FRAMELESS STEREOTACTIC LOCALIZATION AND GUIDANCE

- Roberts and Friets -1980s.

  Theory

- Three points define a volume in geometric space
- If the same three points can be defined on a patient and on an image of that patient, then instruments can be navigated.

Basic components

- Computer workstation with neuronavigation software and computer monitor
- Medical imaging input (either through a DICOM link or a portable digital data format)
- Optical digitizer with infrared emitters and two infrared cameras
- Reference frame (secured to a head clamp)
- Registration stars (frames) for surgical instruments.
- Passive infrared reflectors (aluminum impregnated glass spheres)

Understanding the Basics

The principal concepts that underpin neuronavigation:

- Pre-operative imaging: Sequential , Non-overlapping volumetric slices, MRI/CT slices of 1-3 mm
- Accurate registration of the 'image dataset' with the 'real time surgical space'.
- A triangulation based system (analogous to Satellite navigation) to track operative instruments.
- A dynamic referencing system to maintain the validity of registration during the operative procedure.

Pre-operative Imaging

- Slices are contiguous without overlaps or spaces, the summation of the slices creates a 3-D reconstruction of the brain
- Software enables the imaging dataset to be viewed in multiple planes and as a 3-D reconstruction.
- Image fusion software can now fuse digitized information from other modalities such as CT and PET with the MRI scan at this stage.

Registration

Point or Surface alignment technique

- Point technique : Fiducial or Anatomical landmark.
- Anatomical landmarks identifiable on the imaging and in the surgical field (e.g. nasion, external auditory canal, orbital margins) can be co-aligned for registration.

- Surface alignment: Co-align the surface of the patient's head with the surface of the image dataset. A Laser beam is used within sight of the optical digitizer to delineate the periorbital and forehead regions of the scalp.

- The accuracy of registration must be confirmed with visual checks.
- Known landmarks on dataset are identified in the surgical space using the default pointer tool (e.g. globes, orbits, EAM, tragus).

Dynamic Referencing

- An optical reference frame with passive infrared reflectors is secured to the Mayfield head clamp.
- The optical digitizers recognize the fixed relationship between the reference frame and the patient's head.

Neuro-navigation errors

Image dataset acquisition

- Overlapping or interspacing slices.
- Variable slice thickness due to mechanical factors
- Resolution errors and limitations
- Errors associated with image fusion algorithms

Prevention

- Careful planning on well maintained equipment

Registration

- Adverse skin mobility
- Poor delineation of occipital region in surface mapping models
- Fiducial movement

Prevention

- Careful placement of Mayfield clamp
- Combination of surface and point registration
- Inclusion of the whole head during registration

Intra-operative errors

- Parallax type error when planning craniotomy
- Head movement causing loss of registration
- Brain shift
- Small errors in trajectory angle are magnified at the tip of a biopsy needle

Prevention

- Careful positioning
- Prudent use of mannitol
- Plan flap perpendicular to skull
- Ensure head secure in Mayfield clamp
- Use a rigid biopsy needle
- Use the largest registration star possible when tracking instruments

Brain shift

- Brain shift :

1. CSF drainage
2. use of diuretics
3. tumor resection which makes an error in the accuracy of the preoperative data.

- Deeper structures, such as those at the skull base or along the falx shift less than superficial structures, improving the accuracy of stereotactic systems at those regions.

Steps to prevent Brain shift

- Displacement is often greatest in the direction of gravity
- Minimizing diuretic use
- CSF shunting should be avoided until after the primary approach has been made
- defining the outer margins of a tumor before proceeding with debulking

Fiducial versus nonfiducial

- Fiducial versus nonfiducial neuronavigation assessment and consideration of accuracy. Pfisterer WK, Papadopoulos S, Drumm DA et al. ***Neurosurgery 2008 Mar;62(3 Suppl 1):201-7; discussion 207-8.***
- Conclusion : All three registration methods provided comparable distances to the target tissue for surgical procedures.
- Anatomic registration as a less costly and more time-efficient registration method for frameless stereotaxy.

Pediatric patient

Frameless stereotactic procedures in pediatric patients: safety and diagnostic efficacy. Mary G. Parreño & Xiao Bo & Okezie O. Kanu & Shlomi Constantini & Andrew A. Kanner. ***Childs Nerv Syst (2011) 27:2137–2140***

- N:21
- Age Mean, 8.7 years Range, 0.9– 18.9 years
- 18 biopsies and 4 catheter placement.
- In children below 2 years of age, the head was positioned and draped in a horseshoe holder, and the reference antenna was fixed to the rigid component of the operating table.

- Frameless, pin less stereotactic neurosurgery in children. John F. Reavey Cantwell, Frank J. Bova, David W. Pincus. ***J Neurosurg (6 Suppl Pediatrics) 104:392–395, 2006.***
- Six of the nine patients were younger than 2 years of age.
- beanbag devices were used

- Pinless frameless electromagnetic image guided neuroendoscopy in children. Jason L. McMillen & Marianne Vonau & Martin J. Wood. ***Childs Nerv Syst (2010) 26:871–878.***
- N: 19 ; 14 patients <3 yrs.
- StealthStation AxiEM Neuronavigation System (Medtronic, Louisville, CO, USA).
- Utilizes a coil to generate an electromagnetic field around the patient's head.
- Patients on jelly head ring or the Mayfield headrest

Controversy for its use in DBS

- Clinical Motor Outcome of Bilateral Sub thalamic Nucleus Deep-Brain Stimulation for Parkinson's Disease Using Image-Guided Frameless Stereotaxy. Helen Bronte-Stewart, Stephanie Louie, Sara Batya, Jaimie M. Henderson. ***Neurosurgery 67:1088–1093, 2010.***
- N: 31
- 58% improvement from bilateral STN DBS in the UPDRS III.
- All motor sub scores improved significantly(P <.01). The mean reduction in medication was 50%.
- **CONCLUSIONS**: Bilateral STN DBS for PD performed by an experienced team using a frameless approach results in outcomes comparable to those reported with the use of the frame-based technique.

- Comparison of Accuracy and Precision between Frame-Based and Frameless Stereotactic Navigation for Deep Brain Stimulation Electrode Implantation. Hjálmar Bjartmarz , Stig Rehncrona. ***Stereotact Funct Neurosurg 2007; 85:235–242***
- n : 14.
- The vector of deviation was 2.5 +_ 1.4 mm with the frameless technique and 1.2 +_0.6 with the frame-based technique. The differences were **statistically significant** ($p<0.05–0.001$).
- At clinical follow-ups, tremor reduction was similar irrespective of the implantation technique.

Electromagnetic

- Application of electromagnetic technology to neuronavigation: a revolution in image guided neurosurgery. Caroline HayHurst, PatriCia Byrne, Paul r. Eldridge, Conor l. MalluCCi. ***J Neurosurg 111:1179–1184, 2009.***
- N : 150 procedures
- The Stealth station Axiem navigation system (Medtronic, Inc.).

COMPARISON OF MAGNETIC TRACKING AND OPTICAL TRACKING BY SIMULTANEOUS USE OF TWO INDEPENDENT FRAMELESS STEREOTACTIC SYSTEMS. Christopher R.Mascott. ***Neurosurgery 57[ONS Suppl 3]:ONS-295–ONS-301, 2005.***

- N : 70 , both system simultaneous used.
- Magnetic referencing and tracking was found to be comparable with optical tracking both with regard to calculated and true surgical accuracy.
- Interference from metal objects in the magnetic field was seen rarely.

SonoWand

- Neuro-navigation by Intra-operative Three-dimensional Ultrasound: Initial Experience during Brain Tumor Resection. Geirmund Unsgaard, Aage Gronningsaeter, Steinar Ommedal, Torgrim Lie, Thomas Lango. ***Neurosurgery 50:804–812, 2002***

Intra OP MRI

INDICATIONS OF INTRAOPERATIVE MRI

- Supratentorial tumors- low grade glioma
- Pituitary tumor.
- Epilepsy surgery- side & size localization by functional MRI
- Resection control- cytoreductive surgery of large tumor
- Intra-ventricular shunt placement
- Needle biopsy
- Cyst aspiration
- Electrode placement – deep brain stimulation
- After aneurismal clipping – MR angiography

- Ferromagnetic cardiac implant – heart valve
- Pace- maker (non- compatible)
- Steel implant fixation for bone fracture
- Ferromagnetic spinal implant
- Cochlear implant (non- compatible)

ADVANTAGE OF INTRAOPERATIVE MRI

- Improves the accuracy of craniotomy placement
- Reduce the size of bone flap
- Surgical navigation can be repeatedly upgraded by intraop.
- Reduces the chances of neurological deficit in the surgery of eloquent area of brain
- Identify any amount of residual tumor at the end of surgery
- Identify any residual hematoma in AVM surgery

Frameless stereotaxy in spine

- Preoperative CT based guiding system
- Fluoroscopy based guidance system
- O arm based system.

- Preoperative CT based guiding system

Advantage	Disadvantage
Easy	Preop images must be compatible with IG
No radiation exposure	Registration process is difficult
	Not suitable for minimally invasive procedure

- Frameless stereotaxy to facilitate anterolateral thoracolumbar surgery : technique. E. Thomas Chappell, Laura Pare, Matthew O. Dolich, Mohammed Salepour. ***Neurosurgery 56[ONS Suppl 1]:ONS-110–ONS-116, 2005.***

- Fluoroscopy based guidance system

Advantage	Disadvantage
Registration process is obviated	Radiation exposure
	Depend on quality of images

O arm based system

- Best at present in terms of quality.
- Too costly, bulky needs large OT room, radiation risk to staff.

THANK YOU