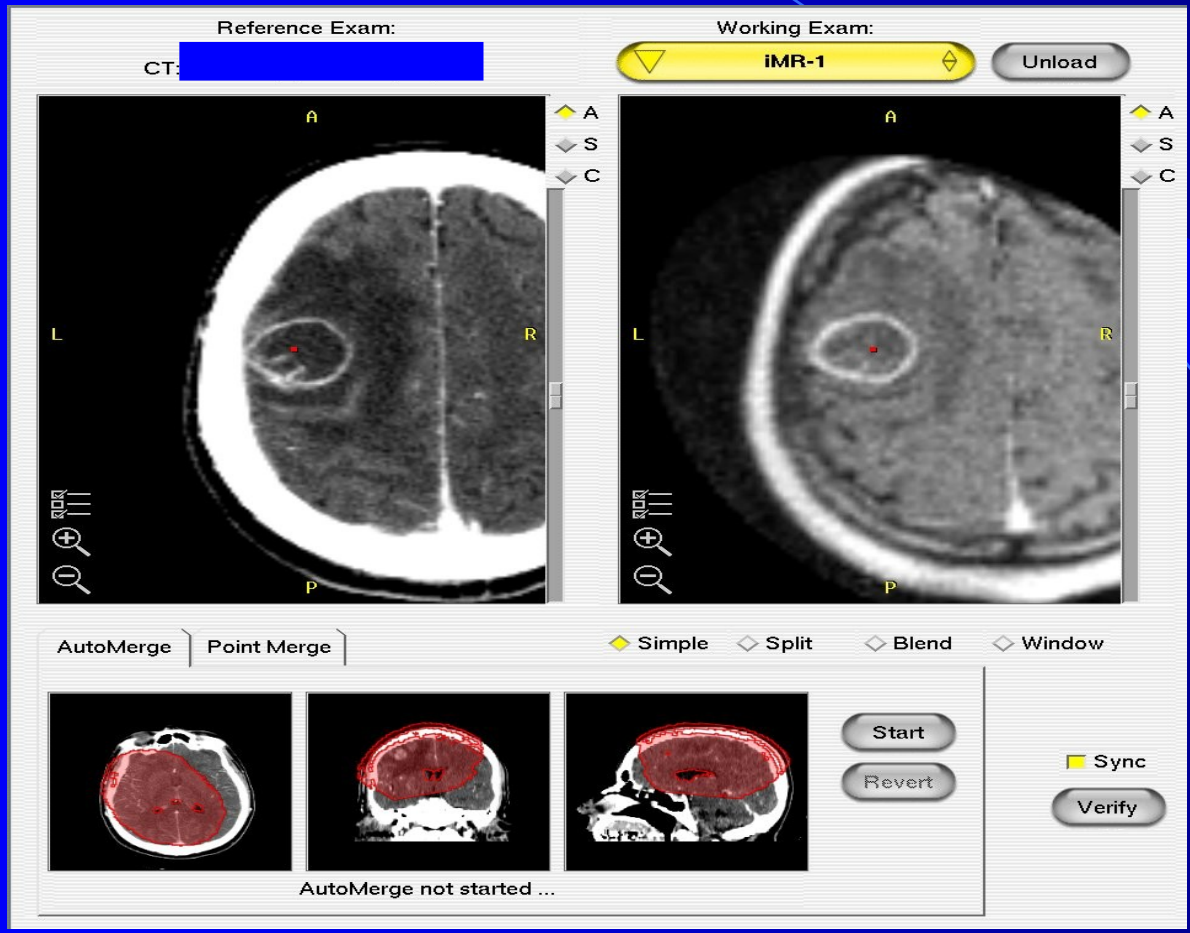
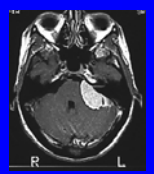
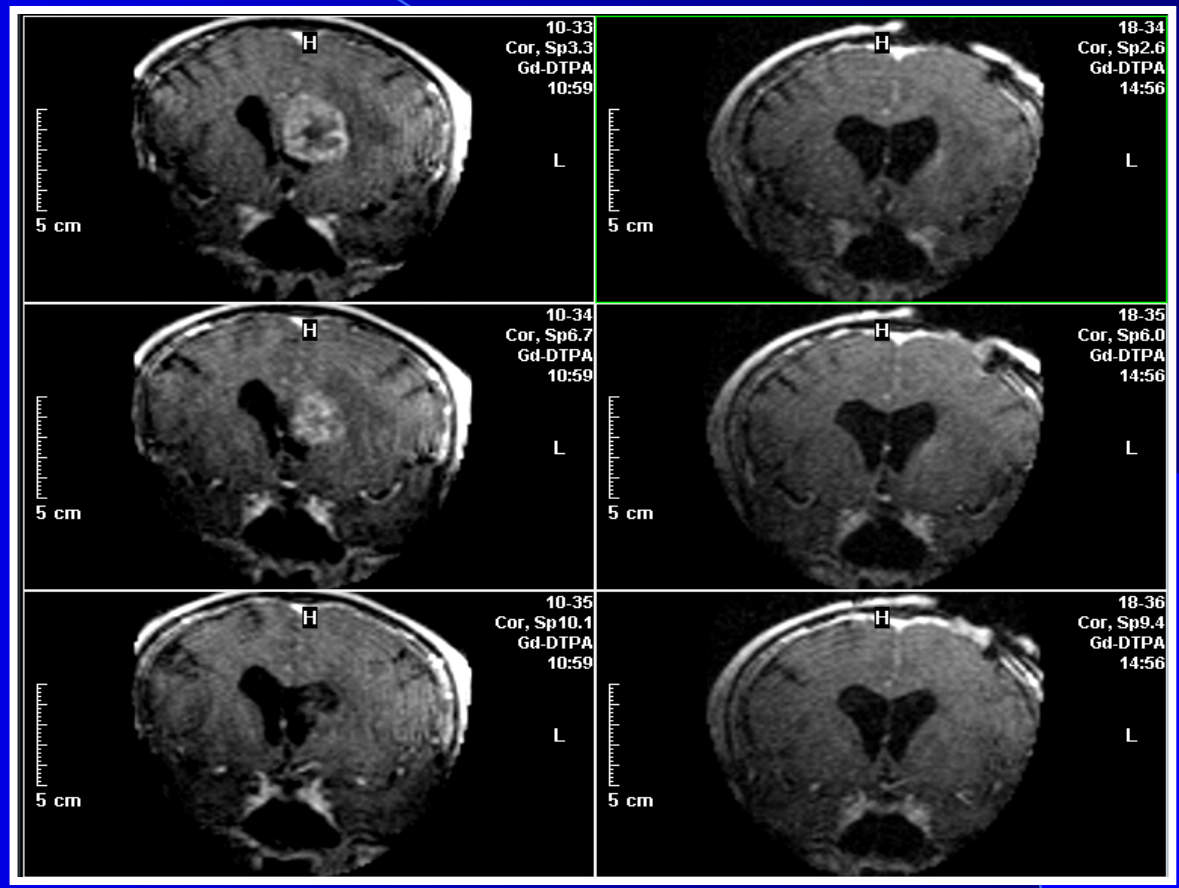
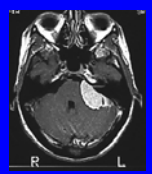
Per-operative low field MRI images quality





Per-operative low field MRI images quality

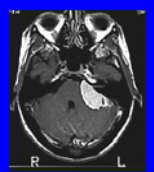




Another application of robotic: DBS Deep Brain Stimulation

- Neuromate robot:

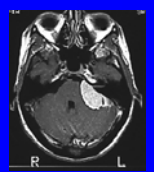
For positioning the electrodes in Parkinson's disease surgical treatment



Now, the future !!!

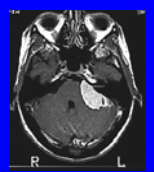
- Tele-assisted Neurosurgery
- Tele-mentoring

- Robotic can be useful.



What can we do?

- To access the operating field in the trajectory defined by the “expert” surgeon
- To define restricted areas: the robot blocks you when you want to go outside the authorized areas
- Guide-tools: endoscope, needle, electrode, drill,…
- To define drill zone, particularly for skull base (petrous bone…)
- Voice control couple to navigation, to tell you that you arrive on a risk zone, or at the end of resection,…

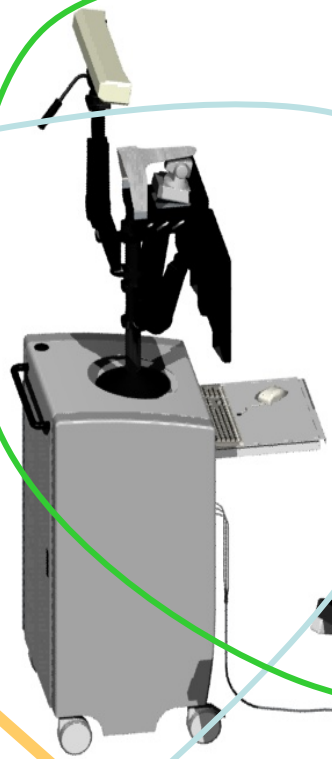


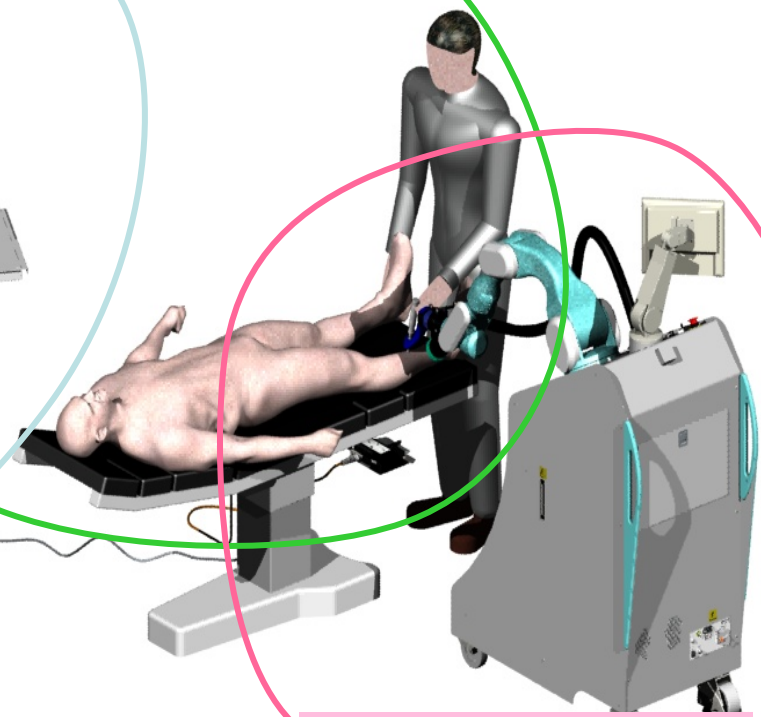
Robotic surgical Tele-assistance

System

Navigation system

Tele-assistance





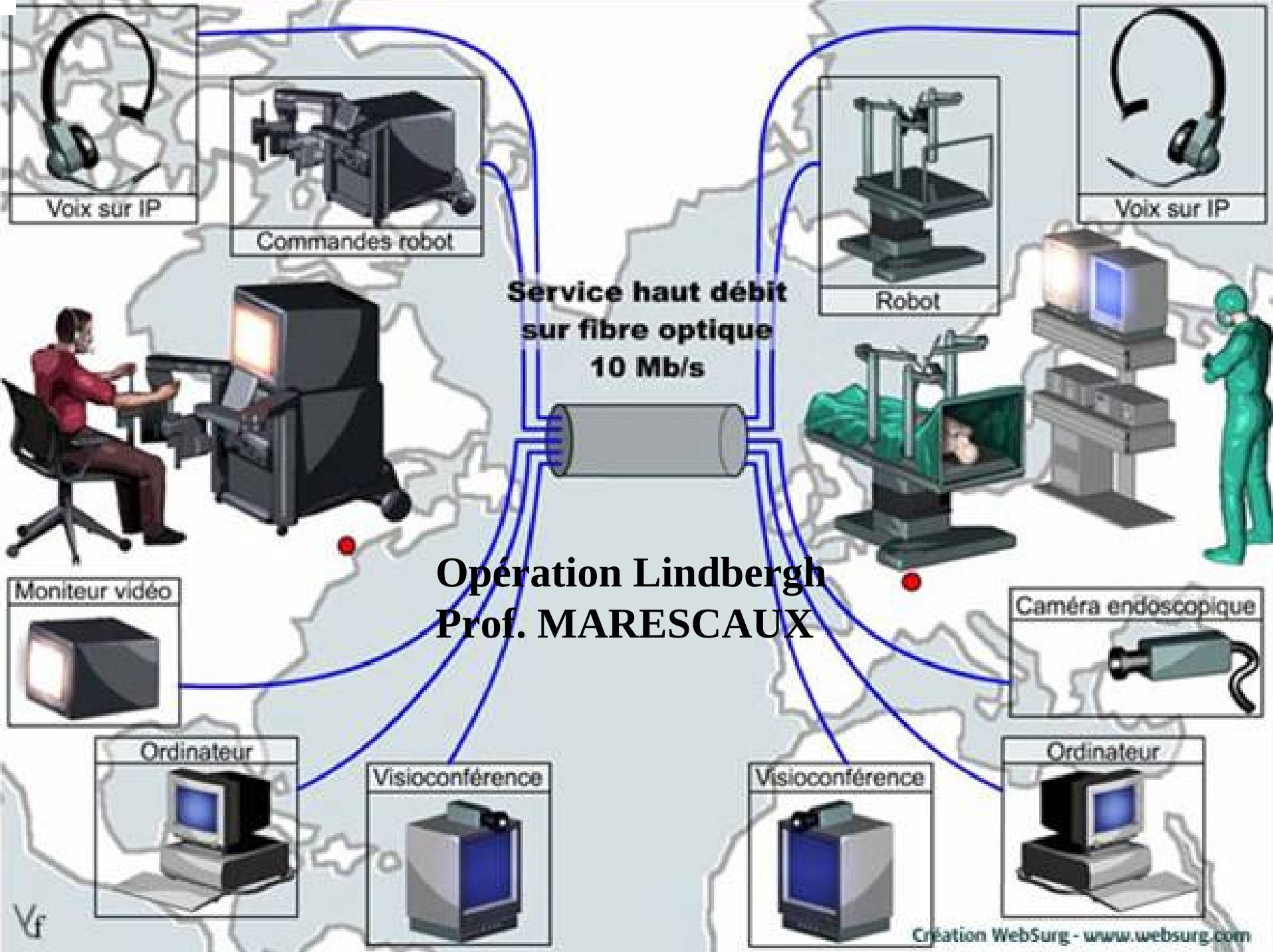
Tools-holder

EXPERT Desk

LOCAL Desk

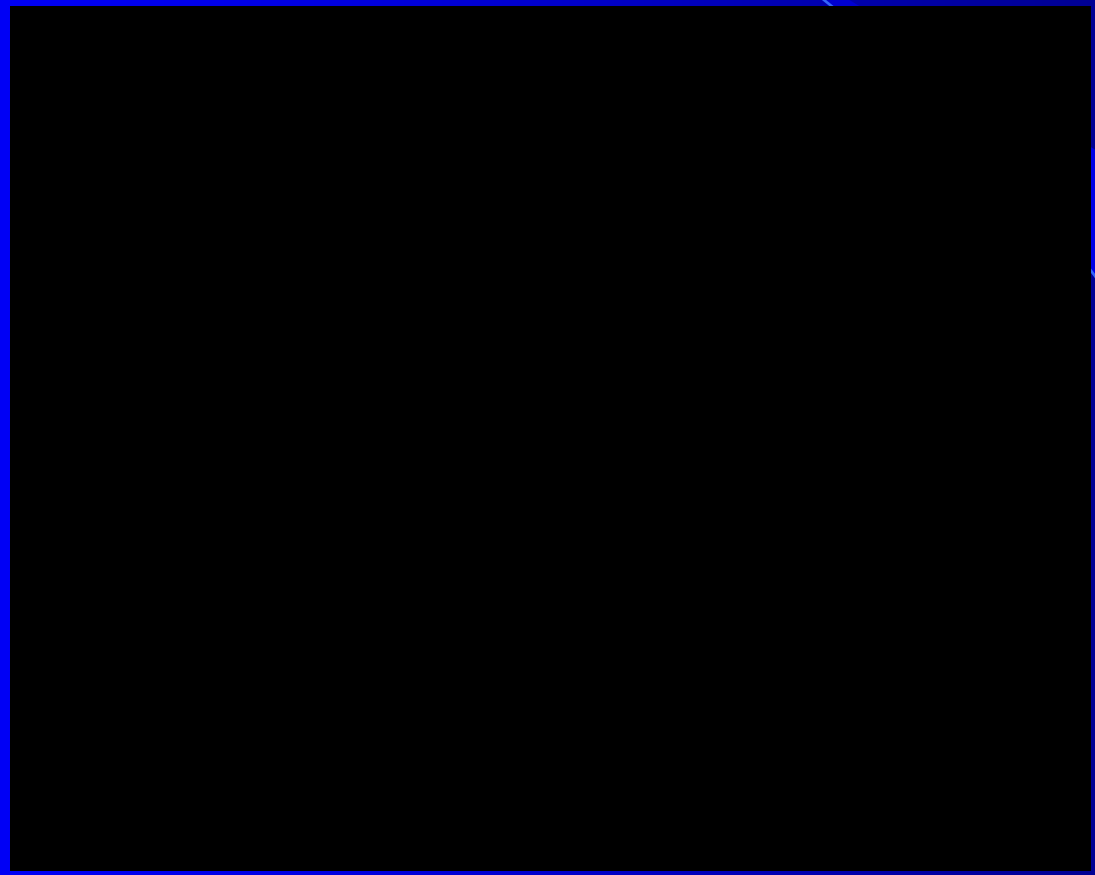
Demonstrator of robotic surgical tele-assistance

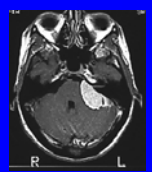
- The one-year tests are finished
- Lindbergh operation demonstrated that it's possible, but not easily and not daily
- The Armed Forces have an important interest with these techniques: we have to give the same quality of treatment to soldiers who are over seas, as if they are in France.
- We have to do animals trials and to miniaturize the system.


Voix sur IP
Commandes robot
Service haut débit
sur fibre optique
10 Mb/s
Robot
Voix sur IP
Opération Lindbergh
Prof. MARESCAUX
Moniteur vidéo
Caméra endoscopique
Ordinateur
Visioconférence
Visioconférence
Ordinateur
Création WebSurg - www.websurg.com

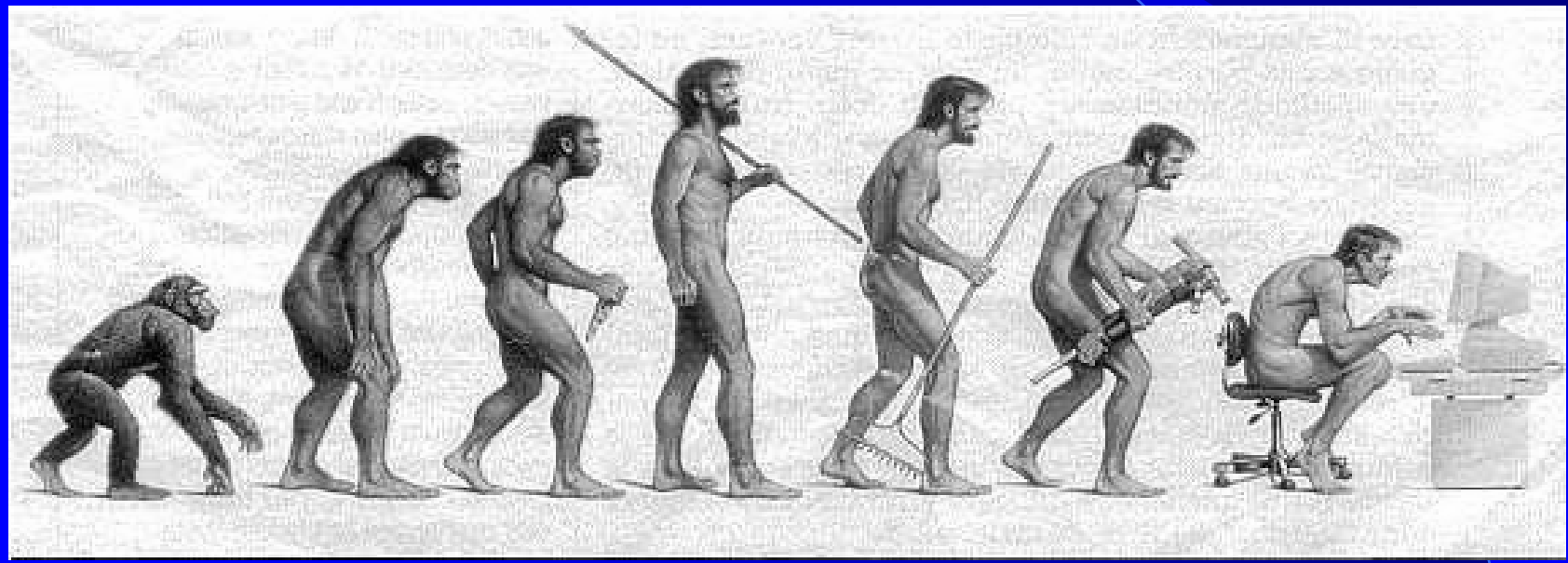
Tools-holder unit
Operative Mode

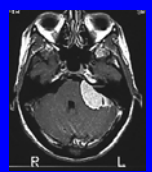
Trial of visioconference by satellite





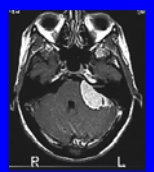
From barber to surgeon



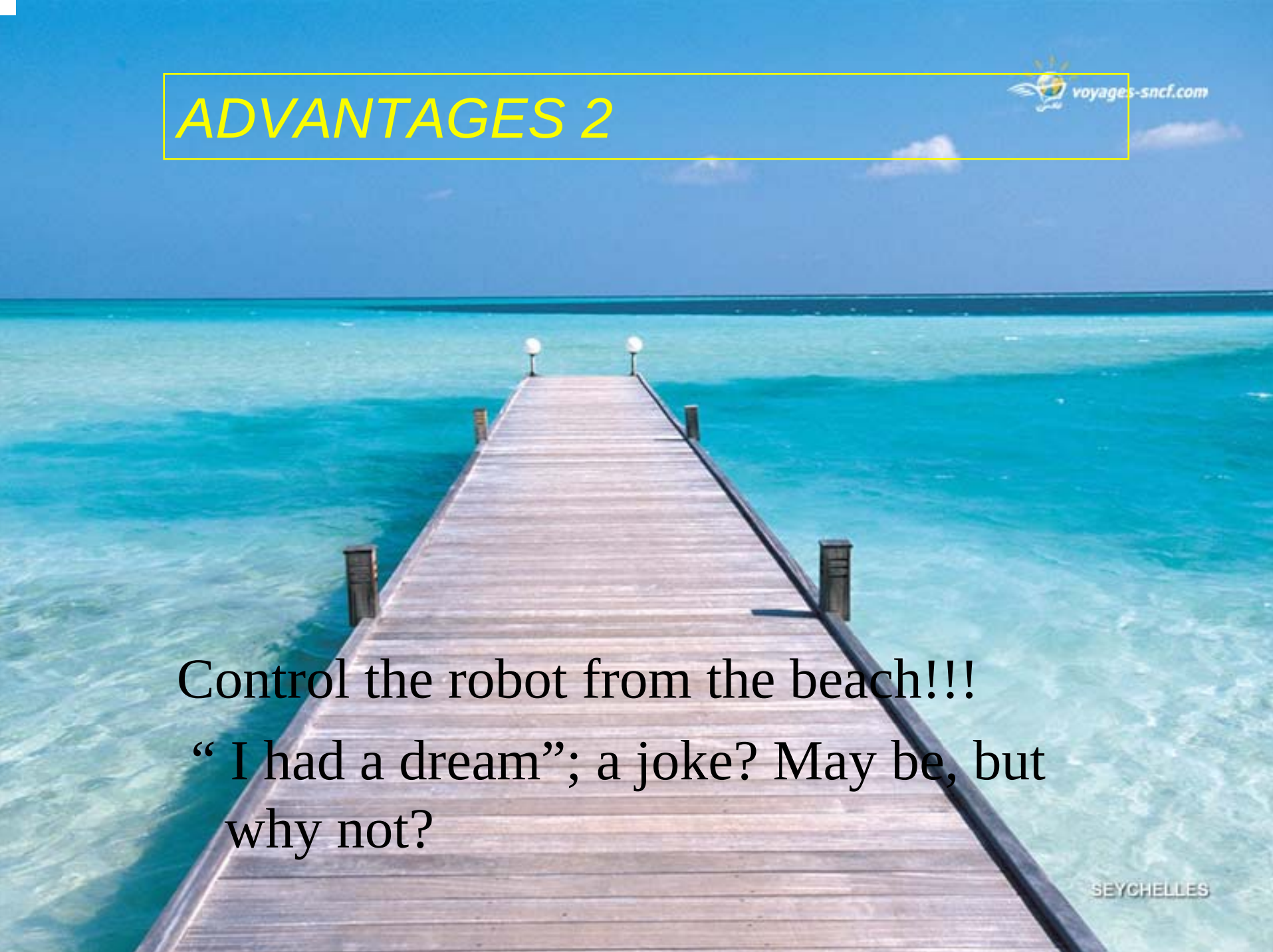


ADVANTAGES

- Accuracy
- Repeat the same movement frequently
- Stability of the guide-tool
- Mentoring on virtual procedures
- Tele-assisted surgery, for surgeons who are in foreign countries, or on hospital boat



ADVANTAGES 2

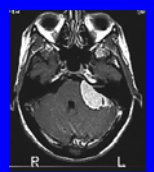


Control the robot from the beach!!!

" I had a dream"; a joke? May be, but why not?

DISADVANTAGES

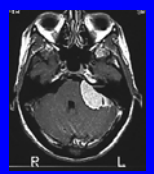
- The cost
- The learning-curve
- Durability: to deal with the sellers
- Increase the pre-operative time
- Miniaturisation is needed



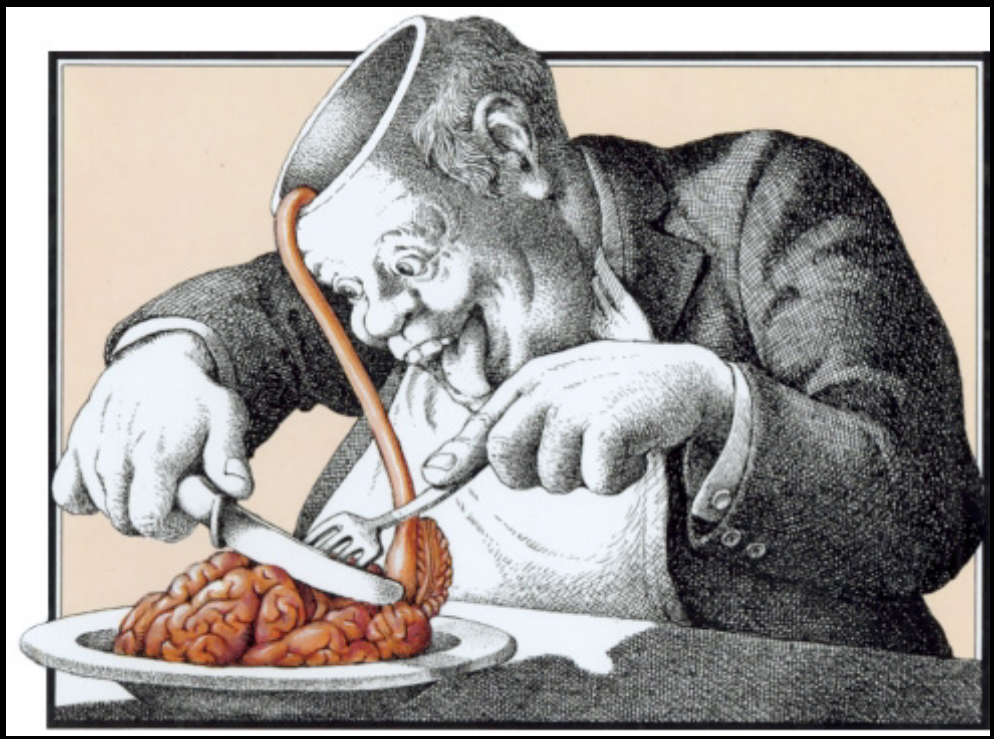
DISADVANTAGES

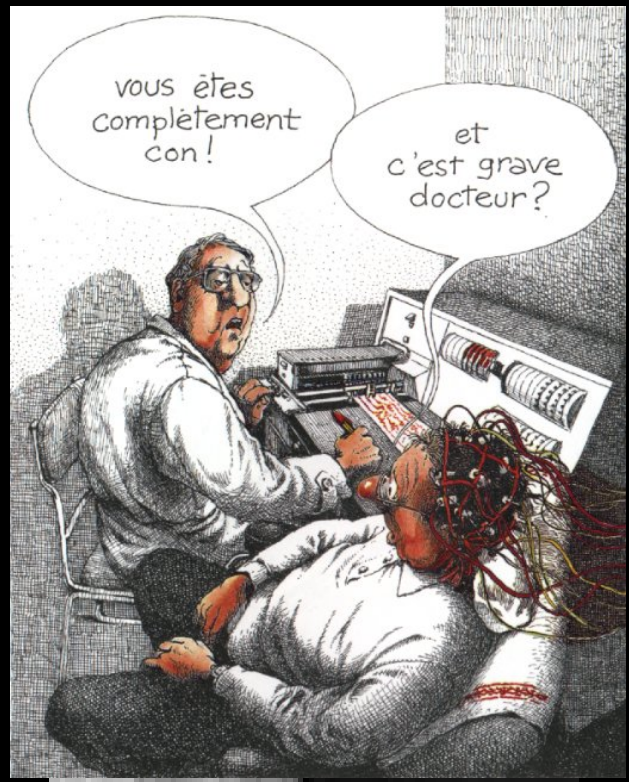
The most important one and the most difficult to eliminate:

To open the minds, before opening the skull for neurosurgeons; to convince surgeon to use it and that it's only a tool. Most of neurosurgeons think is useless at that time. We heard same thing 15 years ago with neuronavigation, minimal invasive surgery, keyhole concept, and 40 years ago with the microscope,…



Open the minds





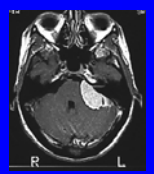
WHAT TO DO?

Progresses at the begins afraid:

We have to explain, convince, to change ours habits: that's the challenge and also the difficulties…

…and to keep always the control on ours tools:

That means to dominate the technique and not the opposite.

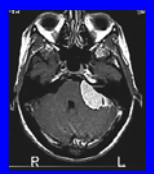


CONCLUSION

- Primum non nocere
- Very exciting challenge
- Keep in mind we have to deal with good post-operative status and total removal
- Keep humble faces a surgery that continues to be dangerous, despite the important technological progresses

Future... →

- Imaging progresses
- Robotic tools coupled with neuronavigation, per-operative MRI, FiberTracking,…



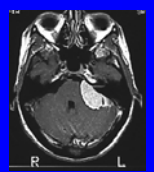
CONCLUSION

-We use daily neuronavigation

-Robotic surgery will be the next step

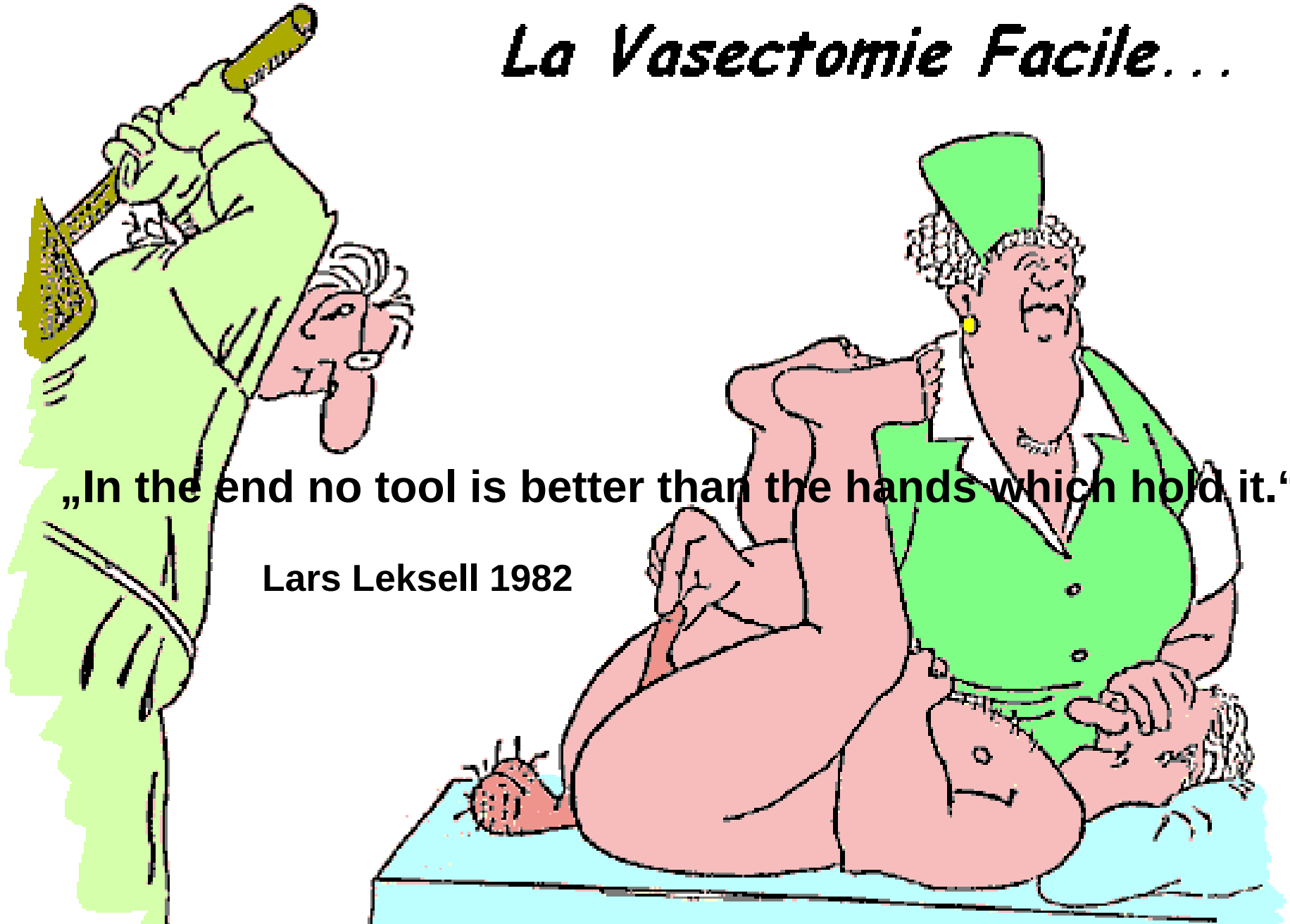
-Star Wars, it's today, with a journey in the depth of the brain

It would be a step to develop a neurosurgical simulator
To teach the young neurosurgeons.



CLINIQUE DES JOYEUX CHIRURGIENS

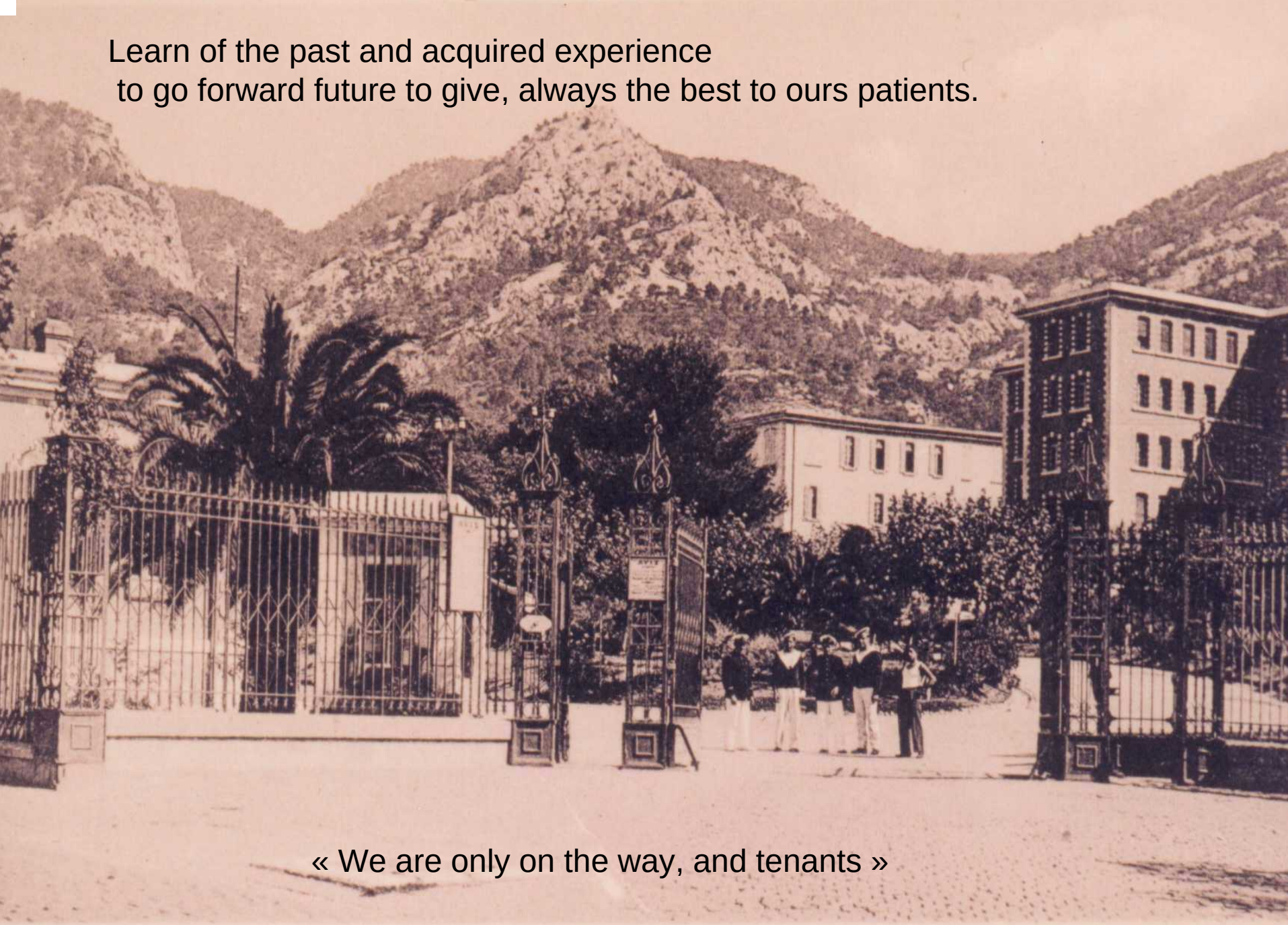
La Vasectomie Facile...



„In the end no tool is better than the hands which hold it.“

Lars Leksell 1982

Learn of the past and acquired experience
to go forward future to give, always the best to ours patients.



« We are only on the way, and tenants »

62. TOULON — Hôpital Sainte-Anne

New OR HIA Sainte-Anne

Our future in 2 months, but the past for the future generations; we have to do the maintenance and upgrading of materials to give them the best at their time.

CONCLUSION

« Mari transve mare hominibus semper prodesse ».