Development of 7 Tesla Magnetic Resonance Imaging Guided Robotic System

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Content

1. Introduction

- Stereotaxy is a technique that can locate targets of interest within the brain using 3D Image-Guided Technology.

- Stereotactic neurosurgery integrates advanced medical imaging and navigation with surgical workflow to localize, visualize, monitor and target clinical procedures.

- Three basic components:
  - ✓ Stereotactic equipment;
  - ✓ Anatomic knowledge;
  - ✓ Image guidance

1. Introduction

- Widely used in variety of clinical procedures:

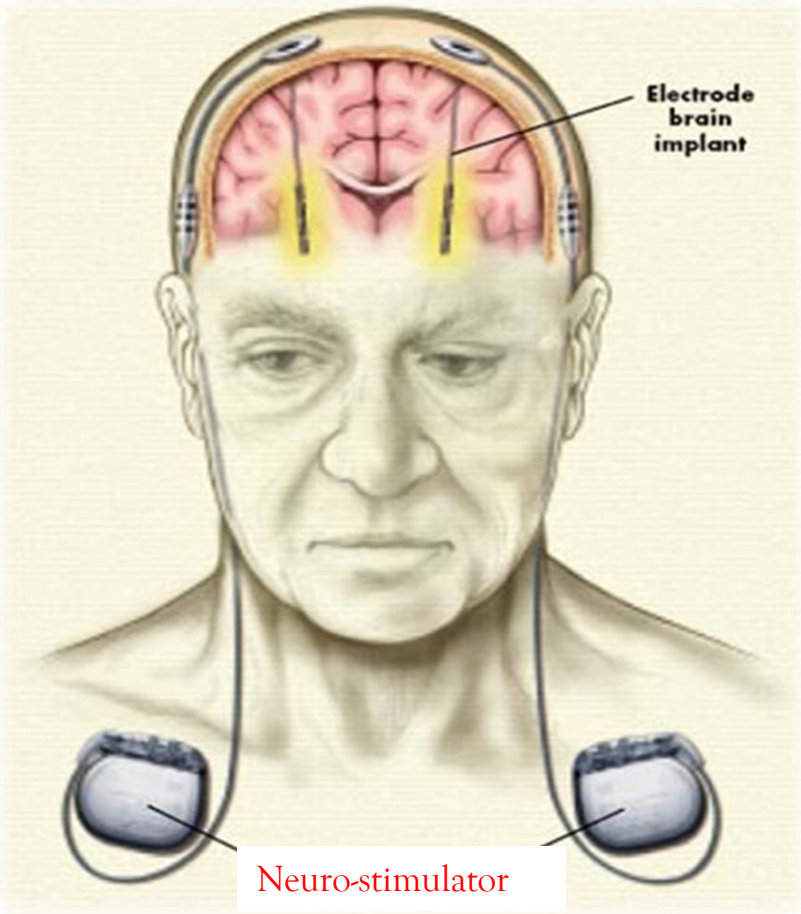
  - ✓ Biopsy;
  - ✓ Injection;
  - ✓ Ablation;
  - ✓ Catheter Placement;
  - ✓ Deep Brain Stimulation (DBS).

1. Introduction

- Magnetic Resonance Imaging (MRI) is an ideal image guidance system:
  - ✓ High spatial resolution and soft tissue contrast;
  - ✓ Multi-parameters imaging function;
  - ✓ Radiation-free, etc.
- MRI Safe/Conditional Robotic System:
  - ✓ Increase neurosurgical accuracy, precision and reliability;
  - ✓ Streamline the clinical workflow.
- Neurosurgical outcomes will be improved significantly by integrating the advanced robotic techniques with developed MRI scanner.

2. Stereotactic Neurosurgery: Deep Brain Stimulation (DBS)

- DBS is one of stereotactic neurosurgeries in which a device called a neuro-stimulator delivers tiny electrical signals to the areas of the brain that control movement.
- It is approved by the FDA for the treatment of essential tremor and Parkinson disease.
- It consists of three parts: Electrode, Lead, and Neuro-stimulator.



2. Stereotactic Neurosurgery: Deep Brain Stimulation (DBS)

◆ APPLICATIONS:

Dystonia

Essential Tremor

Chronic Pain

DBS can also be used to treat the flowing conditions:

- Dystonia
- Essential tremor
- Chronic pain
- Obsessive-compulsive disorder
- Major depression

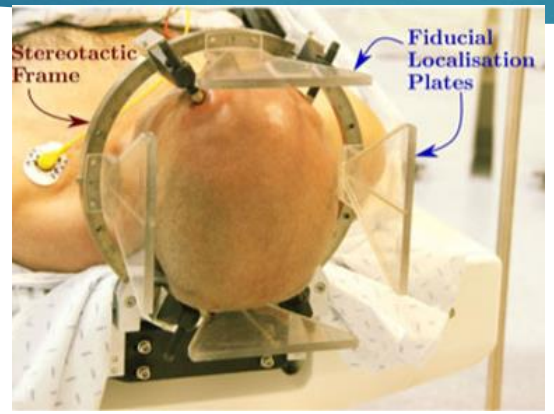
2. Deep Brain Stimulation (DBS)

✓ Conventional steps in the procedure for DBS surgery:

(a) Preoperative imaging positioning;
(b) Confirm preoperative coordinates;
(c) Scalp incision;
(d) Skull drilling;
(e) Implanted electrodes;
(f) MER and calibration of macro-stimulation parameters.

✓ Surgical challenges:

a) Brain shift;
b) Surgical time-consuming (about 6 hours);
c) High cost;
d) Awake patients.



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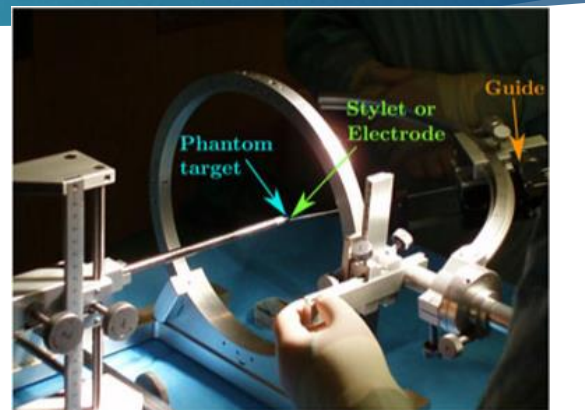

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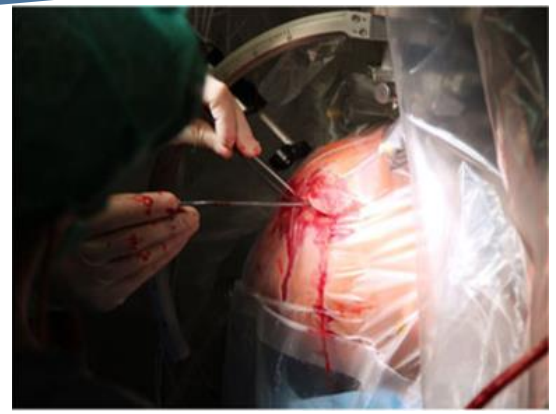
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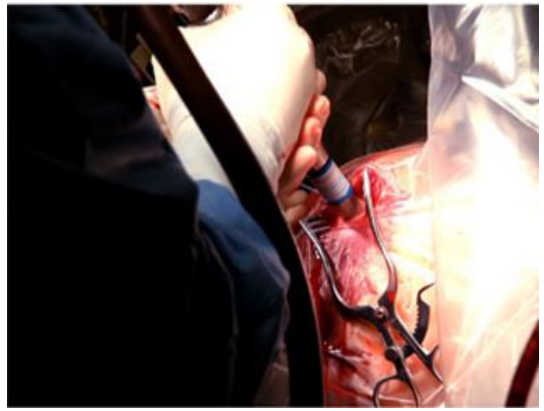
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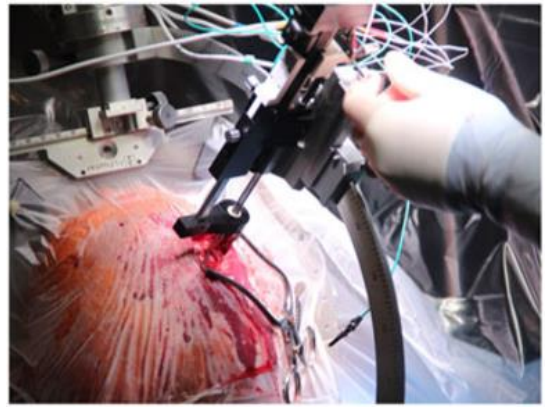
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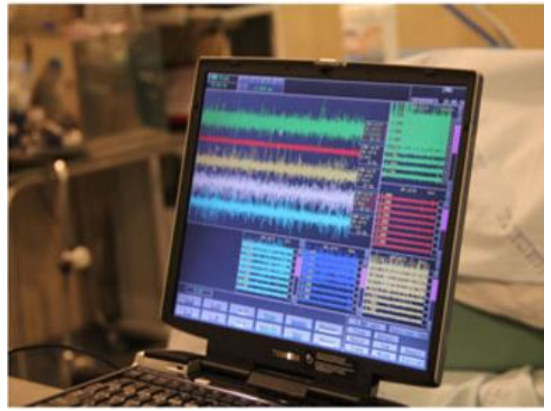
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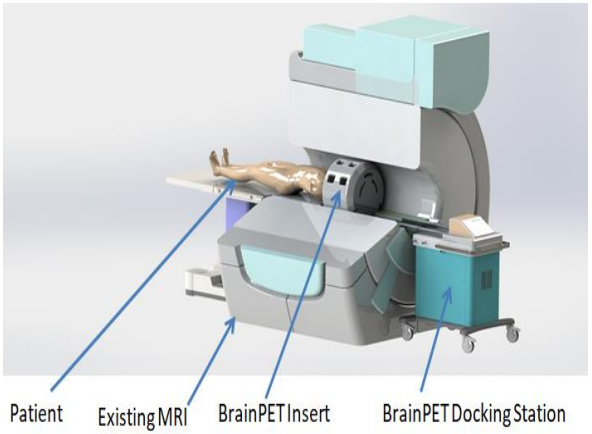
3. Innovation of MRI : 7.0T Brain PET/MRI and 1.0T intra-operative MRI

- 7.0 Tesla Brain PET/MRI:

Siemens 7.0 Tesla MRI

Brain PET

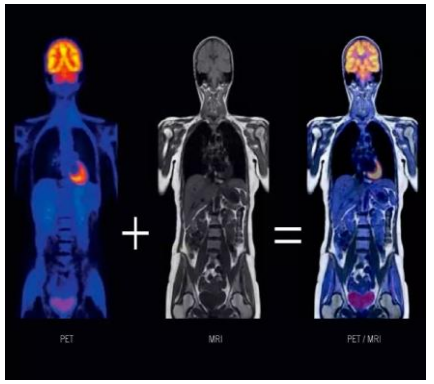


7.0 Tesla Brain PET/MRI

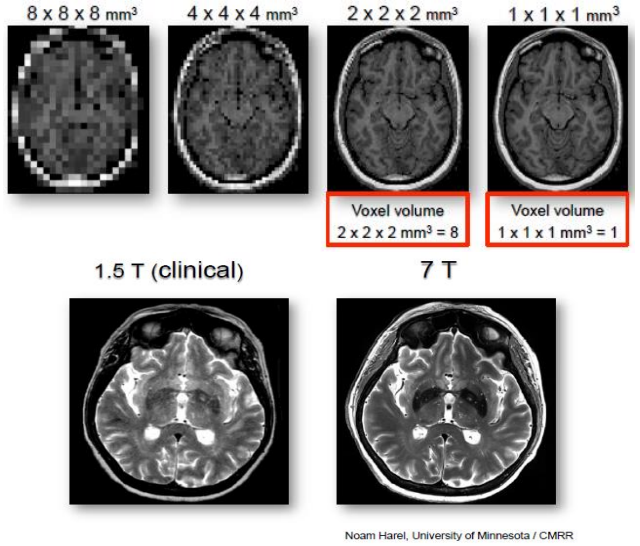
3. Innovation of MRI ： 7.0T Brain PET/MRI and 1.0T intra-operative MRI

➢ Advantages of 7.0 Tesla Brain PET/MRI:

◆ Integrating the high sensitivity molecular imaging (PET) with the superiority of anatomical functional imaging (MRI)

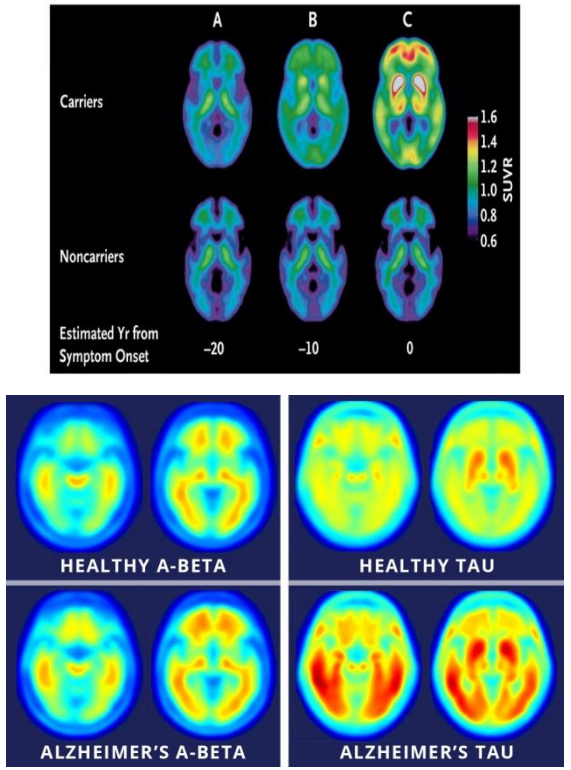


◆ High SNR and spatial resolution, providing more precision for pre-operative imaging positioning.



3. Innovation of MRI ： 7.0T Brain PET/MRI and 1.0T intra-operative MRI

- 7.0T Brain PET/MRI can also detect amyloid plaques in the brain before clinical symptoms appear, and prevent Alzheimer's disease (AD) earlier.

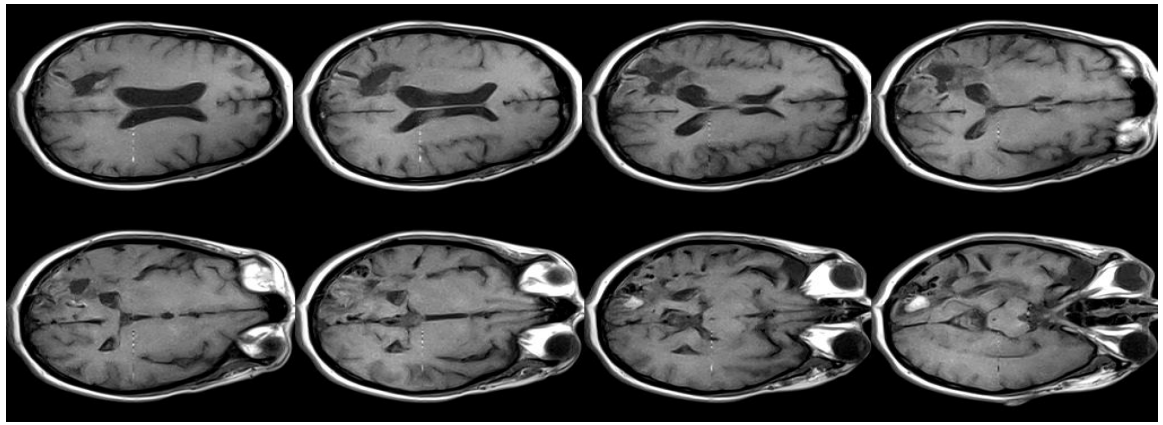


PET imaging of Alzheimer's disease (AD)

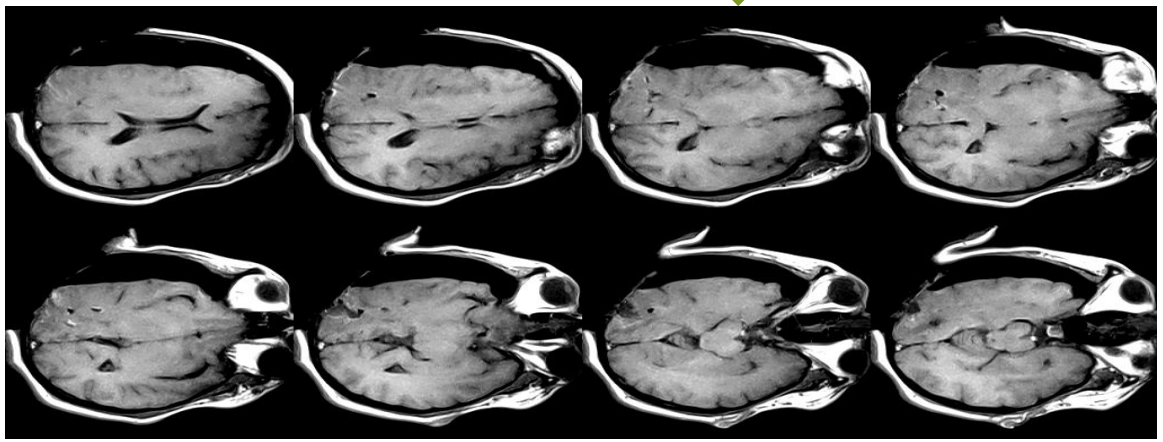
3. Innovation of MRI : 7.0T Brain PET/MRI and 1.0T intra-operative MRI

- Brain Shift can be compensated by intra-operative MRI (iMRI):

Brain Shift during surgery due to changes in brain pressure after craniotomy



Pre-operative image for surgical planning



Intra-operative image after craniotomy

3. Innovation of MRI ： 7.0T Brain PET/MRI and 1.0T intra-operative MRI

- iMRI-guided intracranial surgery was first applied in late 1990s
- The major advantages are the correction for brain shift, and identification of residual tumor and its margin.
- The main limitations are the reduced availability due to the high cost of installing an iMRI solution, the need for MRI compatible equipment and the fact that the procedure is time consuming.

3. Innovation of MRI ： 7.0T Brain PET/MRI and 1.0T intra-operative MRI

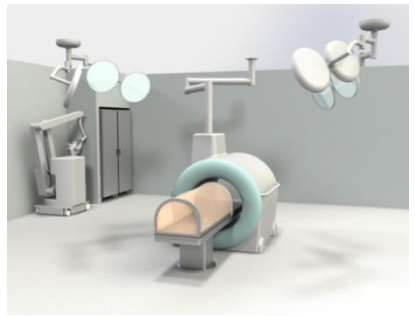
Traditional Intra-operative MRI :

- Moving patients：
  - ✓ Operating room needs to be rebuilt;
  - ✓ High cost for rebuilding;
  - ✓ Patients are at risk during the move.

New 1.0T Intra-operative MRI :

No magnetic field during surgery

Adding magnetic field

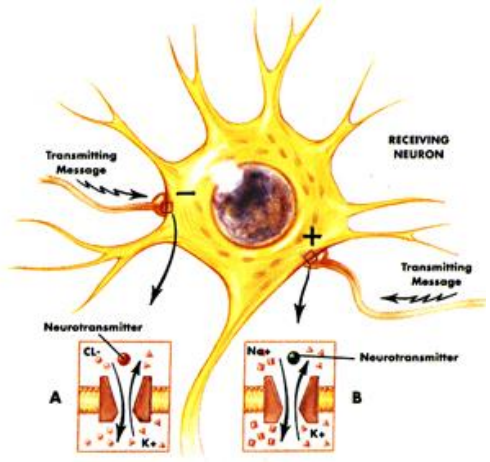


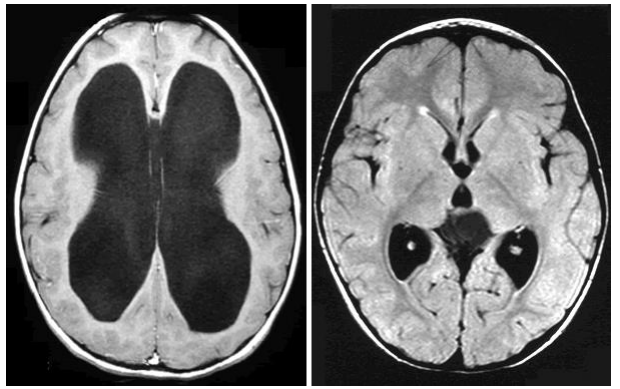
- Moving the magnet:
  - ✓ Using high-Tc superconductors nuclear magnetic;
  - ✓ No magnet support required;
  - ✓ Minimal transformation of the operating room.

4. Robotic-Assistant System in the Brain Neurosurgery

➢ Robots in neurosurgery?

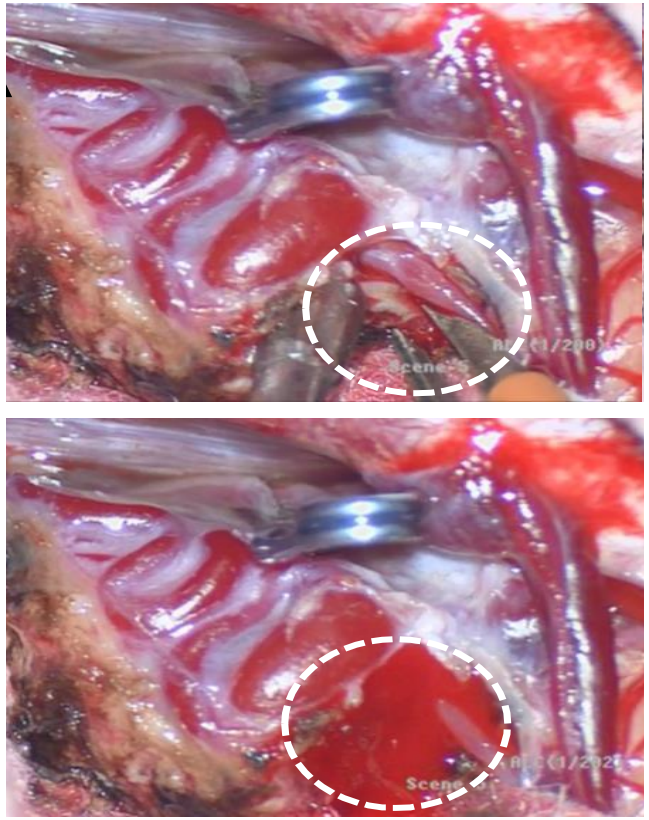
- Eliminate Human error and trauma in brain neurosurgery
  - ❖ Brain tumor removal
  - ❖ Parkinson
  - ❖ Alzheimer's disease
  - ❖ Aneurysm
  - ❖ Brain hemorrhage
  - ❖ hydrocephalus

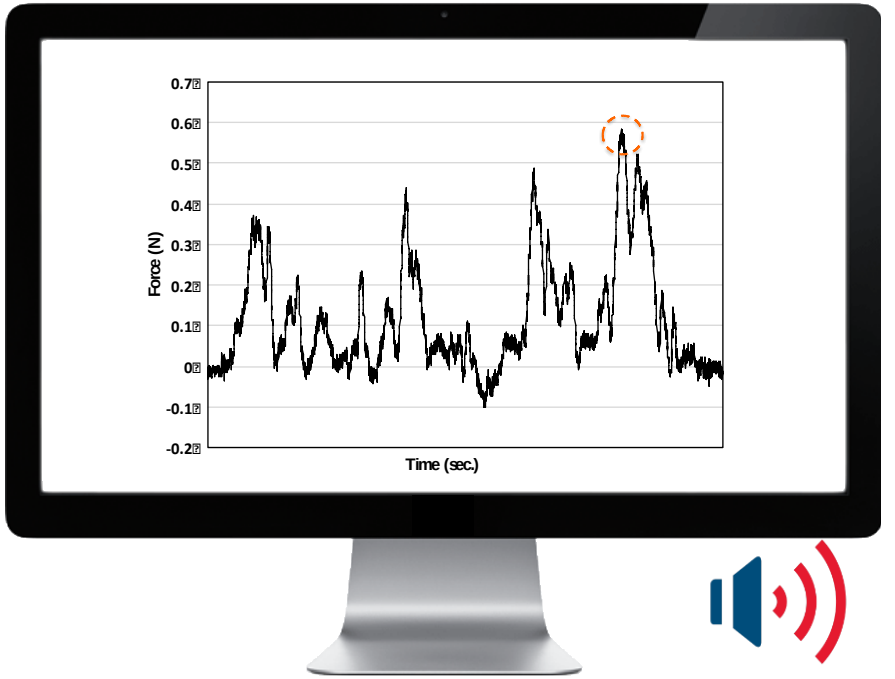




4. Robotic-Assistant System in the Brain Neurosurgery

- More than 50% of neurosurgical errors are due to Inappropriate excessive force

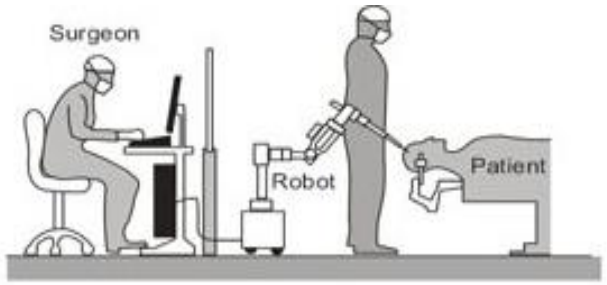




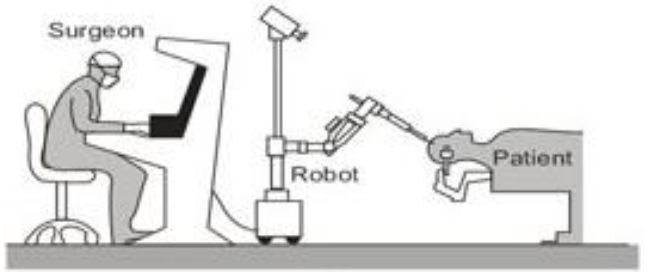
4. Robotic-Assistant System in the Brain Neurosurgery

- Three configurations for neurosurgical robots based on the principle of Human-Machine Interaction:

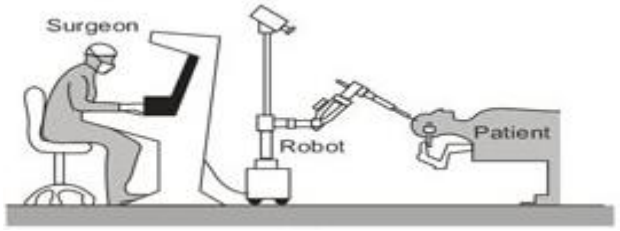
A. Supervisory controlled system:



B. Tele-surgical system:



C. Shared control system:



4. Robotic-Assistant System in the Brain Neurosurgery

Commercially available robotic systems applicable to neurosurgery:

(a) NeuroMate — Integrate Surgical Systems, Inc. Davis, CA, USA;

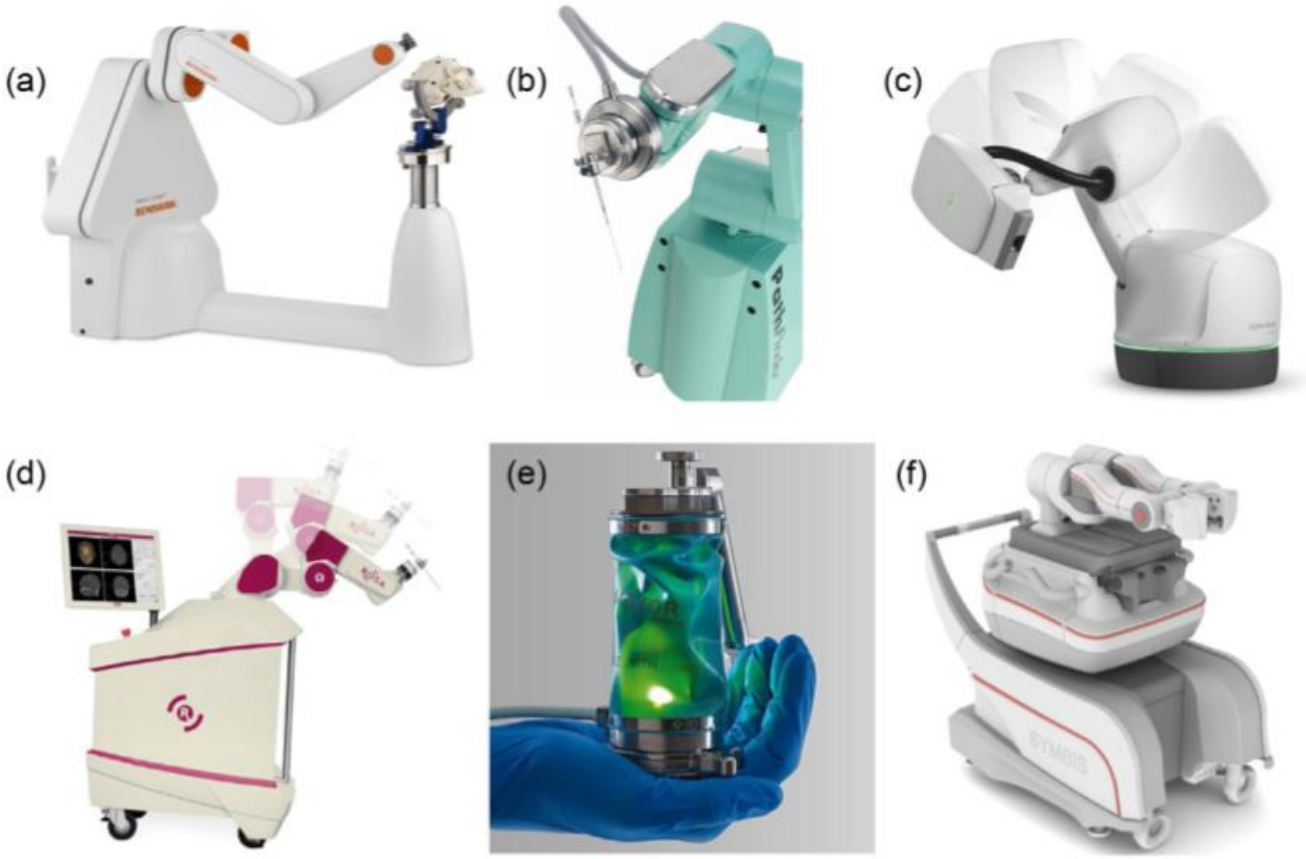
(b) PathFinder — Prosurgics Inc., Cupertino, CA, USA;

(c) Cyberknife — Accuray, Sunnyvale, CA, USA;

(d) Rosa — Medtech, Castelnau Le Lez, France;

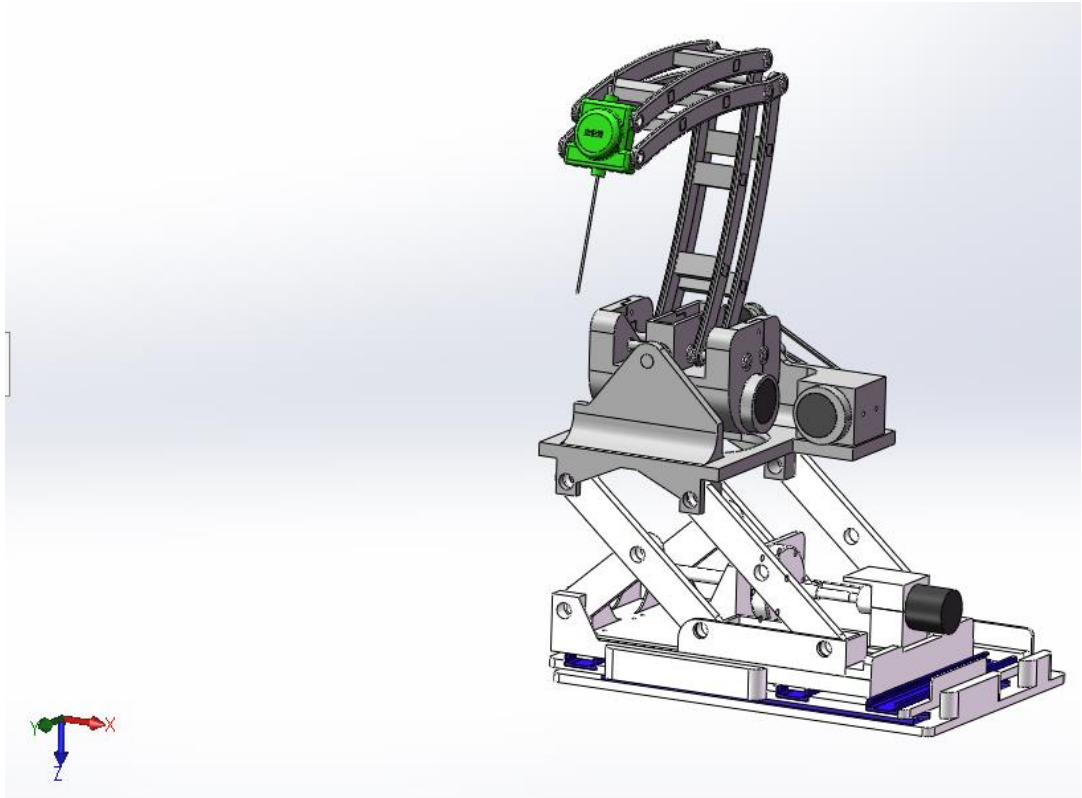
(e) SpineAssist — Mazor Robotics, Amelia Island, FL, USA;

(f) SYMBIS — IMRIS Inc., Minnetonka, MN, USA.



4. Robotic-Assistant System in the Brain Neurosurgery

iMRI Compatible
Stereotactic Robot



5. Integration of Imaging Technology and Robotic System

- Benefits of integrating the robotic technologies with Intraoperative MRI:

a) Increase accuracy:

Improved the accuracy, precision, and dexterity for brain neurosurgery.

b) Improved workflow:

Alleviate the necessity of iterative and time- consuming in neurosurgical procedure.

c) Enhanced ergonomics:

The tightly confined closed-bore scanner (60-70cm in diameter and 170cm in length) leads to awkward ergonomics for performing intervention manually.

5. Integration of Imaging Technology and Robotic System

A Case Study: NeuroArm

- 2 robot arms, 2 cameras, 1 workbench
- Including safety precautions
- Paige Nickason who is 21 years completely removed brain tumors for the first time in May 12, 2008

5. Integration of Imaging Technology and Robotic System

System Applications

- Can be widely used in variety of neurosurgery, such as:
- *Brain tumor;*
- *Cerebrovascular injury malformation;*
- *Brain inflammation;*
- *Some inherited metabolic disorders or dysfunctional diseases.*

Application characteristics

- Real-time image navigation surgery;
- Reduce the incidence of postoperative hemiplegia, aphasia and other neurological dysfunction;
- Provide real-time guidance and precise positioning for intracranial electrode implantation, stereotactic puncture, biopsy, etc.

6. Conclusion

- 7.0 Tesla Brain PET/MRI:
  - High sensitivity and resolution, reducing scanning time, and increasing precision of pre-operative targets.
- Intraoperative MRI:
  - MR-based tracking can provide real-time positional data with high resolution and update rate.
- Robotic System:
  - Robotic platforms for MRI-guided stereotactic neurosurgery enhanced dexterity, stability, and accuracy beyond manual operation.

6. Conclusion

- All technological developments will serve to exploit the information available and augment the surgeon’s abilities by providing enhanced visualization and manipulation.

Questions??