

What to expect the day of your DBS surgery

Parkinson's Foundation of the North Capital Area
2021 Annual Symposium

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Disclosures

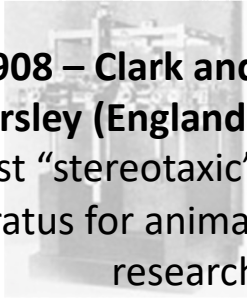
NewTouch Digital, Inc. – Chief Scientific Officer

Goal of stereotactic surgery (unchanged since 1908)

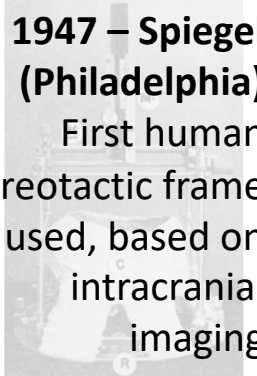


Place a small wire (1.25mm) into a small group of cells (3mm)

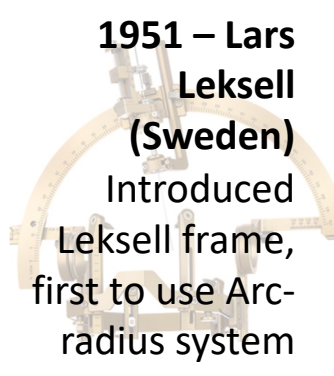
1908 – Clark and Horsley (England)
First “stereotaxic” apparatus for animal research



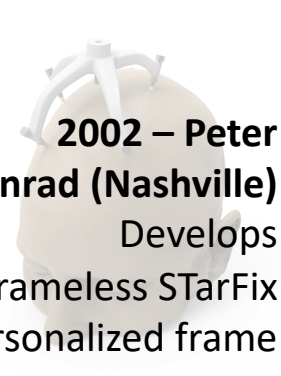
1947 – Spiegel (Philadelphia)
First human stereotactic frame used, based on intracranial imaging



1951 – Lars Leksell (Sweden)
Introduced Leksell frame, first to use Arc-radius system



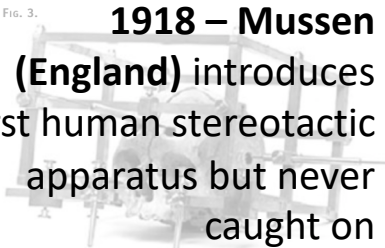
2002 – Peter Konrad (Nashville)
Develops frameless STarFix personalized frame



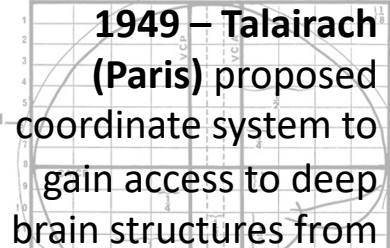
2005, 2013 – Paul Larson (San Francisco)
Develops MRI-guided asleep DBS (ClearPoint)



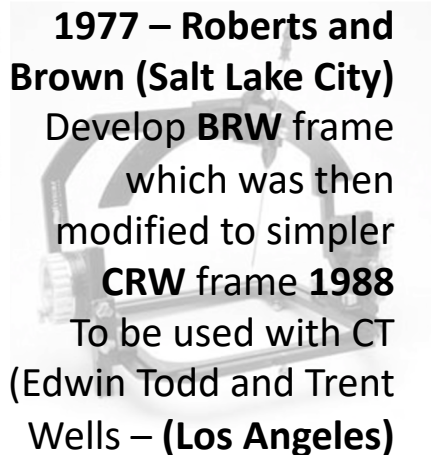
1918 – Mussen (England) introduces first human stereotactic apparatus but never caught on



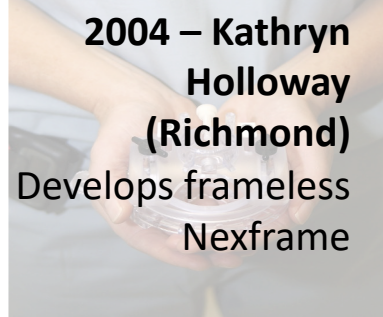
1949 – Talairach (Paris) proposed coordinate system to gain access to deep brain structures from lateral approach



1977 – Roberts and Brown (Salt Lake City)
Develop **BRW** frame which was then modified to simpler **CRW** frame **1988**
To be used with CT (Edwin Todd and Trent Wells – **Los Angeles**)



2004 – Kathryn Holloway (Richmond)
Develops frameless Nexframe



Two major stages in DBS surgery

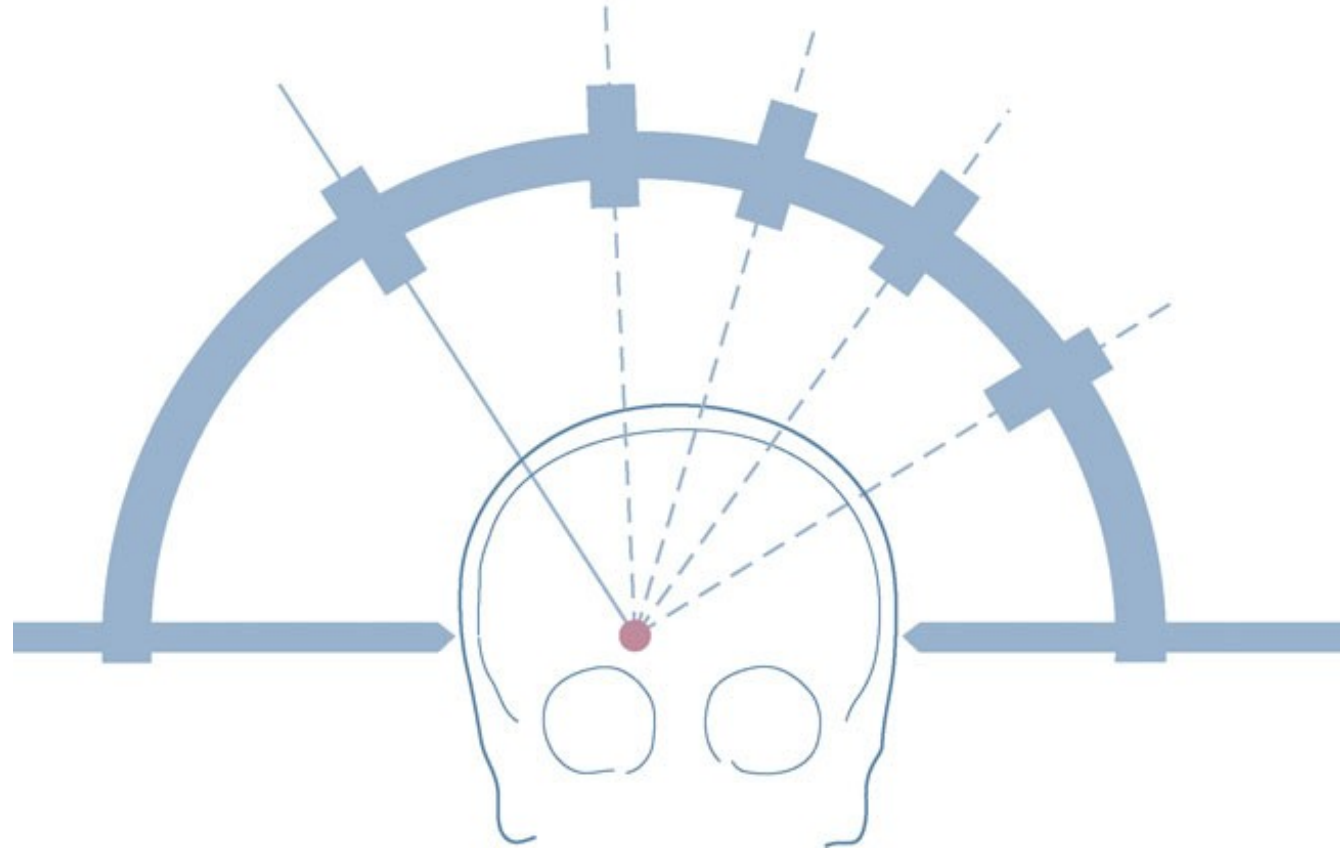
1. Placement of electrode leads into nucleus of interest (STN, GPi, Vim)
 - Awake vs. asleep
 - Frame-based vs. frameless
 - Image-guided
2. Placement of internal pulse generator (IPG)
 - Single procedure (during lead placement)
 - Separate procedure

Objectives

Describe the day of surgery events for...

- Phase 1: awake DBS surgery (frame-based and frame-less)
- Phase 1: asleep DBS Surgery
- Phase 2: IPG implantation

Awake frame-based surgery



Awake frame-based surgery – technical overview

1. Preoperatively - trajectory toward target planned using indirect (coordinates) and direct preoperative imaging (MRI)
2. Frame (CRW vs. Leksell) fixed to patient's head using scalp pins
3. Imaging (CT or MRI) performed to match pre-operative MR-space with trajectory plan to patient's 3D space
 - Coordinates toward target obtained:
 - x (left/right)
 - y (anterior/posterior)
 - z (superior/inferior)
 - arc angle (left/right)
 - ring angle (anterior/posterior)
4. Patient fixed to bed and incision made to access skull
5. Burr hole created / dura cut to access brain

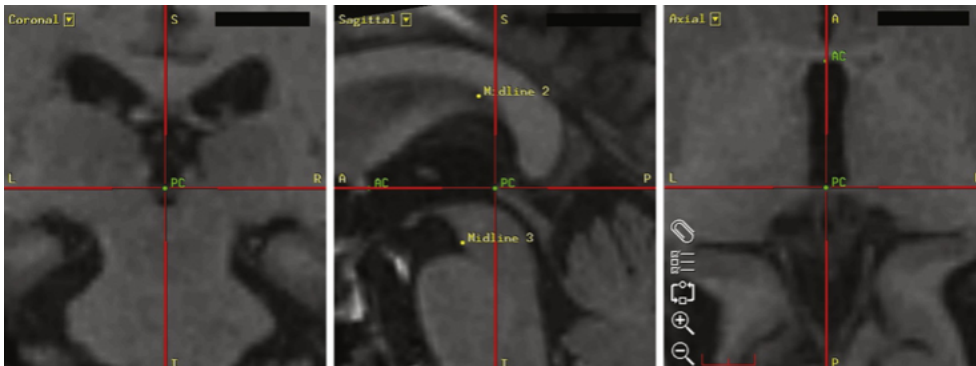
Awake frame-based surgery – technical overview

6. Micro-electrode recordings used to localize nucleus of interest (1-5 electrodes)
7. Macro-electrode stimulation while testing for symptom improvement or stimulation side-effects
8. Placement of permanent lead to depth of target based on recording and stimulation
9. Permanent lead stimulation to test for symptom improvement or stimulation side-effects
10. Intra-operative CT to localize and confirm lead placement within target
11. Closure of skin, repeat on other side

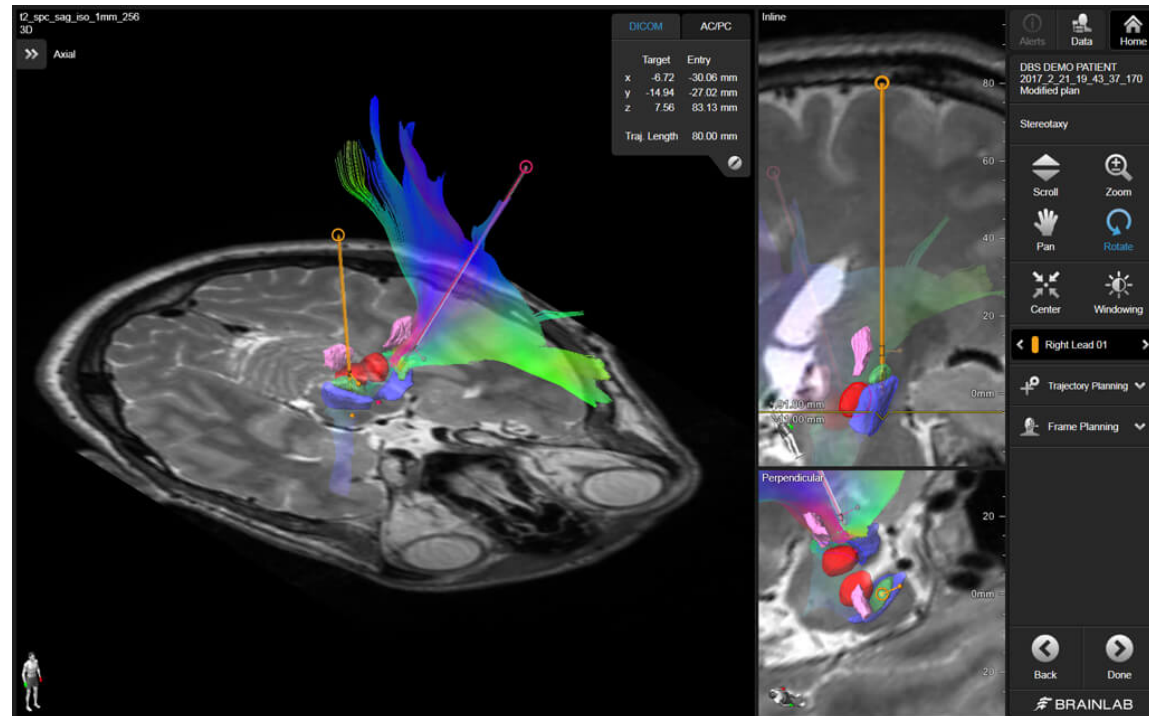
Awake frame-based surgery – preoperative planning

Preoperatively - trajectory toward target planned on BrainLab or Medtronic Stealth software

Indirect targeting (AC-PC coordinates)



Direct targeting (MR-imaging)



Target	Lateral (x) to MCP	Anterior/Posterior (y) to MCP	Vertical (z) to MCP
Vim	0.55 (AC-PC length)	0.25 (AC-PC length) posterior	0
STN	12 mm	3 mm posterior	4 mm below
GPI	21 mm	2 mm anterior	4 mm below

Awake frame-based surgery – frame placement

Frame (CRW vs. Leksell) fixed to patient's head using scalp pins



CRW Frame



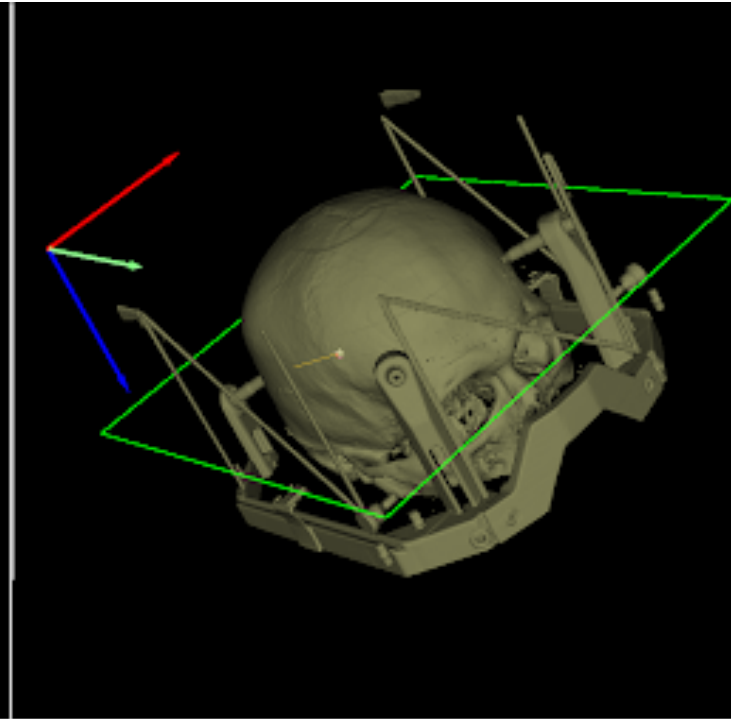
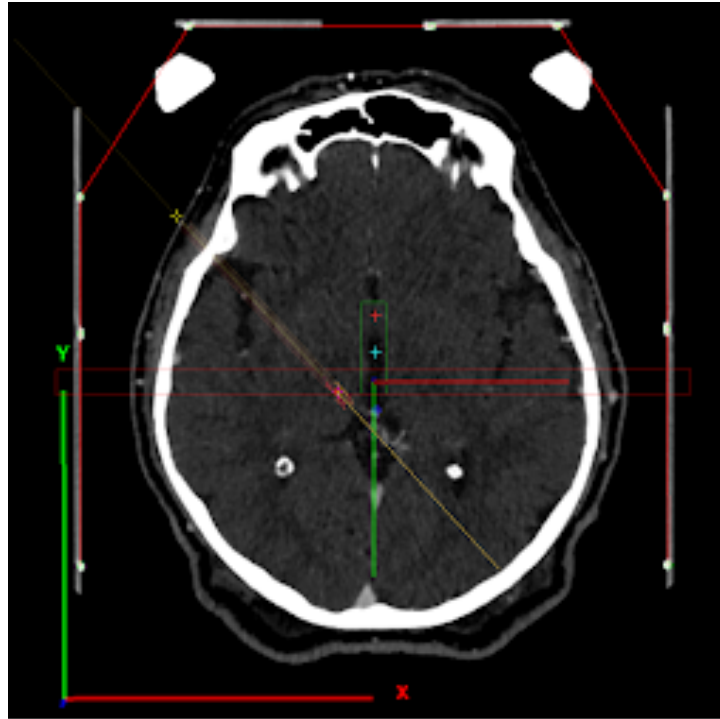
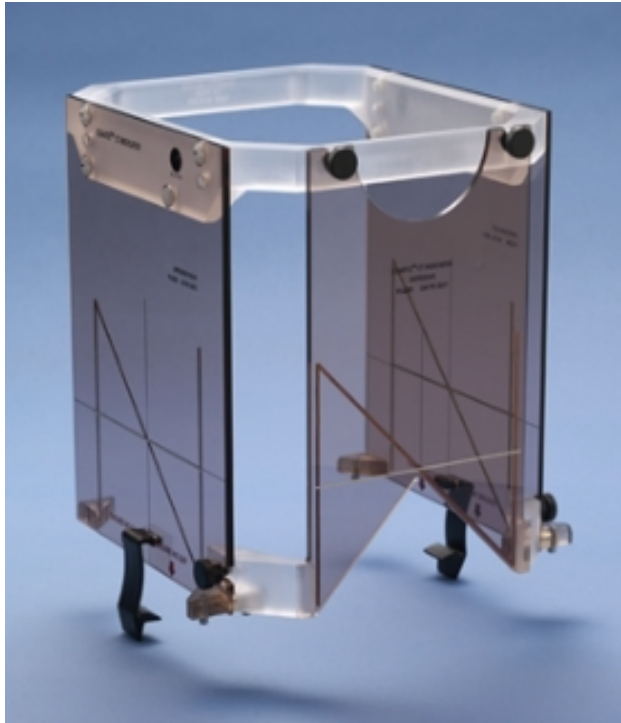
Leksell Frame



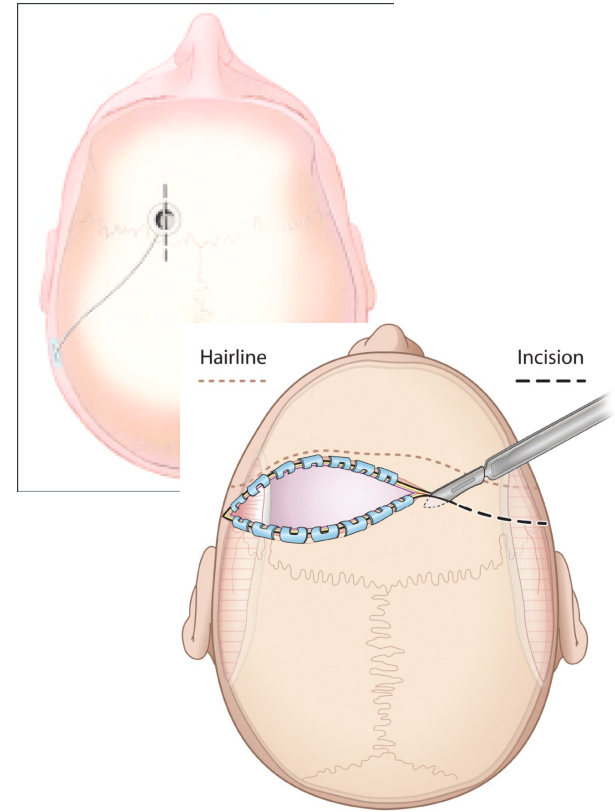
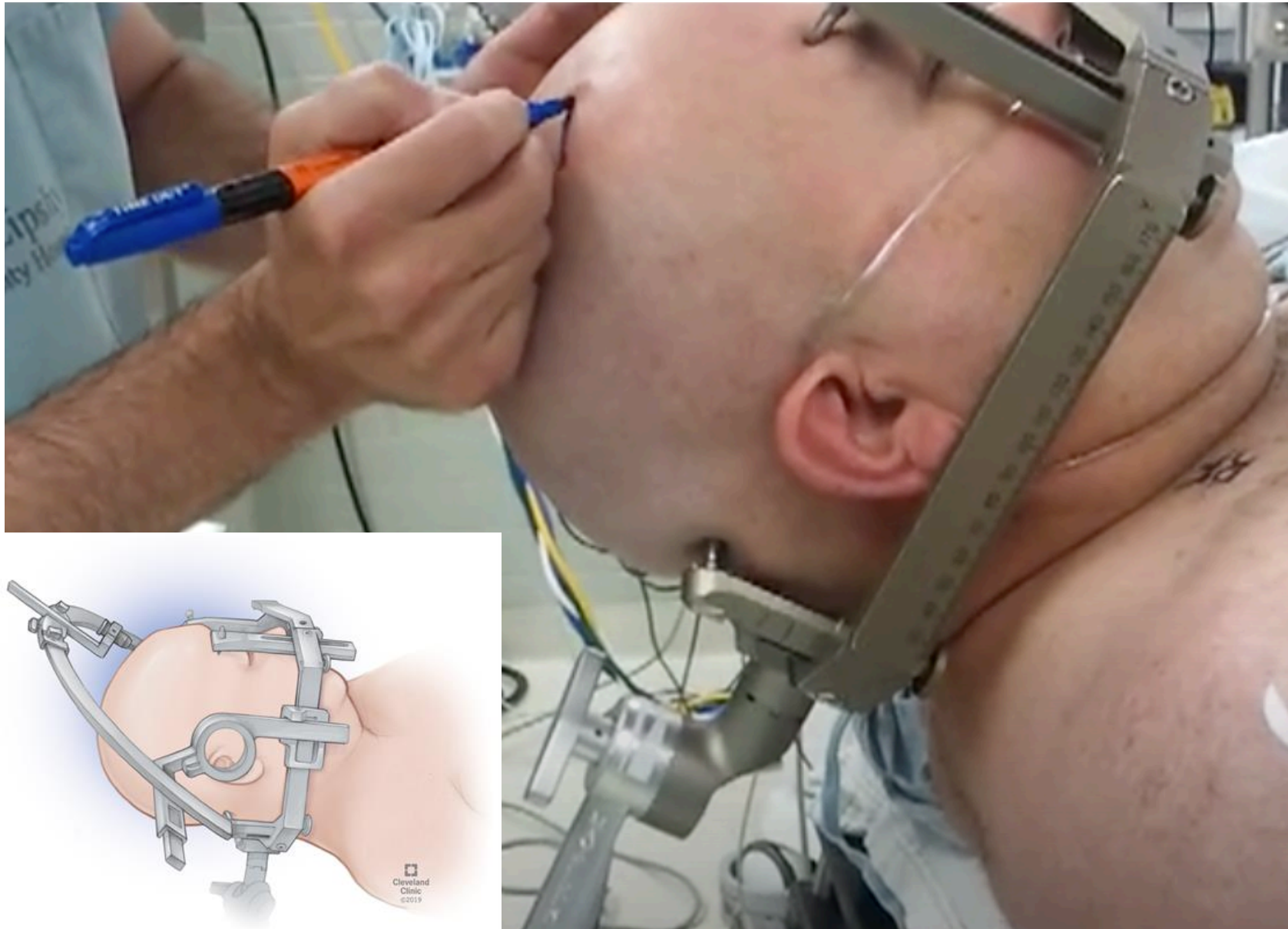
Awake frame-based surgery – post-frame imaging

Imaging (CT or MRI) performed to match pre-operative MR-space to patient's 3D space

- Intraoperative vs. extraoperative CT/MRI



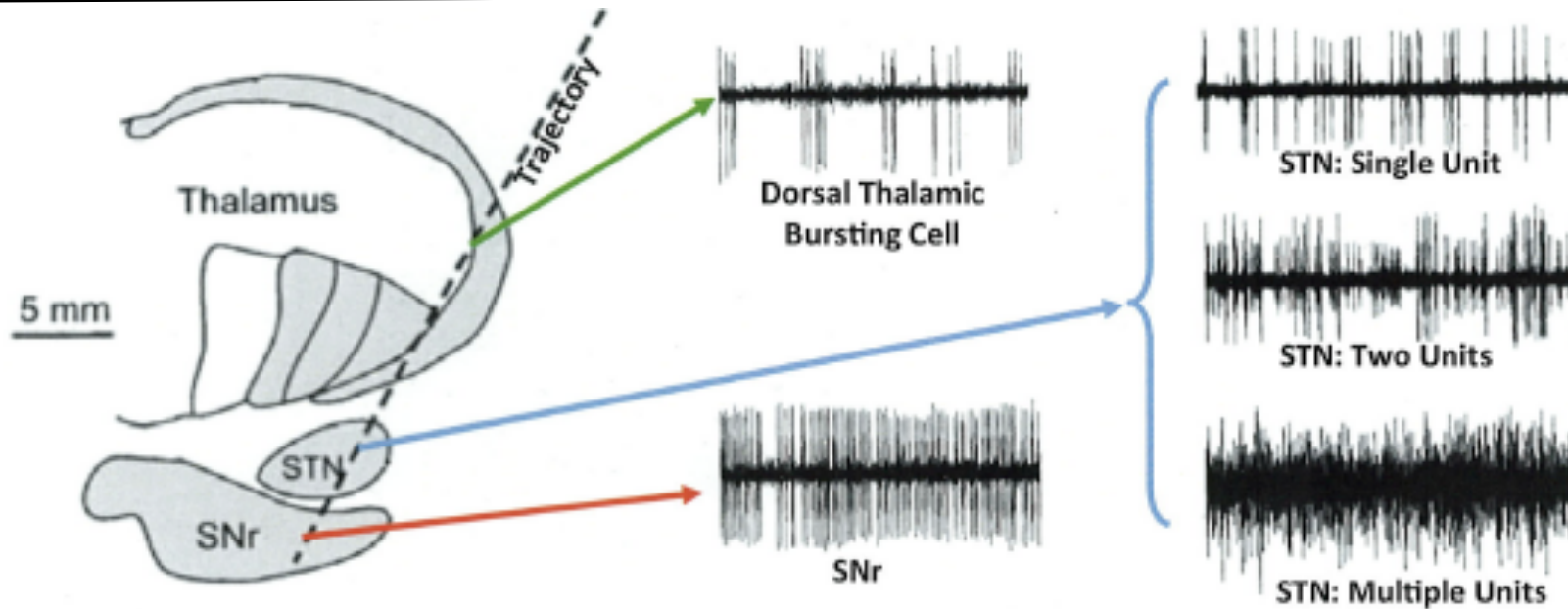
Awake frame-based surgery – attach to bed and incision



Awake frame-based surgery – burr hole and MER



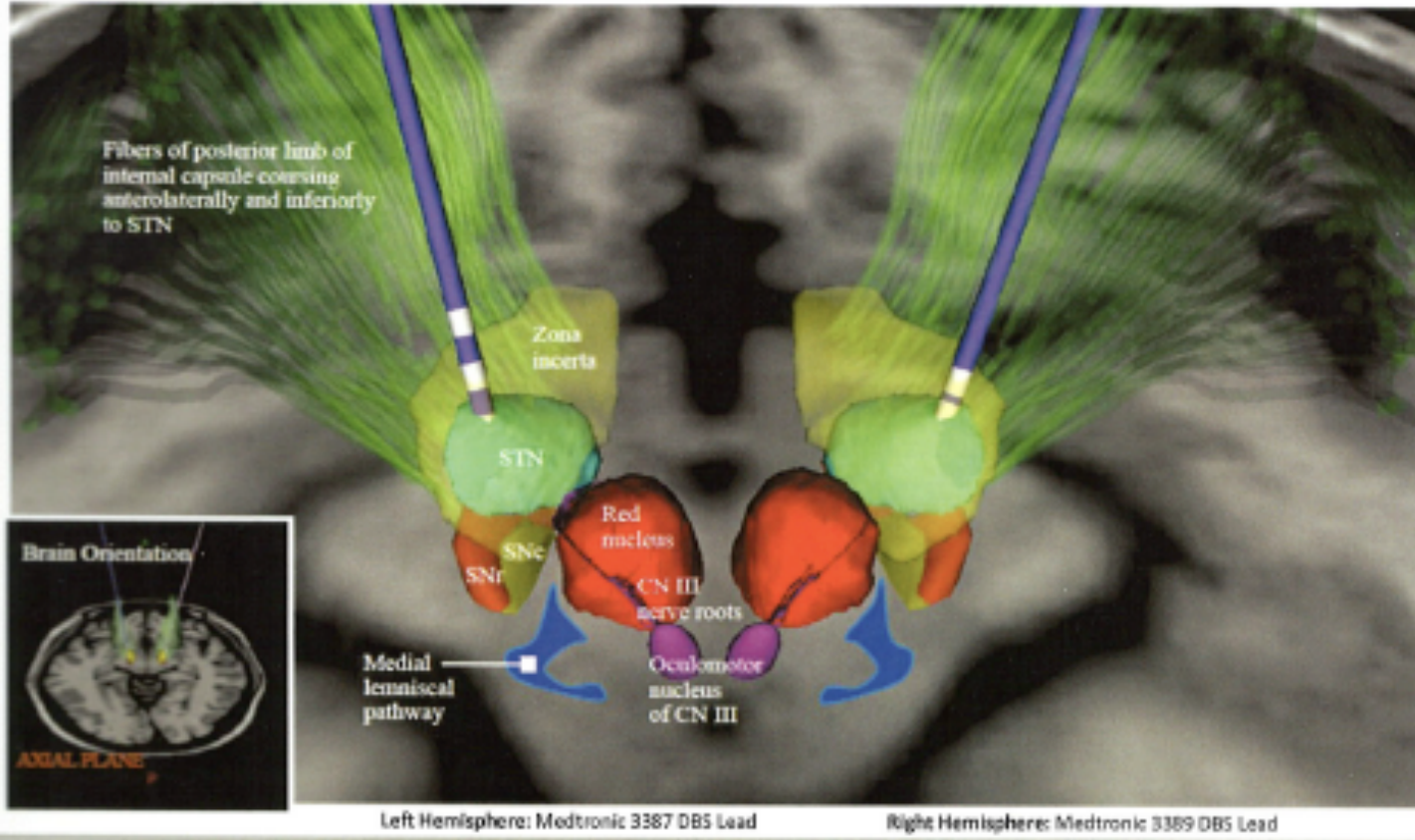
Surgical technique – STN MER and macrostimulation



		Location*	Stimulation Effects (& Anatomical Correlate)
Dorsal or Reticular Thalamus	- Low density of spontaneously firing neurons, not movement-responsive	Posterior	- Paresthesias (<i>Medial lemniscus</i>)
<i>Ventral Oralis anterior (VOa) Nucleus of the Thalamus*</i> OR <i>Ventral Oralis posterior (VOp) Nucleus of the Thalamus*</i>	- Low density of sporadically firing neurons, not movement-responsive - Moderate density and discharge frequency, voluntary movement-responsive cells - Presence of cells with bursting activity	Anterior	- Muscle Contractions, Dysarthria (<i>Internal Capsule</i>)
Base of Thalamus	- Marked decrease or cessation of neuronal activity	Lateral	- Muscle Contractions, Dysarthria, Contralateral Gaze Deviation (<i>Internal Capsule</i>)
<i>Zona Incerta</i>	- Low frequency units, low cellular density	Medial	- Diplopia, deviation of Ipsilateral eye, dizziness, ALO (<i>CN III</i>) - Personality/impulsivity changes, depression (<i>Limbic STN</i>) - Sweating, nausea, extreme discomfort, paresthesias, warm sensations (<i>Red nucleus, posteromedial</i>)
STN	- Significant increase in background activity and neuronal density - Very active with possible tremor cells - Movement-responsive neurons in dorsal 2/3 of STN - Dramatically elevated background	Superior†	- Possible impact on dyskinesias and/or tremor (<i>Zona incerta</i>)
White Matter (Quiet zone)	- Quiet zone of variable thickness between STN and SNr	Inferior†	- Possible mood changes, akinesias (<i>SNr</i>)
SNr	- High-frequency activity with regular discharge rates, lower background		

* dependent on trajectory and angle. A more anterior approach may traverse VOa while a more posteriorly-positioned approach may encounter VOp

Surgical anatomy – STN macrostimulation



2.1 ANATOMY SURROUNDING STN:

Posterior Limb of Internal Capsule

Lateral, anterior and ventral to dorsolateral STN

Zona incerta

Dorsal to dorsolateral STN

Substantia Nigra

Ventral to dorsolateral STN

Medial Lemniscus

Posterior to dorsolateral STN

Red Nucleus

Posteromedial to dorsolateral STN

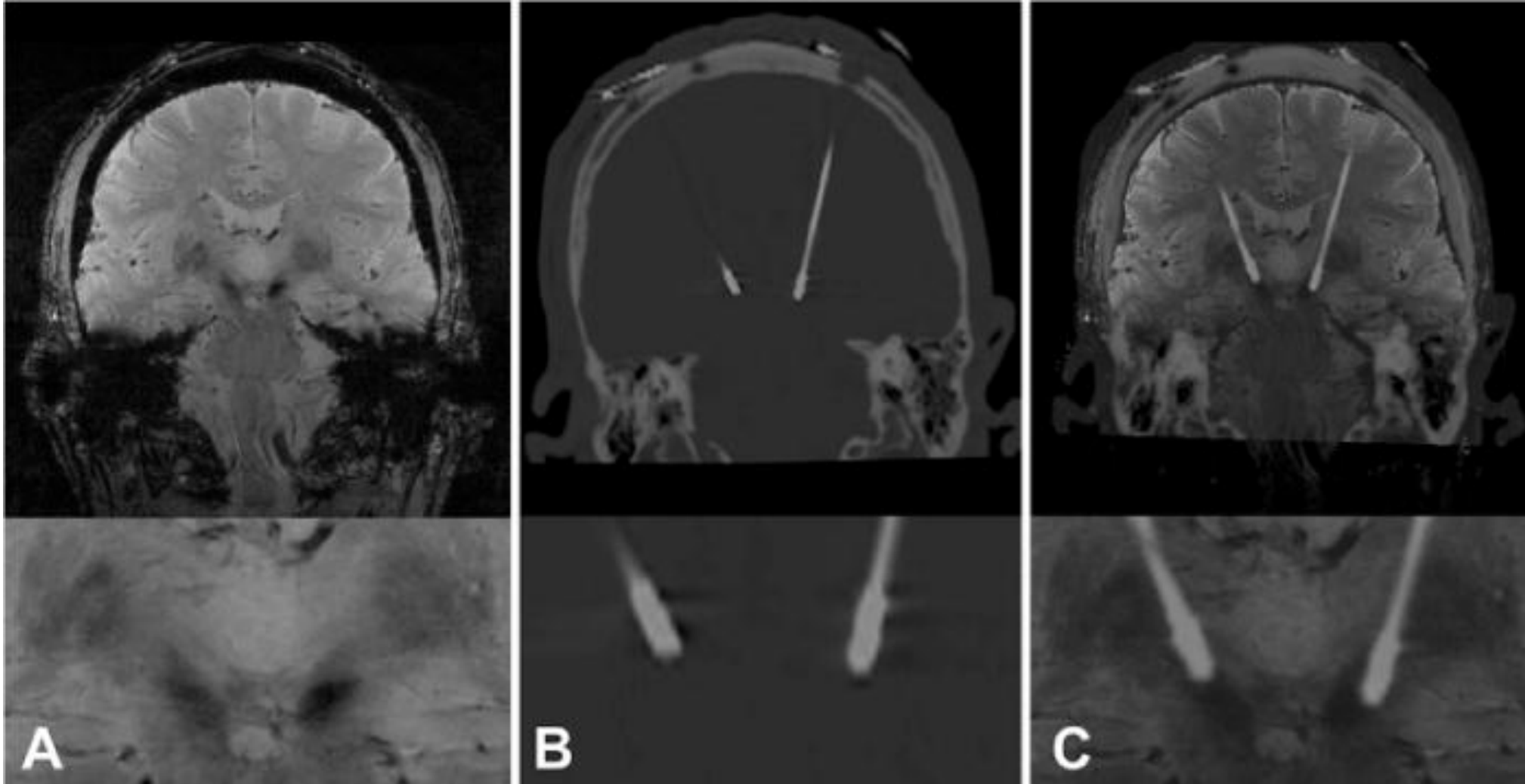
Nerve Roots of CN III

Ventromedial to dorsolateral STN

Awake frame-based surgery – permanent lead and test



Awake frame-based surgery – final CT and skin closure



Awake frame-less surgery



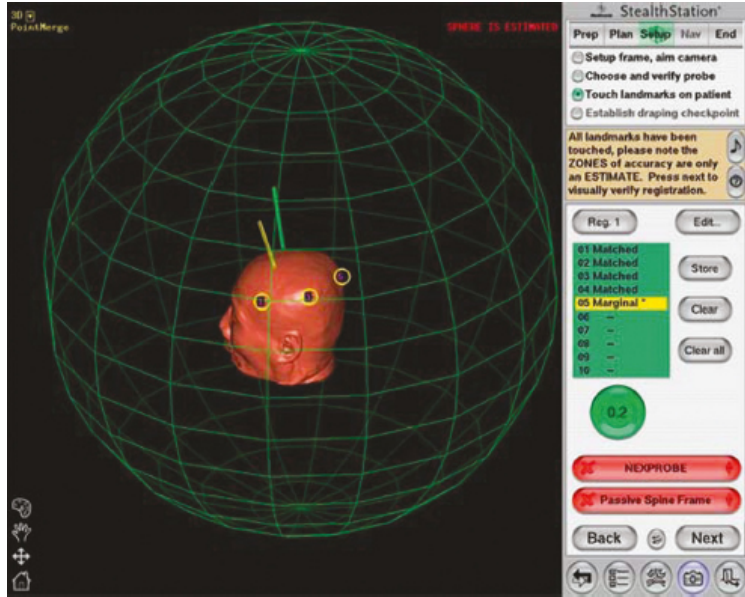
Awake frame-less surgery – technical overview

1. Preoperatively (**NexFrame**) – Bony fiducials placed into skull, CT and MRI performed, trajectory planned
2. No further imaging necessary, patient goes directly to OR.
3. Patient not fixed to bed, head supported by padded headrest, incision made to access skull
4. NexFrame registered to arc
5. Rest of procedure same as awake frame-based surgery

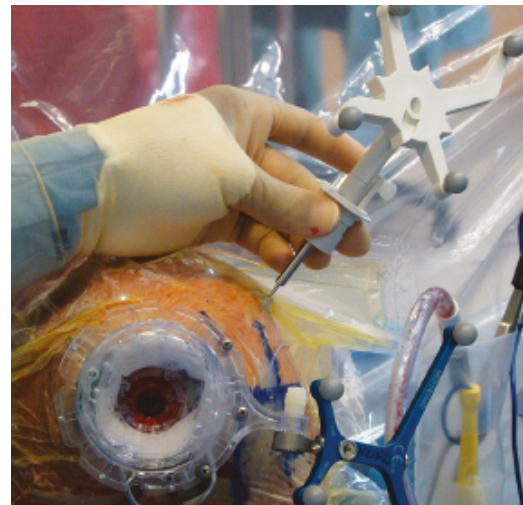
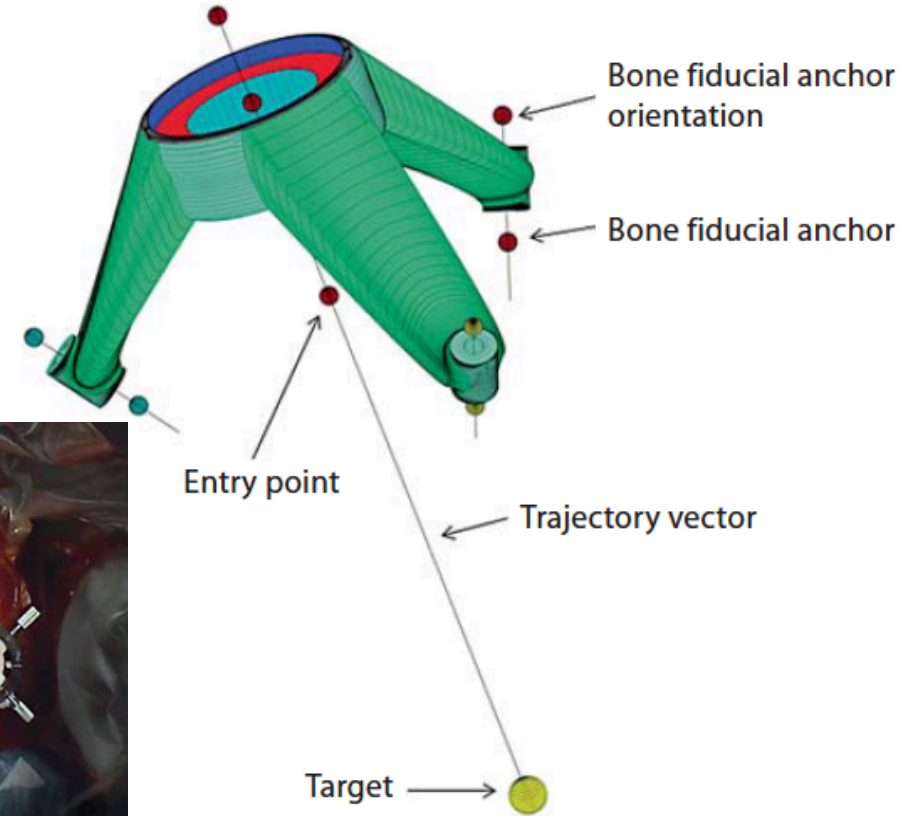
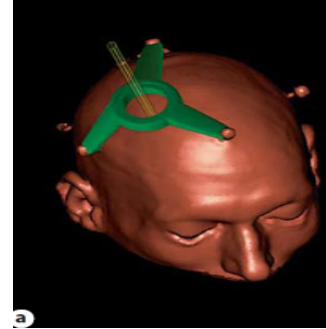
1. Preoperatively (**StarFix**) – Bony fiducials placed into skull, CT and MRI performed, trajectory planned and sent to company → custom frame built and sent back (3 days)
2. No further imaging necessary, patient goes directly to OR.
3. Patient not fixed to bed, head supported by padded headrest, incision made to access skull
4. Rest of procedure same as awake frame-based surgery

Awake frame-less surgery – technical overview

NexFrame



StarFix



Awake frame-based vs frame-less surgery

Frame-based

1. Tried and true targeting, used since 1950s
2. Most literature showing sub-millimeter accuracy
3. Versatile – can change trajectory on day of surgery if needed
4. Not dependent on integrity of bony fiducials (can be displaced / moved leading to loss of accuracy)

Frame-less

1. Bony fiducials placed pre-operatively and all imaging and targeting is based on fiducials
2. No imaging needed on day of surgery
3. No placement of stereotactic frame to patient head
4. No fixation of patient head to bed
5. Recent publications suggest similar accuracy to frame-based

Asleep frame-less surgery (ClearPoint)



Asleep frame-less surgery – technical overview

1. Preoperatively - trajectory toward target planned using indirect (coordinates) and direct preoperative imaging (MRI)
2. Patient anesthetized with general anesthesia
3. MRI (intra-operative vs. clinical) performed to localize burr hole placement
4. Skin incision and burr hole
5. ClearPoint frame attached to each side of patient head

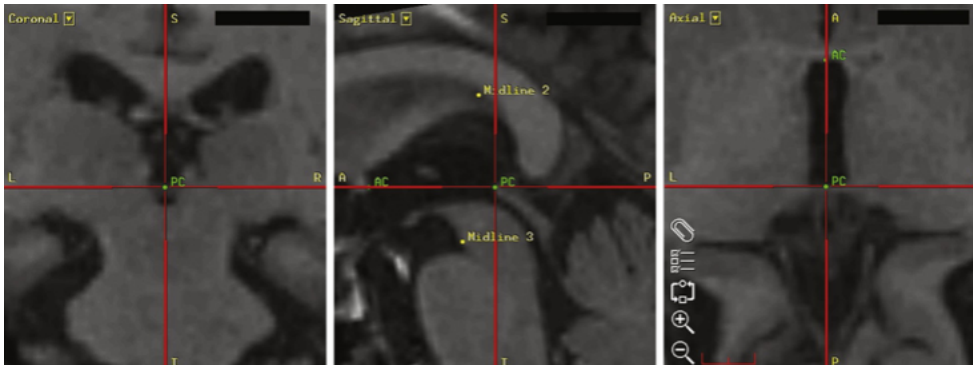
Asleep frame-less surgery – technical overview

6. MRI-based targeting performed with patient in MRI scanned
 - Macro- and micro-adjustments performed based on trajectory toward desired target
7. Placement of permanent lead to depth of target based on final position on MRI
8. Final MRI to confirm placement
9. Closure of skin, repeat on other side

Asleep frame-less surgery – preoperative planning

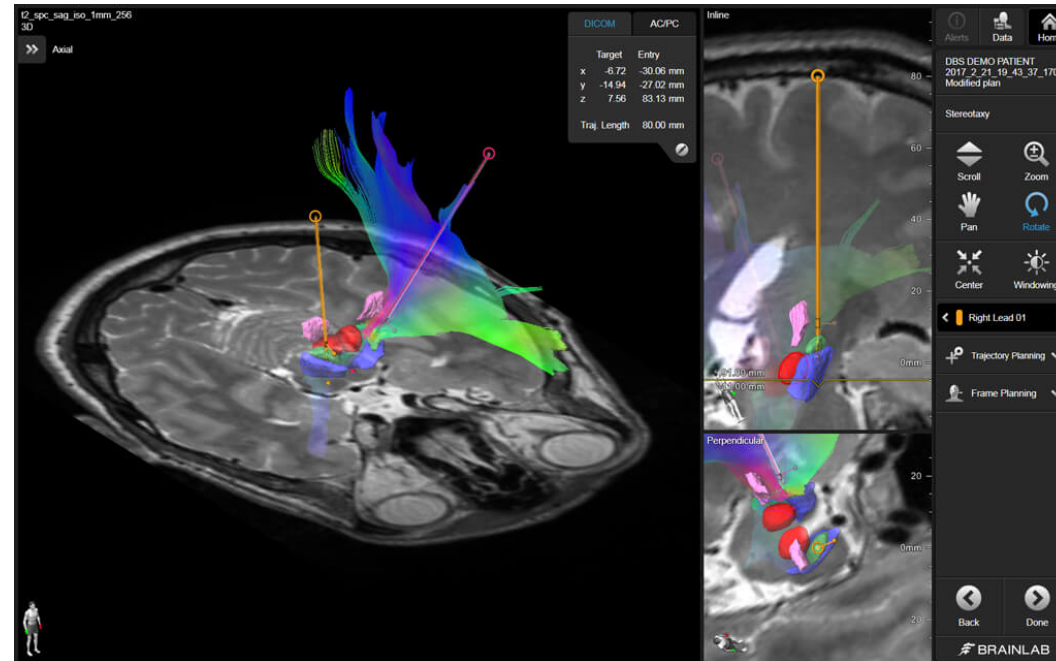
Preoperatively - trajectory toward target planned on BrainLab or Medtronic Stealth software (same planning step and system as awake frame-based)

Indirect targeting (AC-PC coordinates)

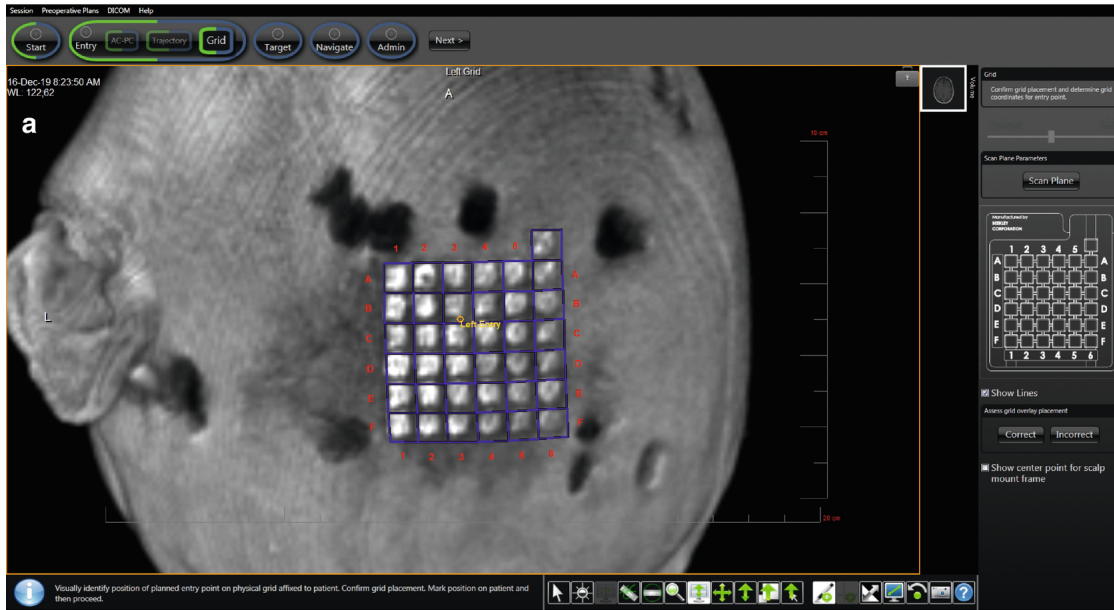


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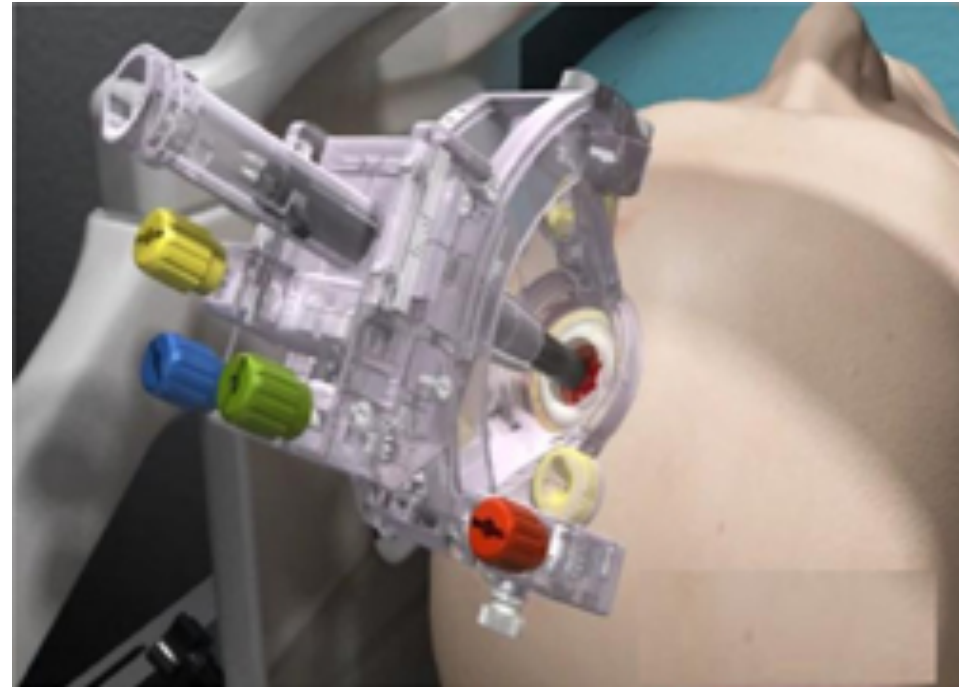
Direct targeting (MR-imaging)



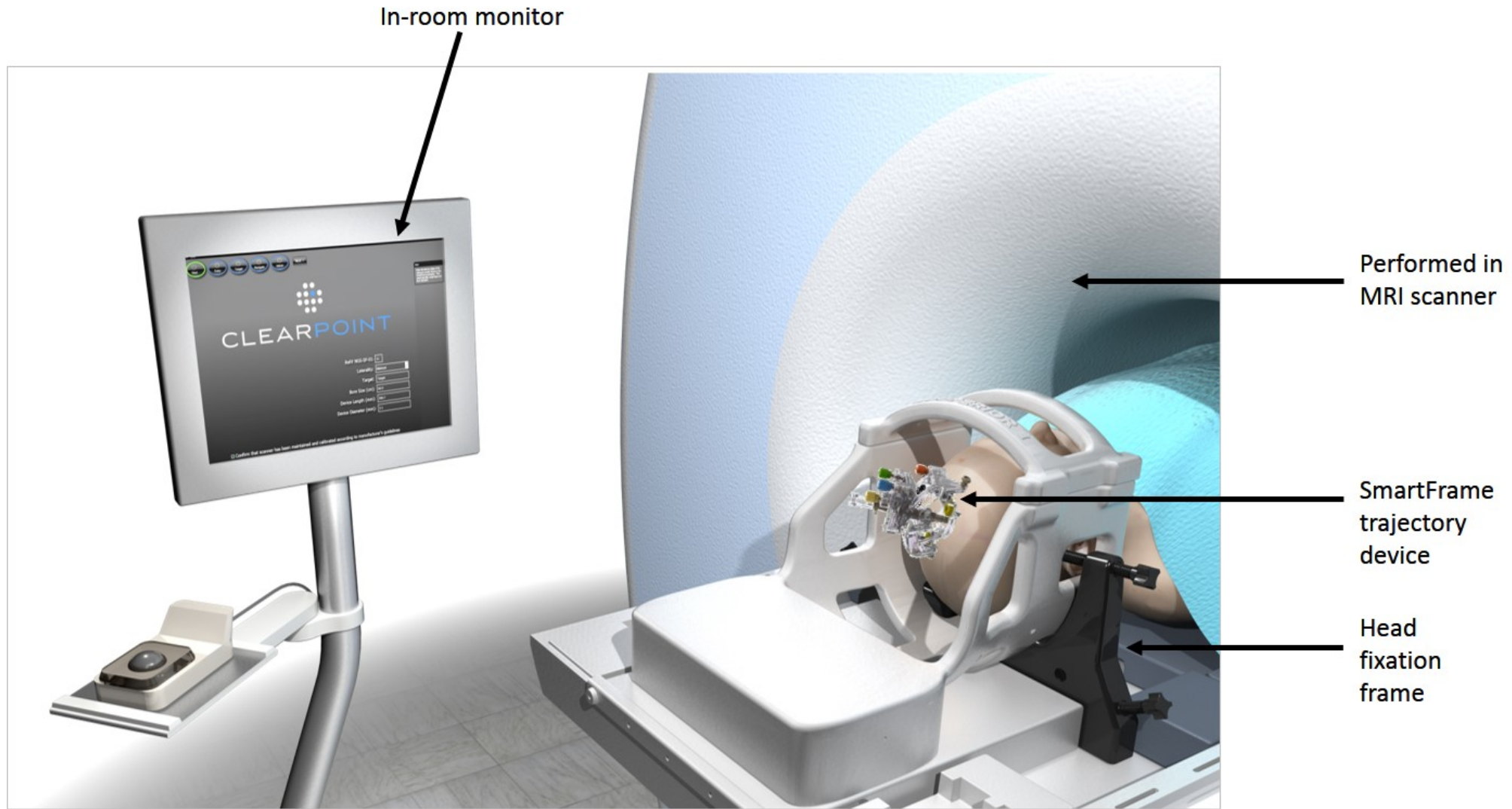
Asleep frame-less surgery – MRI, burr hole, frame



MRI (intra-operative vs. clinical) performed to localize burr hole placement, frame placed



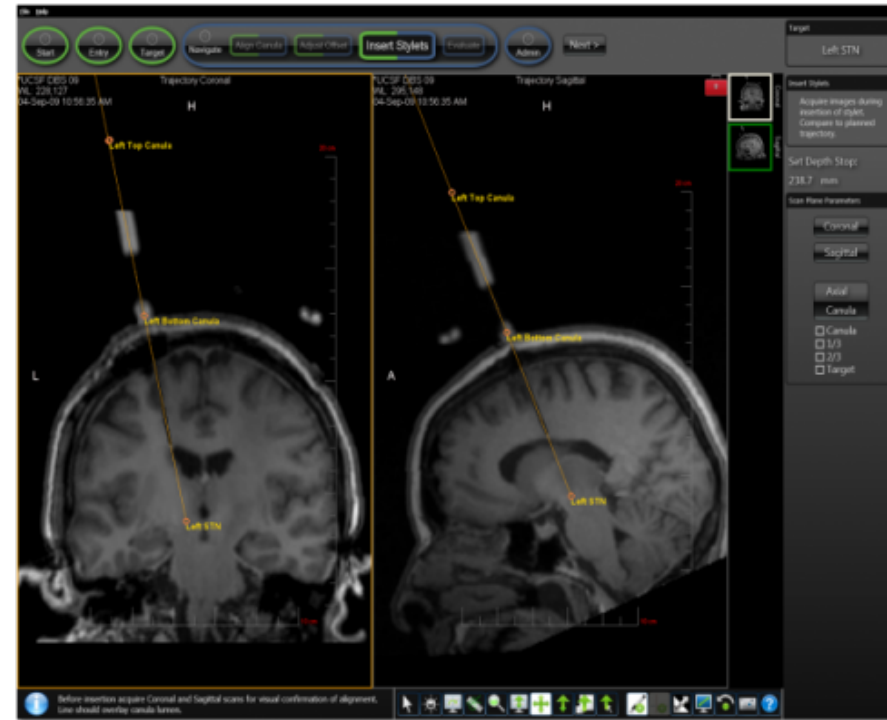
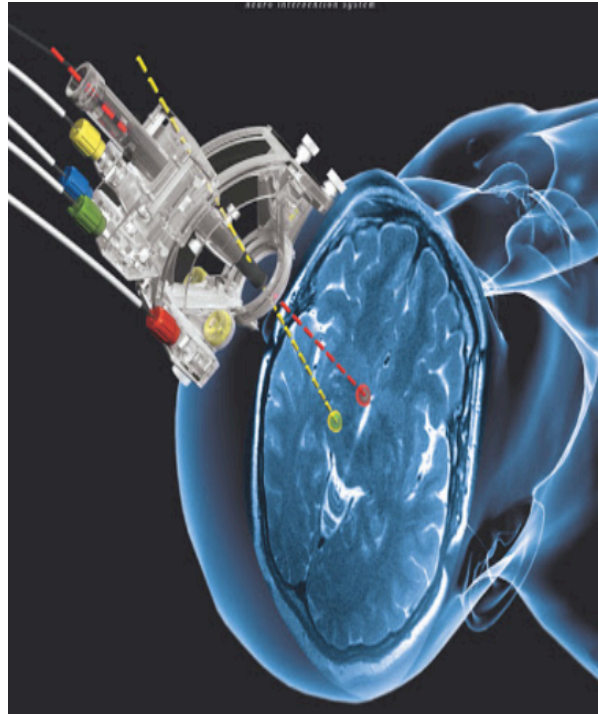
Asleep frame-less surgery – imaging



Asleep frame-less surgery – MR-based targeting

MRI-based targeting performed with patient in MRI scanned

- Macro- and micro-adjustments performed based on trajectory toward desired target



Asleep frame-less surgery – technique



Awake frame-less/based vs asleep MRI-based

Awake frame-less/based

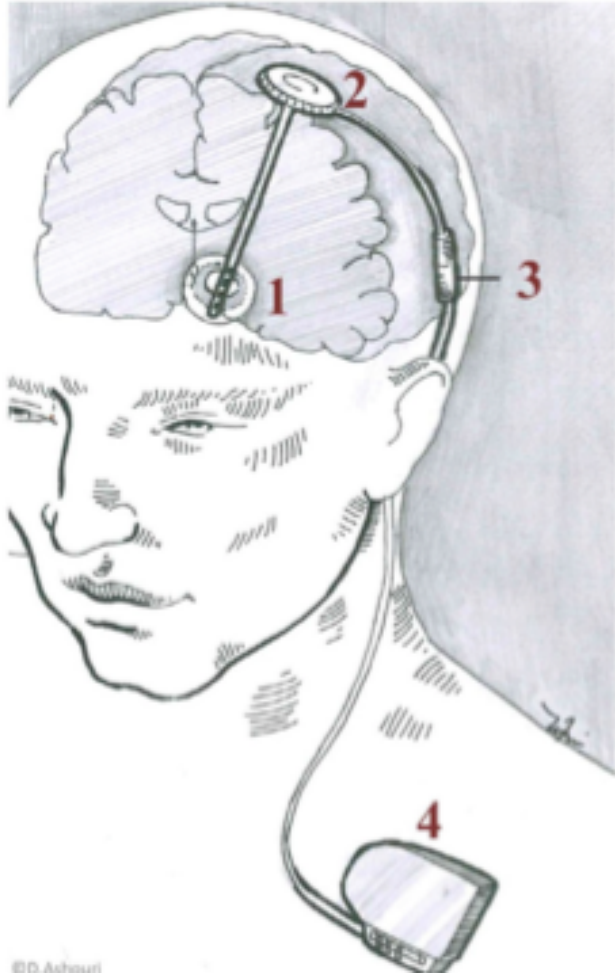
1. Uses pre-defined trajectory (direct vs. indirect) which is aligned to stereotactic space (fiducials vs. frame)
2. Awake allows for MER (neurophysiological targeting)
3. Awake allows for symptom testing prior to final electrode
4. Extremely accurate (1mm)
5. Can be uncomfortable if anxious or claustrophobic
6. Recover quicker without general anesthesia

- No direct (prospective) comparisons
- Similar UPDRS outcomes
- Similar complications (although trend toward ClearPoint being slightly safer)
- Mostly depends on patient comfort and training / expertise of surgeon

Asleep MRI-based

1. Uses intraoperative imaging with frame attached to define stereotactic space
2. Uses imaging ONLY as targeting (no neurophysiological targeting)
3. No symptom testing
4. Extremely accurate placement of electrode (0.6 – 1.2mm) based on desired imaging
5. More comfortable surgery
6. Could be slightly longer recovery from general anesthesia

Surgery details – stage 2



- 1 Stimulation probe**
- 2 Fixation cap**
- 3 Extension lead**
- 4 Pulse generator (IPG)**

- DBS internal pulse generator (battery) placement
 - Same day vs. outpatient procedure on separate day
1. Implanted DBS leads exposed
 2. Extension leads tunneled under scalp → behind ear → to chest
 3. IPG implanted under clavicle in subcutaneous pocket

Thank You



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SCHOOL OF MEDICINE

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