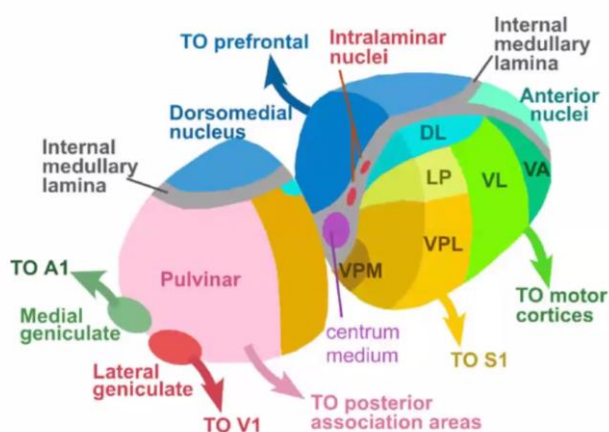


DBS in Epilepsy

Last updated: February 8, 2023

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DBS is indicated for poorly localized or multiple regions of seizure origin.
 Comparison of Neuromodulations (RNS, DBS, VNS) – see p. E11 >>
 Thalamic SEEG – see p. E13 >>



HARDWARE

MEDTRONIC

PATIENT REMOTE

- same as for movement disorders but has **blue button “Seizure”** – it is programmable (e.g. logging the event, restarting stim cycle).

BATTERY

ACTIVA PC

– same as for movement disorders. see p. Op360 >>
 List price – 17,000 USD (2019 October)

PERCEPT PC (B35200)

Medtronic.com/Percept >>



Weight	61g
Height	68mm
Length	51mm
Channels	2

- BrainSense™ technology - captures **local field potentials (LFP)** using the implanted DBS lead simultaneously while delivering therapeutic stimulation. see below >>
- full-body 3T MRI eligibility (1.5T with Activa PC)
- > 15% longer battery life than Activa PC (smart battery technology provides real-time **prediction of remaining battery life** based on usage history).
- 20% smaller than Activa PC.

PLUGS

SENSIGHT™ CONNECTOR PLUG KIT
B31061

Each Connector Plug Kit includes:

- Two connector plugs

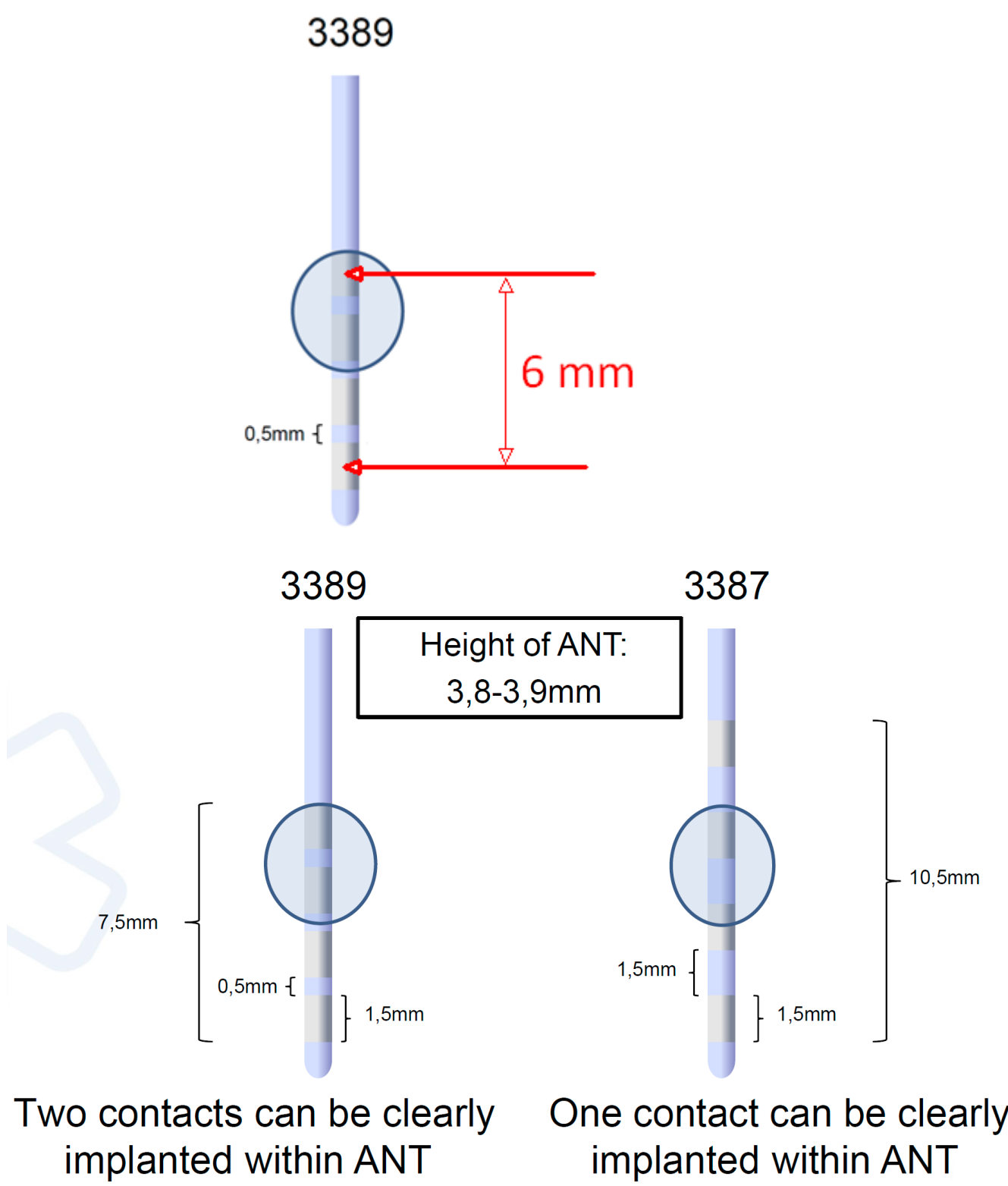
- Connector Plug works with SenSight™ Extension as well as Activa™ RC/PC and Percept™ PC Devices
- Note the change in model number from B31060 to B31061, but there is no change to the plug itself

LEADS

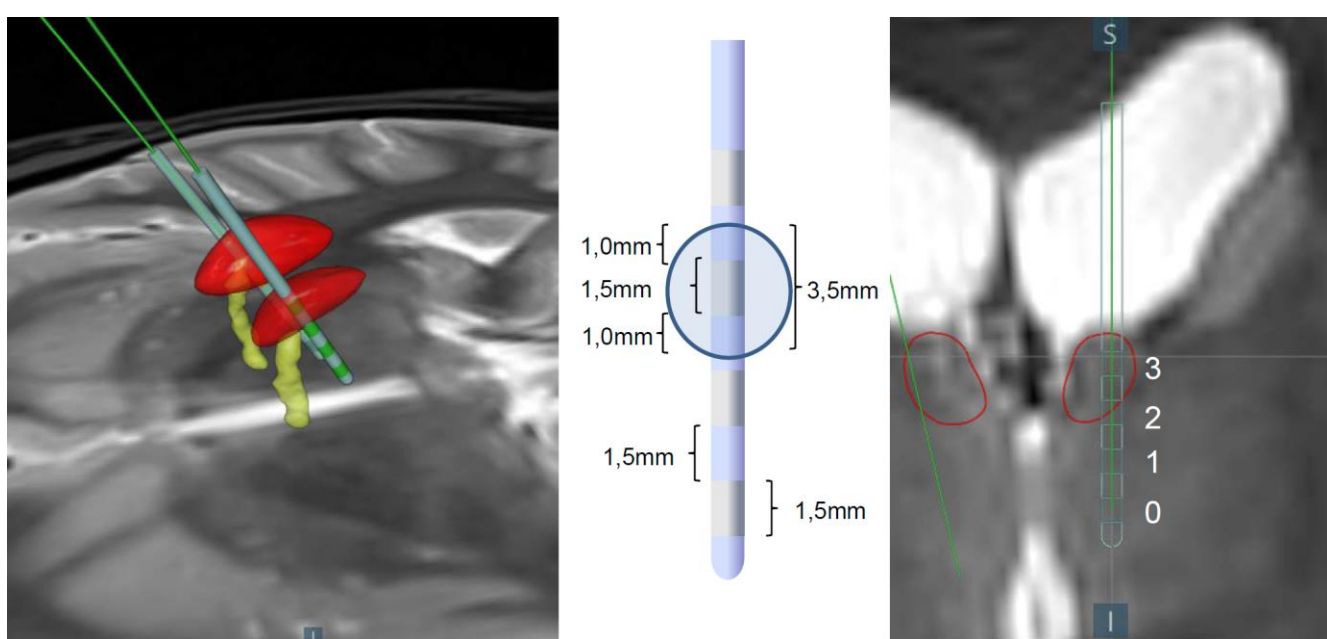
FDA approved:
 3387 (used in SANTE trial)
 3389 - preferred

- use **“at target” cannula**; “10 mm above” cannula may cause DBS lead to deviate (some experts set target 8 mm deeper so that “10 mm above” cannula enters the parenchyma).

N.B. with lead 3389, the distance between the centers of first and last contact is **6 mm** – when planing trajectory and target, plan that **6 mm segment to incorporate into ANT** (if want all contacts be in ANT, target must be 8.5 mm deep in ANT)

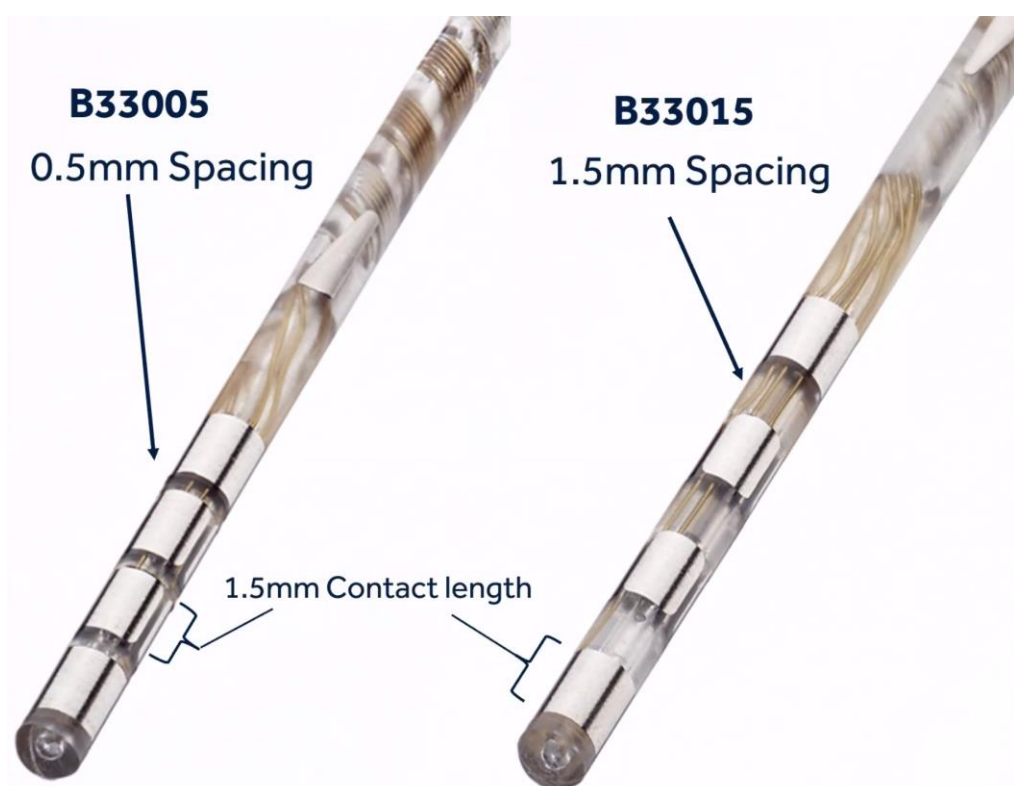
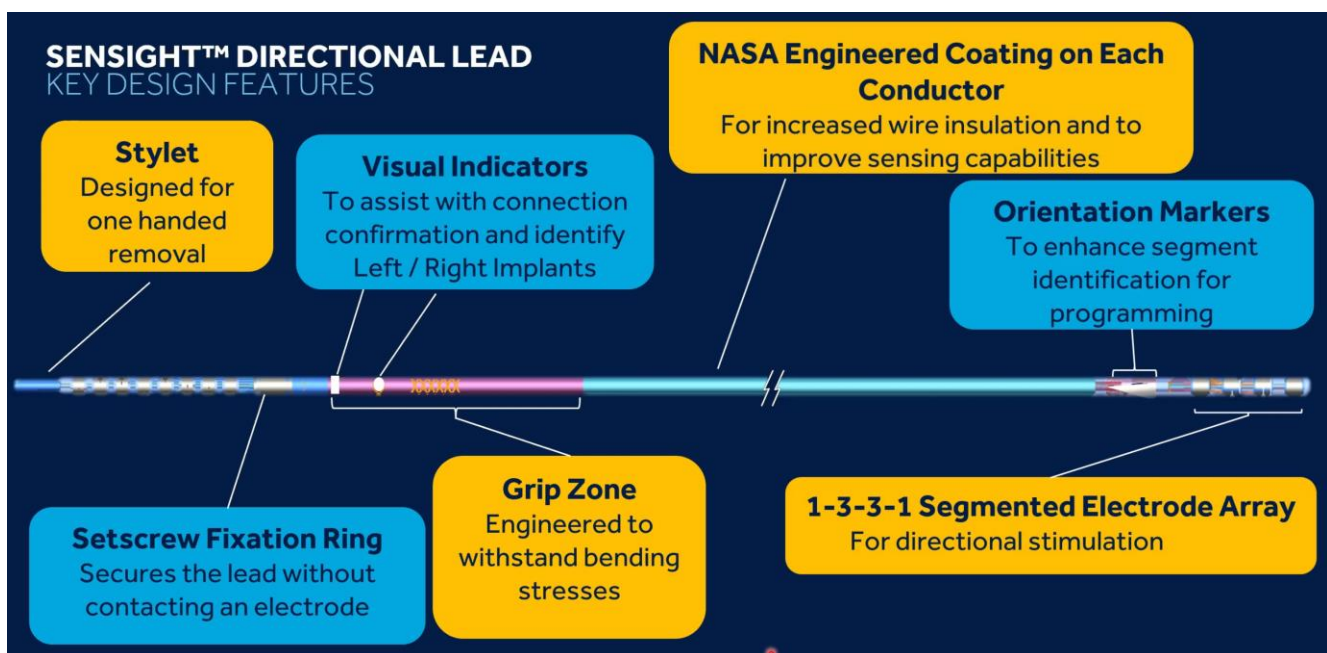


Lead 3387 – plan to place contact (3 or 2) inside ANT:



SENSIGHT (MEDTRONIC) – DIRECTIONAL 1-3-3-1 LEAD

- lead tip is 1 mm from bottom of distal (0) contact.
- lead diameter **1.36 mm*** – inner diameter of cannula must be at least 1.57 mm.
- aim to place contacts 1 and 2 at target – greatest programming and sensing flexibility.
*old leads (3389, 3387) - **1.27 mm**



B33005 lead: from tip to the proximal end of the most proximal contact – **8.5 mm** (i.e. if planning ANT, **plan 8.5 mm within nucleus**)

33 cm and 42 cm lengths.

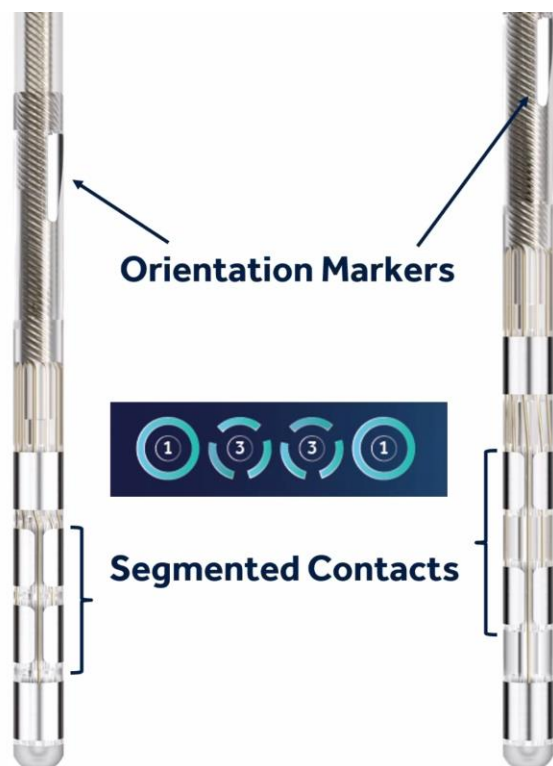
SENSIGHT™ LEAD DESIGN

1-3-3-1 electrode design

- Electrode levels 0 and 3 are full rings
- Electrode levels 1 and 2 are split into 3 isolated electrodes to enable directional stimulation

Orientation markers

- 2 inverted and independently isolated triangles
- Produce two distinguishably visible artifacts on Fluoroscopy and X-Ray to guide directional programming post-operatively



SENSIGHT™ SURGICAL WORKFLOW
LEAD PLACEMENT

Stylet

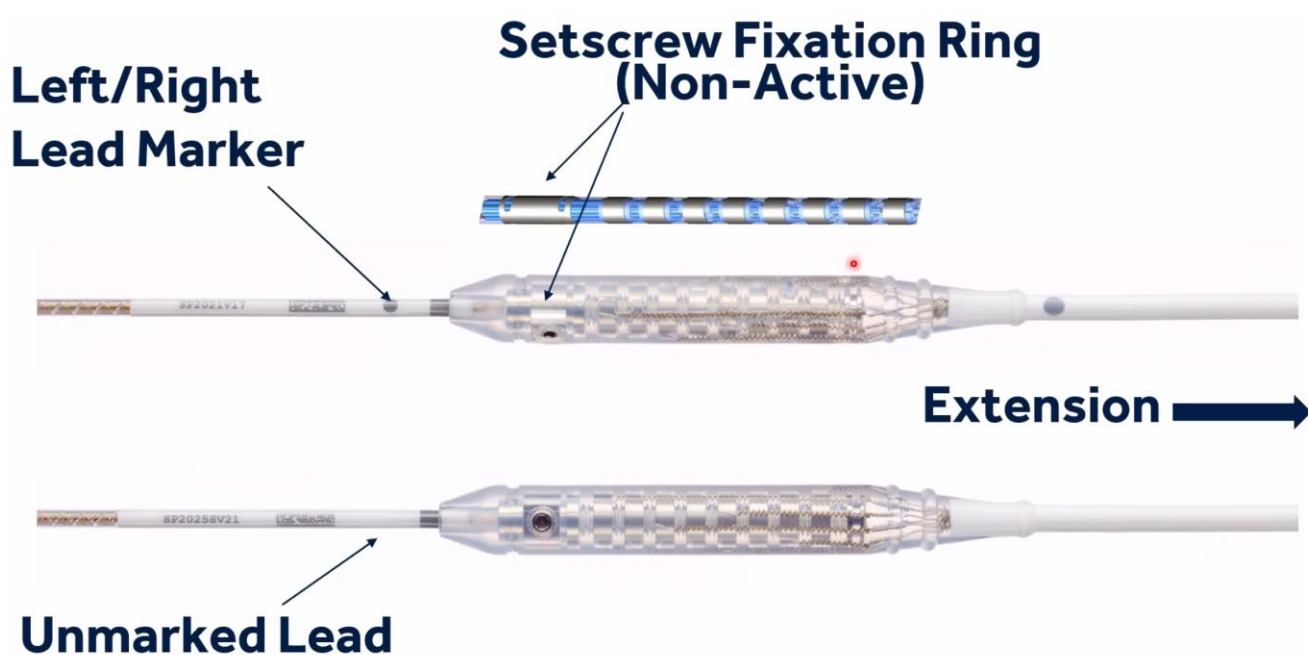
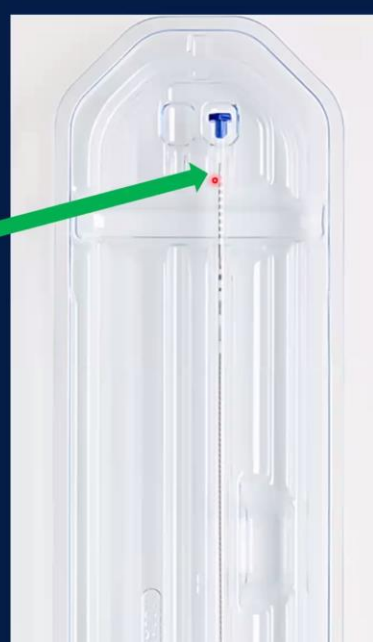
- Ensure stylet is fully seated in the lead before attaching depth stop
- Best to do this right out of the packaging, as it may move during shipping

Left/Right lead markers

- No recommended convention, clinician preference

Alignment of segments

- Can be entered into the clinician programmer post operatively



LEAD CAP

Single Setscrew

Connects to the lead via the Setscrew Fixation Ring

Boot-Less Connection

Electrical isolation is provided by 2 wiper seals built into the SenSight™ Lead Cap

Elongated Exit

Increased stability

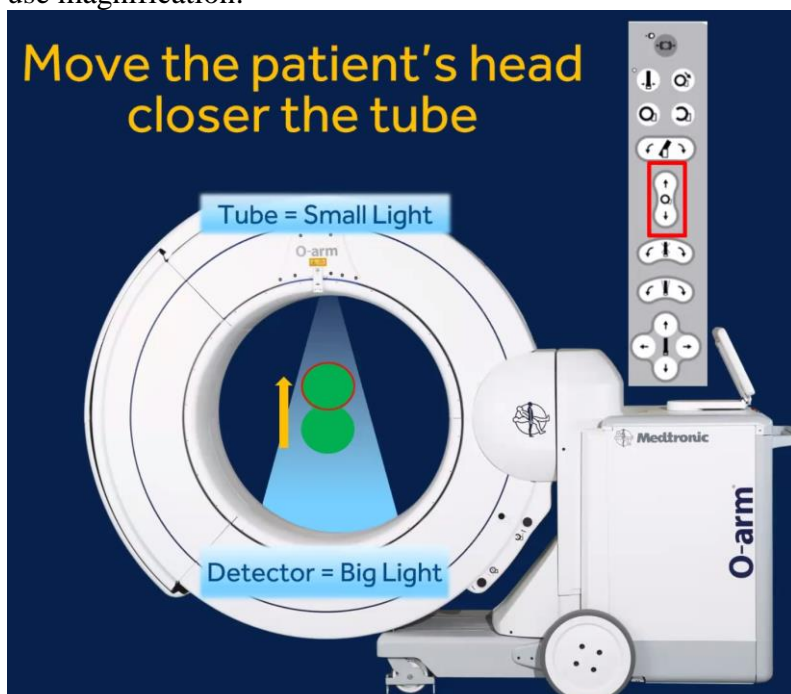
Suture Groove

Sutures aren't necessary for function, but these are available to help identify leads if marked leads aren't used

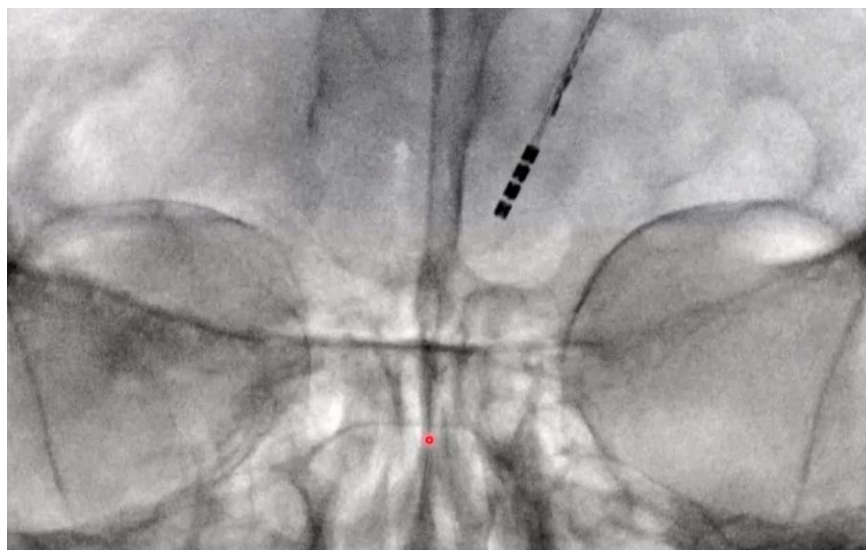


ORIENTATION MARKERS

- best to image 1 month postop (brain settles); but can be done intraop:
 - either fluoro or O-arm (MRI does not show markers)
 - remove stylet
- use magnification:



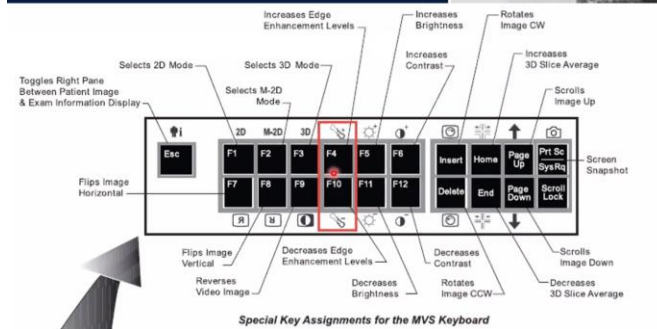
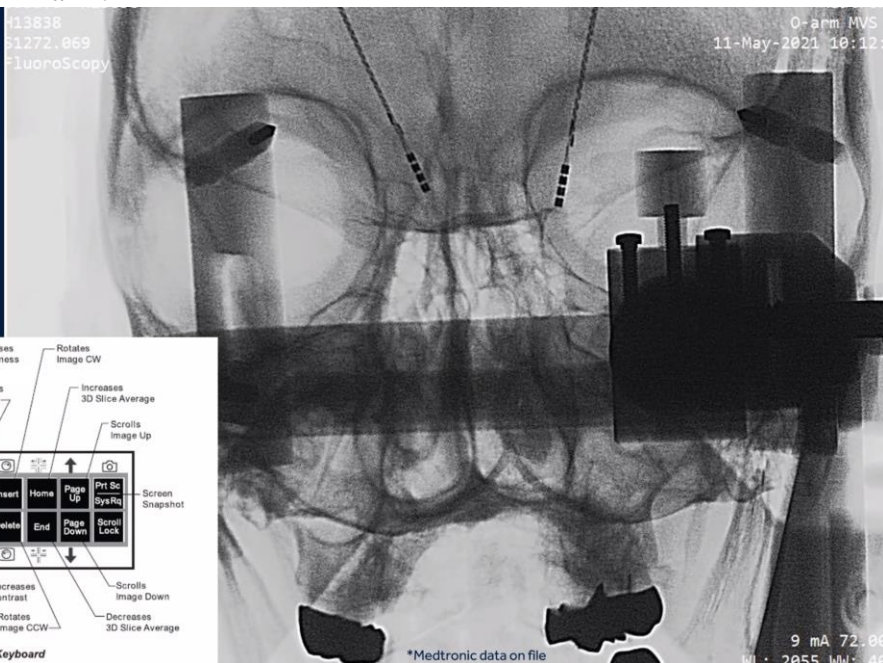
- avoid overlap with frame, eye sockets:



- use "edge enhancement" feature in O-arm:

SENSIGHT™ LEAD ORIENTATION MARKER

Consider using the "edge enhancement" feature to highlight the triangular orientation markers



- proximal marker aligns with 1a and 2a segments
- distal marker aligns with 1b and 2b segments

Electrode Segments

Tablet Display (Surgeon's perspective)

3		
2c	2a	2b
1c	1a	1b
0		

Proximal Marker Segment "a"

Distal Marker Segment "b"

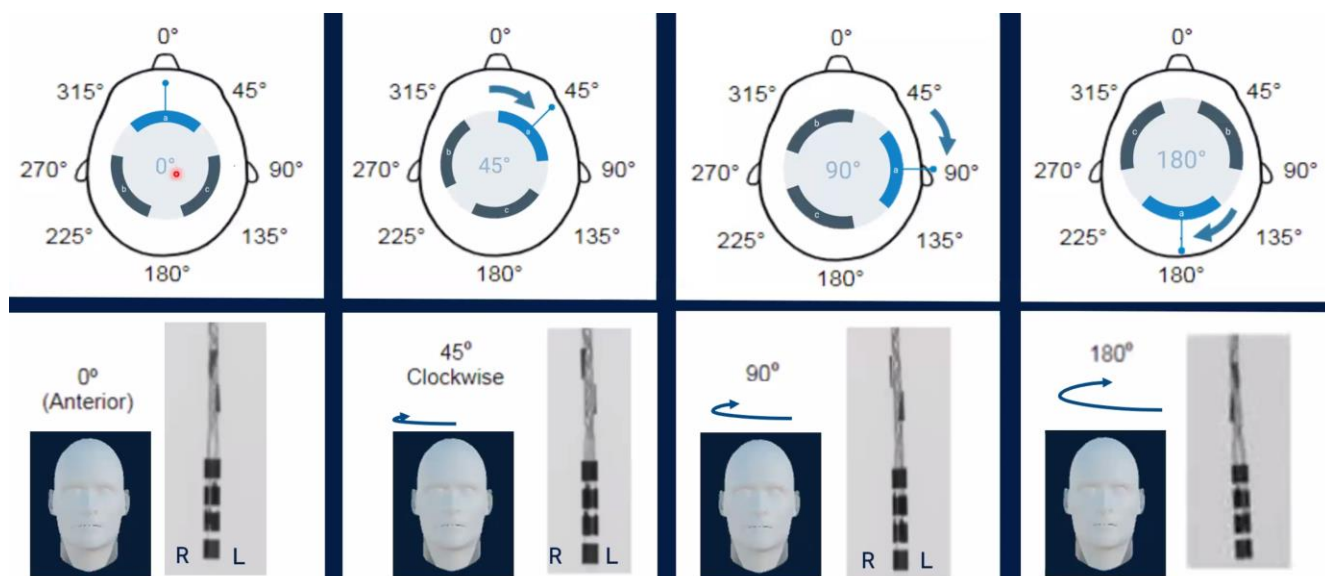
No Marker Segment "c"

Proximal Marker Segment "a"

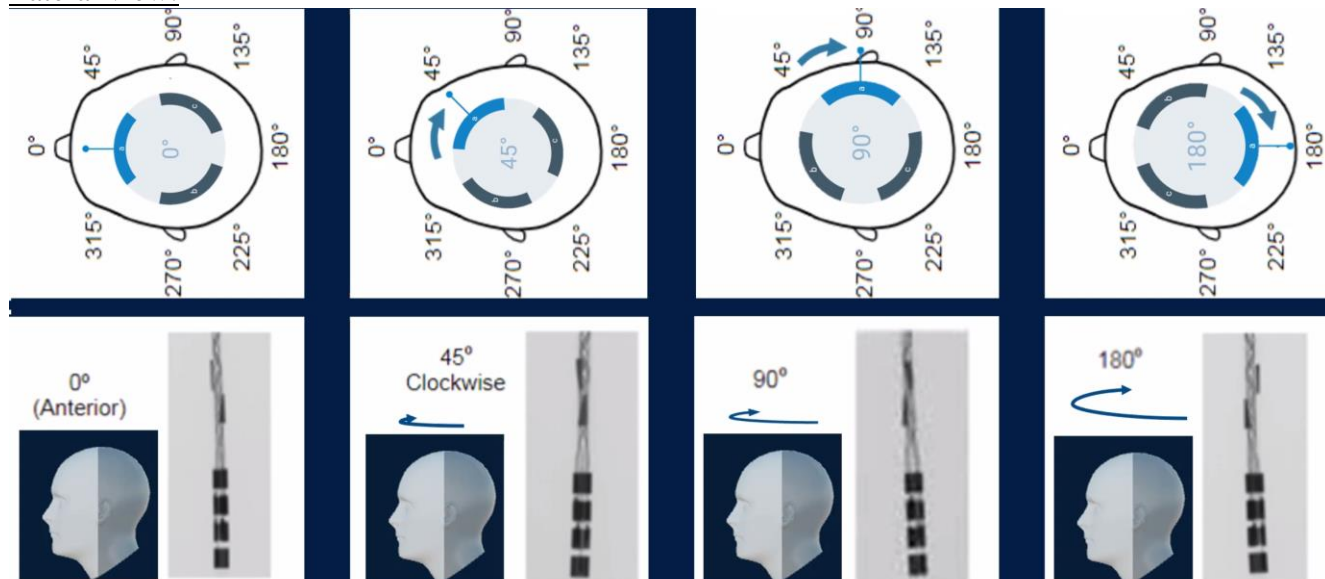
Distal Marker Segment "b"

No Marker Segment "c"

AP view is the best (no lead overlap):



Lateral view:



IMPEDANCES

- due to smaller segmental contacts, normal impedances have higher upper limit:
 monopolar: 350-8000 Ohm
 bipolar 350-10000 Ohm

BURHOLE COVER

SENSIGHT (B32000)

- only for SenSight leads (for old leads need to use Stimloc)
- improved visual contrast – cap is clear plastic, ring is white plastic (line up triangles when applying cap).

SENSIGHT BURR HOLE DEVICE

Lower profile
 Profile height that is 14.7% lower than legacy StimLoc™ Burr Hole Device.

Flexible Base
 Designed to be placed in any orientation and conform with the skulls' natural curvature

Improved Lead Stability
 57% improvement in lead tip stabilization **

More options for placement
 4 holder slots and 16 exit angles available

SenSight™ BHD Cap

SenSight™ Burr Hole Device 14.7% lower profile*

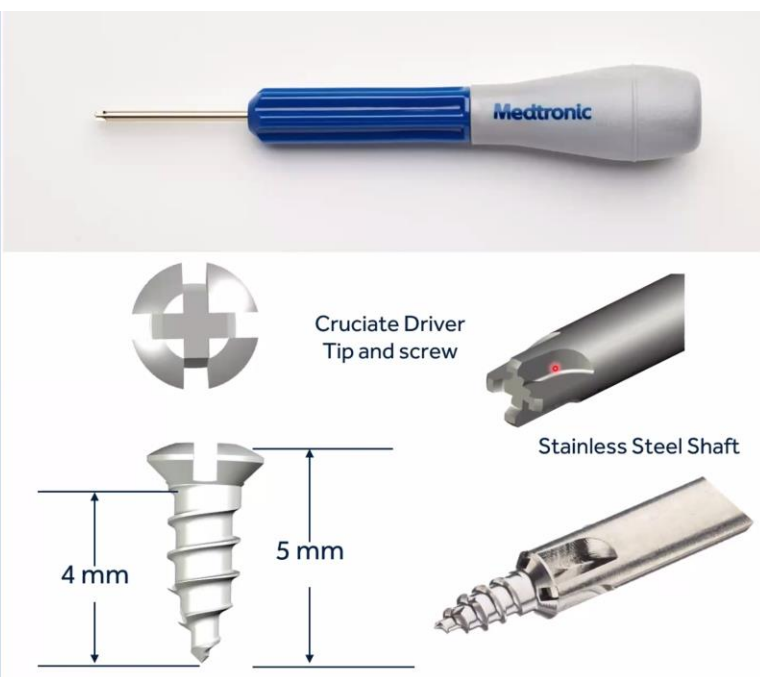
SenSight™ BHD Base Ring

*When compared to Medtronic StimLoc™ device

**Based on a study in an animal model compared to legacy system. Animal data may not be representative of human clinical performance.

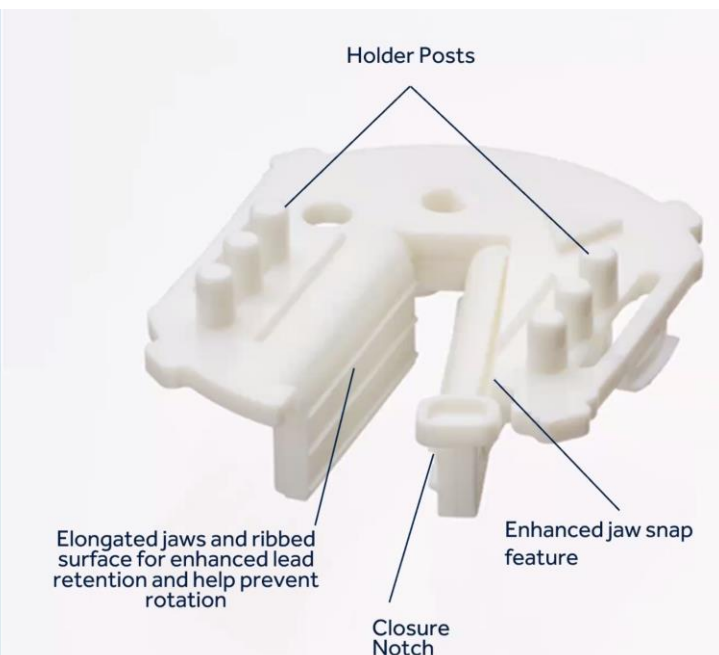
SENSIGHT BURR HOLE DEVICE
 SCREWS AND SCREWDRIVER

- Cruciate Screwdriver tip that reduces slipping
- Screwdriver tip is made out of stainless steel
- Screw tip is self tapping and self drilling
- Screw threaded length is 4 mm, and total length is 5mm



SENSIGHT™ BURR HOLE DEVICE
 SUPPORT CLIP

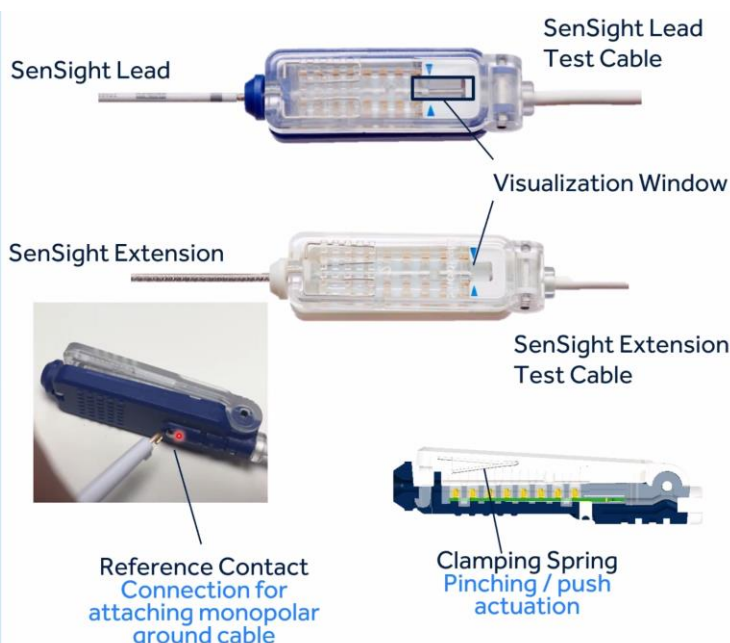
- **Holder Posts**- Provide flexibility for lead exits and keeps lead perpendicular to either jaw.
- **Elongated jaws**- Enhanced lead retention
- **Ribbed jaw surface**- Helps prevent rotation
- **Moveable jaw snap feature** to avoid accidental unlocking
- **Moveable jaw rests on base ring** to avoid accidentally being pushed underneath.



TESTING CABLES

SENSIGHT™ TEST CABLES
B31040 AND B31050

- **Visualization Window**
 - Allows you to see that lead/extension is fully inserted
- **Usable with or without stylet**
- **Single handed application**
 - pinching/push button actuation
- **Bipolar and Monopolar stimulation**
 - Reference contact available on both lead and extension cables
- **Longer Lead Test Cable**
 - 241 cm which is 33 cm longer than the TwistLock cable

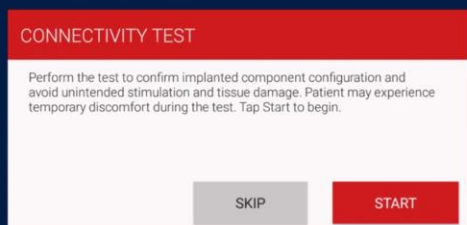


SENSIGHT™ SURGICAL WORKFLOW
TESTING THE LEAD

Lead Testing

- Lead Testing Cable has a blue connector box
- Lead Testing in Voltage mode only with ENS
- Monopolar available
 - J-clip on connector
 - Attach alligator clip to a grounding location, eg, a surgical instrument, or the insertion cannula. Do not attach the alligator clip to the lead as it may damage the lead
- Secure lead testing cable
- Connectivity test
- Impedance differences
 - New Normal Impedances

MONOPOLAR	350Ω to 8,000Ω
BIPOLAR	350Ω to 10,000Ω
 - If impedances are over 40K, twisting cable connector to get better contact may help (breaks through oxide layer)

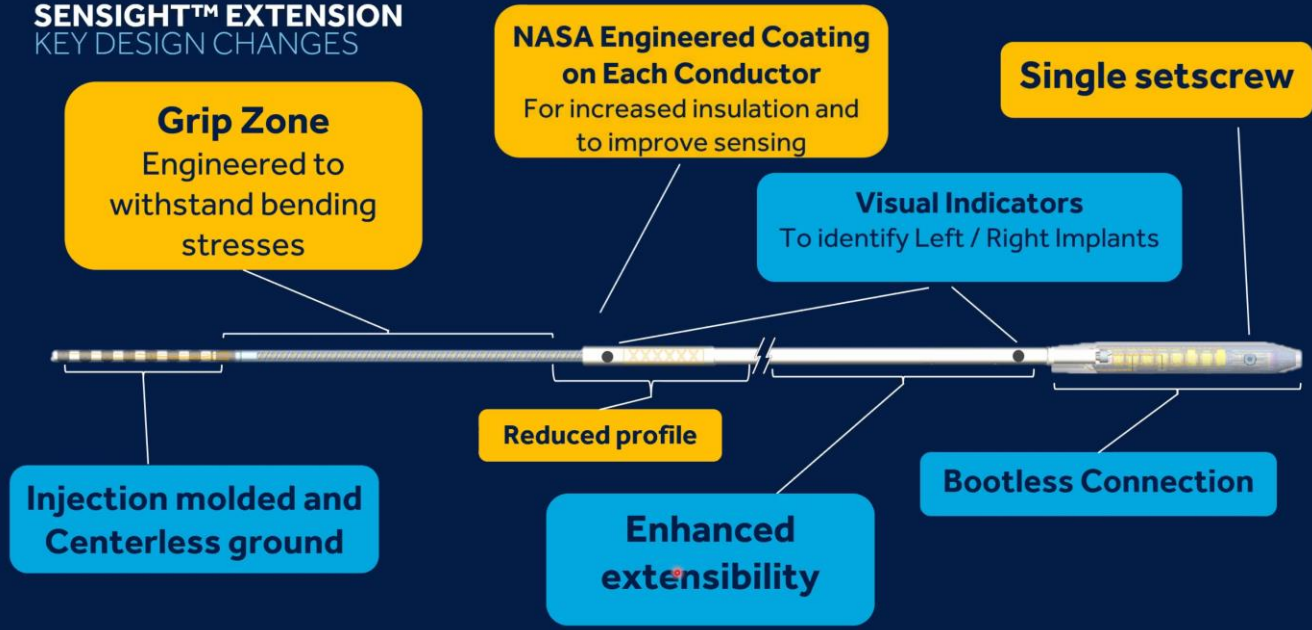


EXTENSIONS

- allow 15% length stretch.
- tunneler (passer) is inserted from cranium towards thorax – as then to pull extension hubs up (towards cranium).

SENSIGHT™ EXTENSIONS

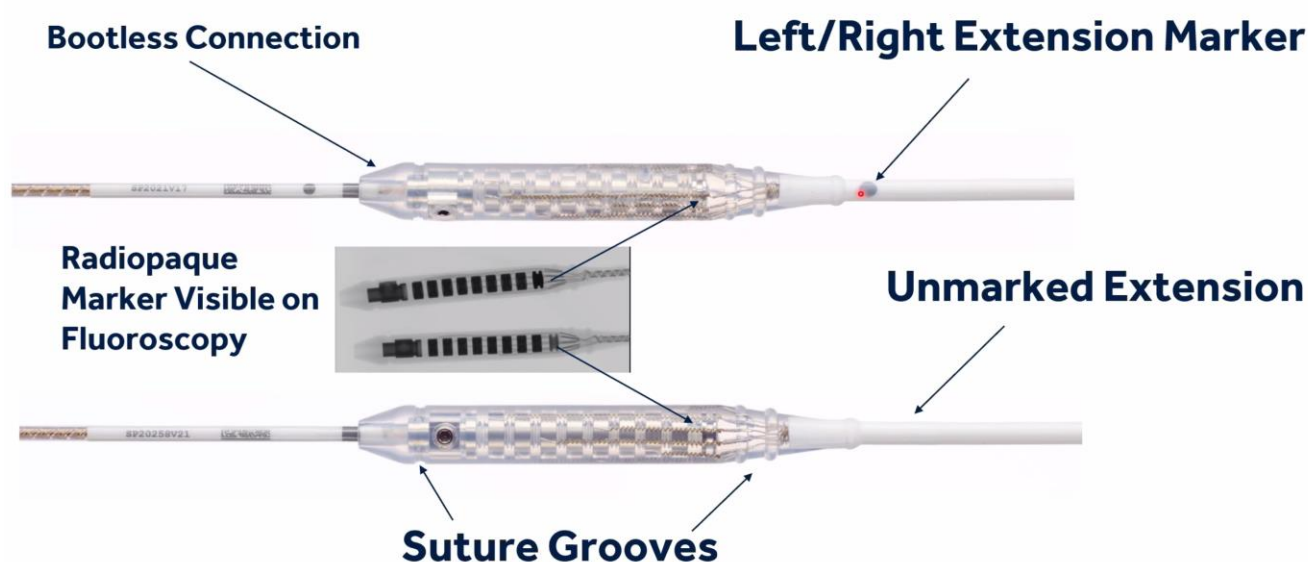
SENSIGHT™ EXTENSION
KEY DESIGN CHANGES

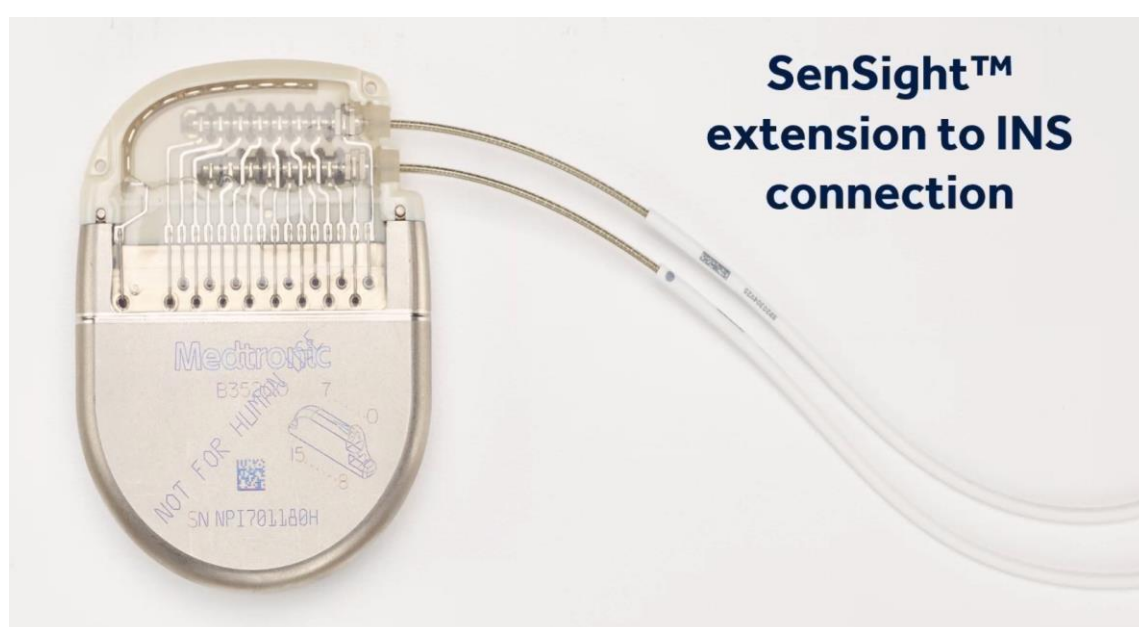


SENSIGHT™ EXTENSION
MECHANICAL FEATURES

- **Extension Body Diameter**
 - approximately 26.7% smaller than the legacy Medtronic extensions 37085 & 37086 (excluding the extension connector end)
- **Length**
 - comes in three lengths 40cm, 60cm, and 95cm
- **Extensibility**
 - has a 64% reduction in the force required to elongate it, when compared to the Model 37085 and 37086 Extensions.

SENSIGHT™ EXTENSION
DESIGN FEATURES





White 5 in.-oz torque wrench used for connections to Percept™ PC INS

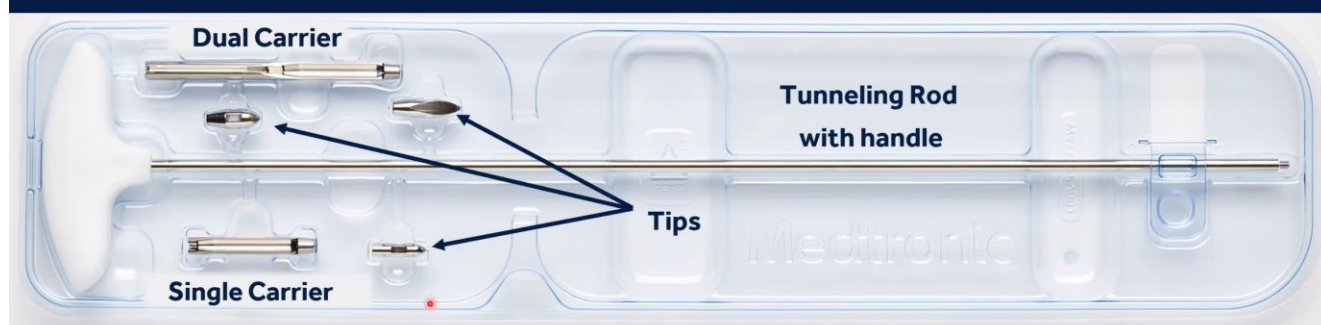
NOTE: The blue 4 in.-oz wrench should still be used for connection to Activa™ Devices

SENSIGHT™ EXTENSION TUNNELER KIT B31030

Each tunneling tool kit includes:

- One Tunneling rod with handle
- Three Tips (Single, Dual and Wedge)
- Two Carriers (single and dual)

The SenSight™ Extension Tunneler Kit has specifically designed dual & single extension carriers for the SenSight™ Extensions. It is not compatible with Legacy Extensions



ANTERIOR NUCLEI OF THALAMUS (ANT)

Möttönen T, Katisko J, Haapasalo J et al. Defining the anterior nucleus of the thalamus (ANT) as a deep brain stimulation target in refractory epilepsy: delineation using 3 T MRI and intraoperative microelectrode recording. *Neuroimage Clin* . 2015;7:823-829.

V. Salanova. Deep brain stimulation for epilepsy. *Epilepsy Behav*, 88 (2018), pp. 21-24

Bouwens van der Vlis TAM, Schijns O, Schaper F, et al. Deep brain stimulation of the anterior nucleus of the thalamus for drug-resistant epilepsy. *Neurosurg Rev*. 2018.

Cukiert, Lehtimäki et al. Deep brain stimulation targeting for refractory epilepsy. *Epilepsia* 2017

M.C.H. Li, M.J. Cook. Deep brain stimulation for drug-resistant epilepsy. *Epilepsia* (2017), pp. 1-18

Lehtimäki K, Möttönen T, Järventausta K, Katisko J, Tähtinen T, Haapasalo J, et al: Outcome based definition of the anterior thalamic deep brain stimulation target in refractory epilepsy. *Brain Stimul* 9:268–275, 2016

Krishna V, King NK, Sammartino F, et al. Anterior Nucleus Deep Brain Stimulation for Refractory Epilepsy: Insights Into Patterns of Seizure Control and Efficacious Target. *Neurosurgery*. 2016;78(6):802-811.

Kamali A, Zhang CC, Riascos RF, Tandon N, Bonafante-Mejia EE, Patel R, et al: Diffusion tensor tractography of the mammillothalamic tract in the human brain using a high spatial resolution DTI technique. *Sci Rep* 8:5229, 2018

Received: February 22, 2016 Revised: May 3, 2016 Accepted: May 11, 2016

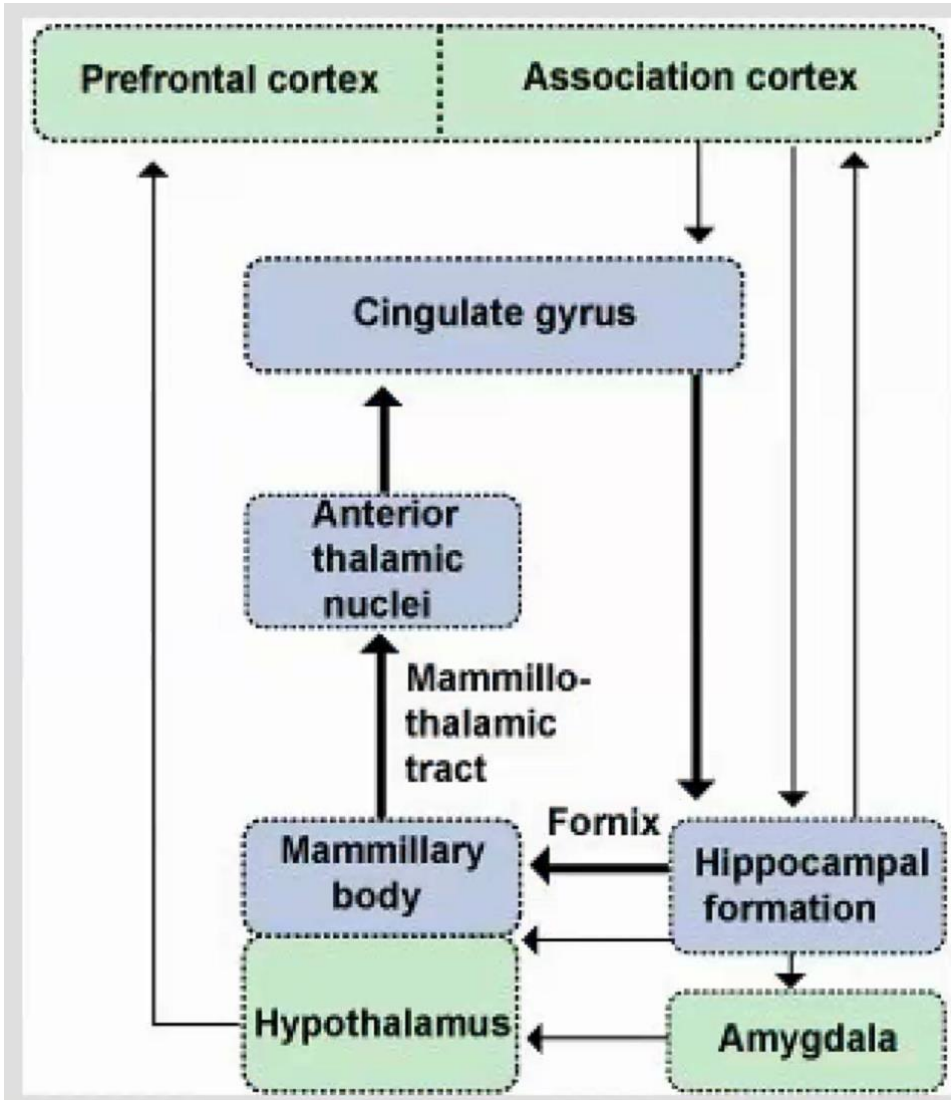
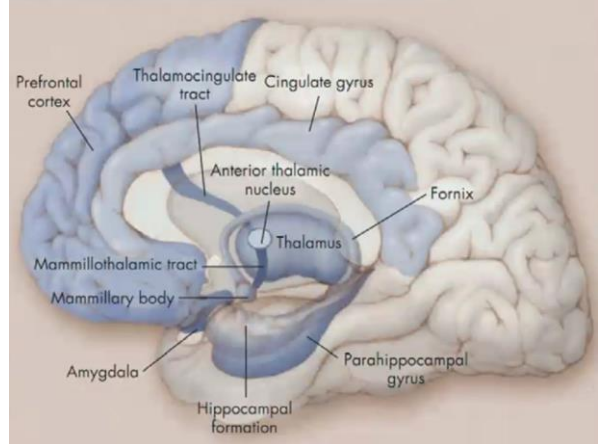
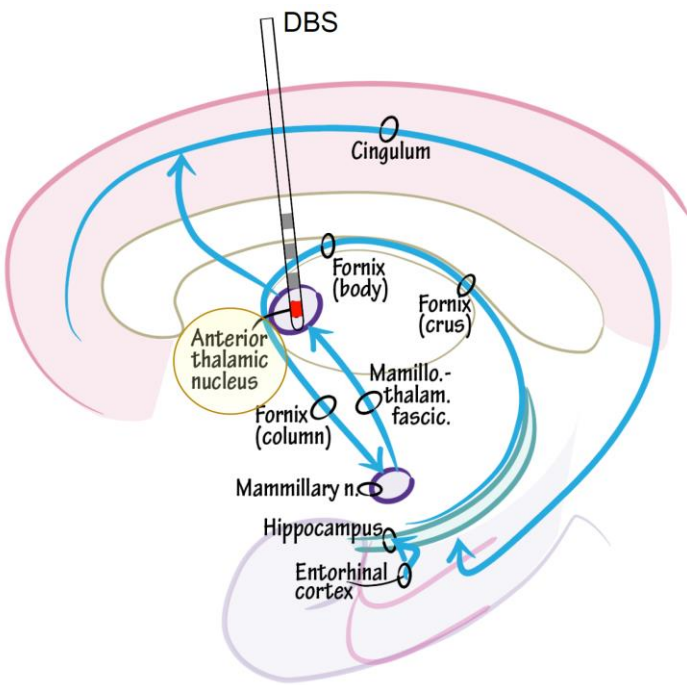
(onlinelibrary.wiley.com) DOI: 10.1111/ner.12468

Imaging of Anterior Nucleus of Thalamus Using 1.5T MRI for Deep Brain Stimulation Targeting in Refractory Epilepsy

Elena Jiltsova, MD*; Timo Möttönen, MD[†]; Markus Fahlström, MSc[‡]; Joonas Haapasalo, MD, PhD[†]; Timo Tähtinen, MD[†]; Jukka Peltola, MD, PhD[†]; Juha Öhman, MD, PhD[†]; Elna-Marie Larsson, MD, PhD[‡]; Tommi Kiekara, MD, PhD[§]; Kai Lehtimäki, MD, PhD*[†]

ANATOMY

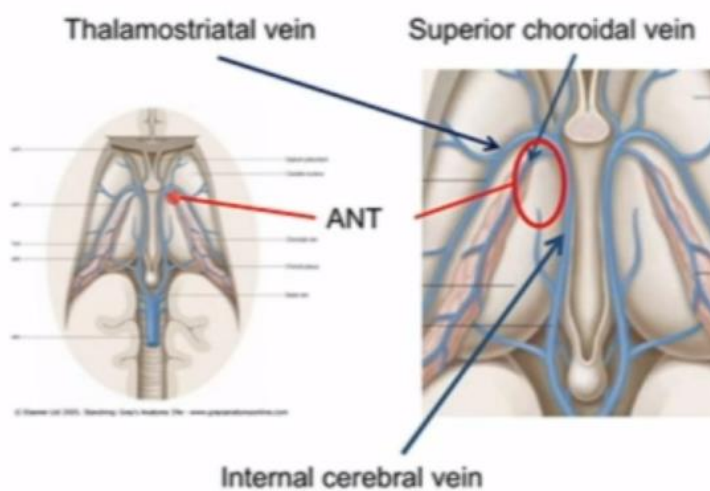
Central node of **Papez circuit** (close anatomical connectivity between the ANT and **mesial limbic structures** - desirable target for MTLE)



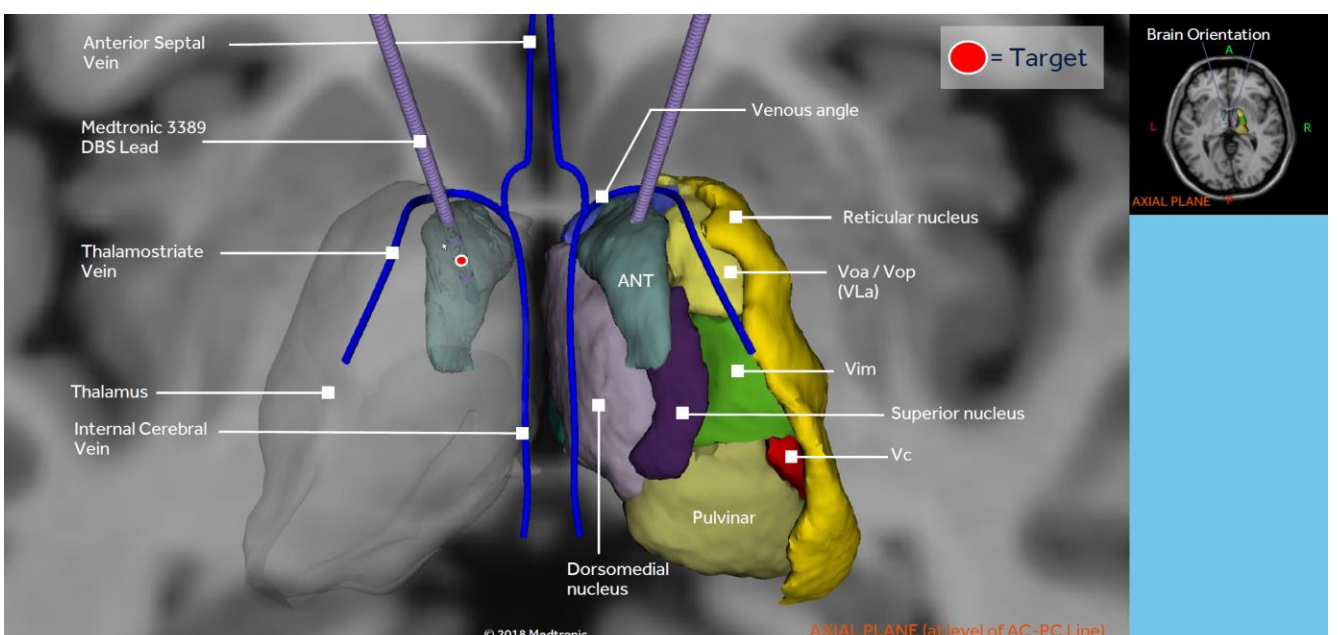
Fronto-temporal epilepsies may respond best (as opposed to parieto-occipital epilepsies).

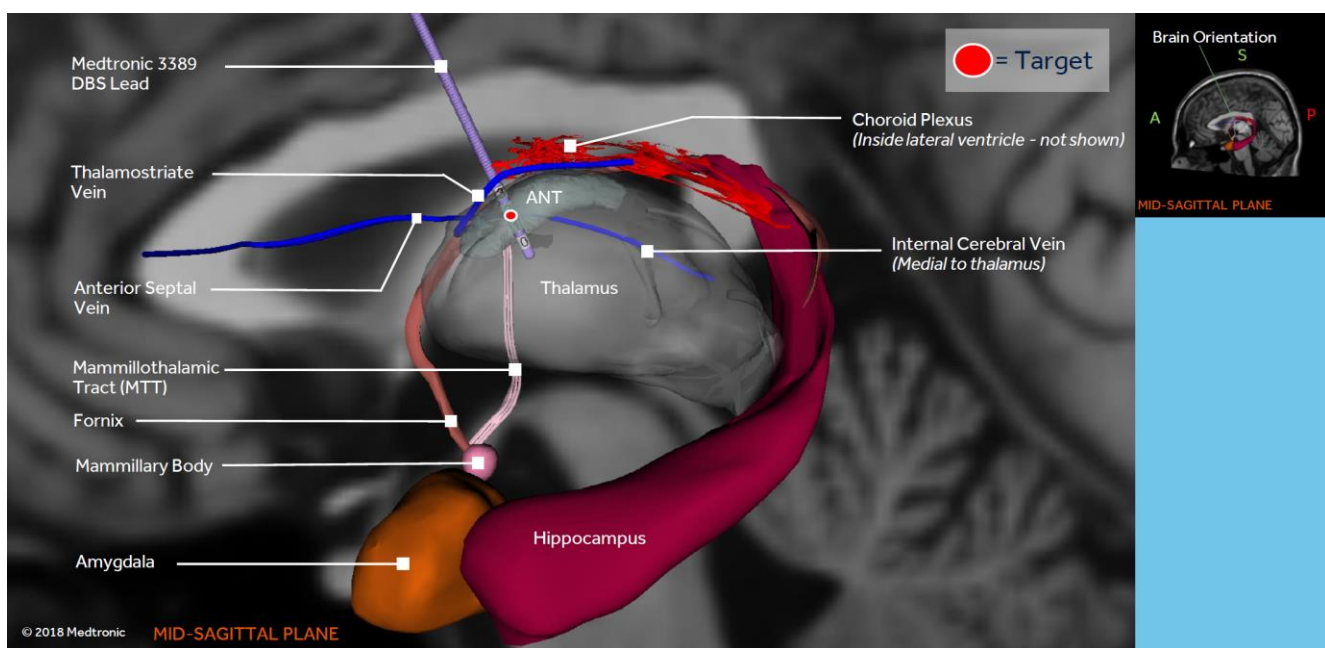
Irving Cooper reasoned that due to its location in Papez circuit, ANT could serve as a key location to disrupt limbic seizures.

- dimensions 4 x 10 x 5.5 mm
- located at the floor of the lateral ventricle
- surrounded by plexus choroideus, thalamostriatal vein, and internal cerebral vein:



- located at the anterior-superior-medial aspect of the thalamus and constitutes its anterodorsal border.
- partially enveloped (isolated from the rest of thalamus) by a myelin-rich sheath belonging to the **mammillothalamic tract (MTT)** and the **internal medullary lamina**
- **subnuclei** (all have distinct patterns of connectivity): anterodorsal, anteroventral, and anteromedial.
- **projects** to superior frontal and temporal lobe structures commonly involved in seizures.
- **inputs** from the subiculum, mammillary bodies via mammillothalamic tract, and retrosplenial cortex.
- MTT joins ANT at its inferior border slightly anterior to the midpoint of ANT in the anterior-posterior axis (this junction is close to the border between anterior principal and anteromedial subnucleus according to the Schaltenbrand–Wahren atlas).





INDICATIONS

- most useful in **partial epilepsy** (with/without secondary generalization).
- there is no seizure type that would predict response to DBS.
 - according to study by Piacentino et al. (6 patients) ANT DBS was most effective in patients with epileptic origins strictly in the limbic system who had no discrete anatomical lesions.
 - DBS is least effective for FAS (focal aware seizures); however, maybe DBS converts FUAS (focal unaware seizures) to FAS and gives such false impression?

Approved in Europe since 2010.

FDA APPROVAL

May 1, 2018 FDA has granted premarket approval for Medtronic's DBS therapy:

- adjunctive therapy for reducing the frequency of seizures
- bilateral anterior thalamic nucleus stimulation
- 18 years of age or older
- partial-onset seizures, with or without secondary generalization
- refractory to ≥ 3 antiepileptic medications.
- ≥ 6 seizures per month over the 3 most recent months (with no more than 30 days between seizures).

Medtronic has preauthorization request guides and also letter samples for appeals in denial cases.

TARGET

Nucleus (antero)principalis

- superior, anterior part of ANT
- best stim contacts – 2-3 mm above where mammillothalamic tract terminates.

High anatomical variability (more variable coordinates than any other stereotactic target) – direct targeting is preferable!

INDIRECT TARGETING

AC-PC coordinates (golden coordinates in parentheses): **12-5-2**

- 10-16 (12) mm superior
- 4-7 (5) mm lateral
- 0-5 (2) mm anterior to MCP or 8 mm anterior to PC

N.B. individual variations up to 5 mm (even between sides) – need direct targeting!

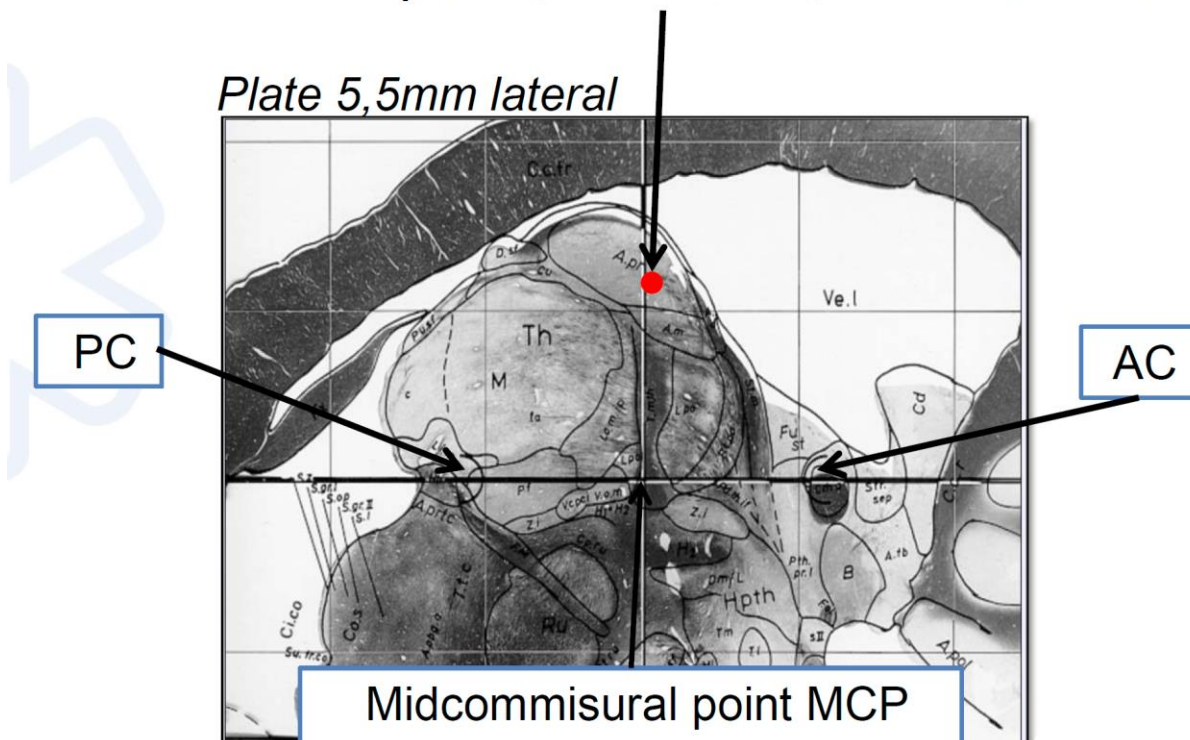
- indirect targeting is particularly challenging in epilepsy as the thalamus is known to atrophy in the setting of chronic epilepsy.
- no characteristic MER signatures.
- no side effect profile to guide targeting.
- Dr. Lehtimäki targets **slightly lateral** to prevent **lead slipping medially** into 3rd ventricle.

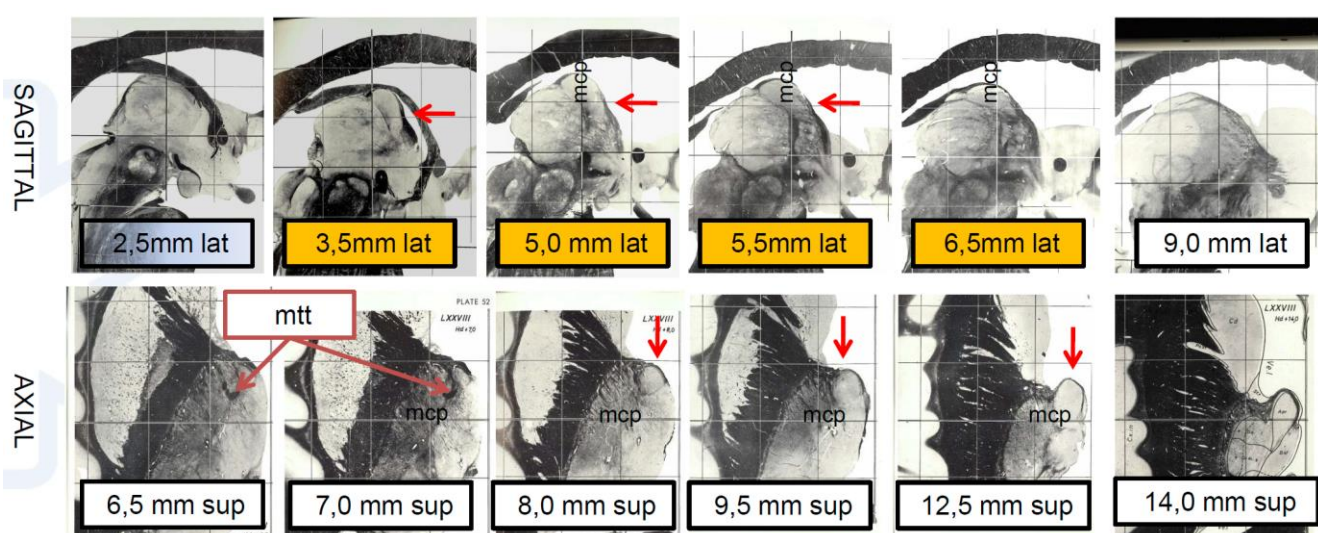
Lehtimäki et al. analyzed the placement of 62 contacts in 15 patients, 10 of whom were responders. Using an ANT-normalized coordinate system, they found that contacts in responders were placed significantly more **anteriorly and superiorly** than they were in nonresponders. They hypothesized that the white matter structures at the inferior and posterior aspects of the ANT prevented the spread of stimulation current into the ANT, which limited the utility of electrodes placed in that region.

Krishna et al. found similar results, noting that patients with the most long-term stimulation benefit had electrodes placed in the **anteroventral** ANT in close proximity to the **mammillothalamic tract**.

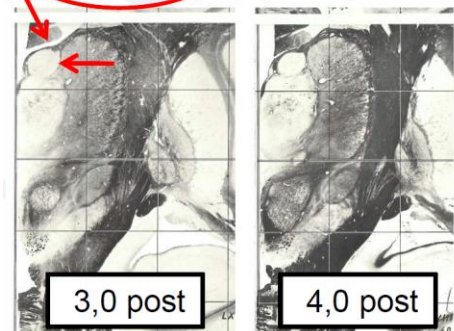
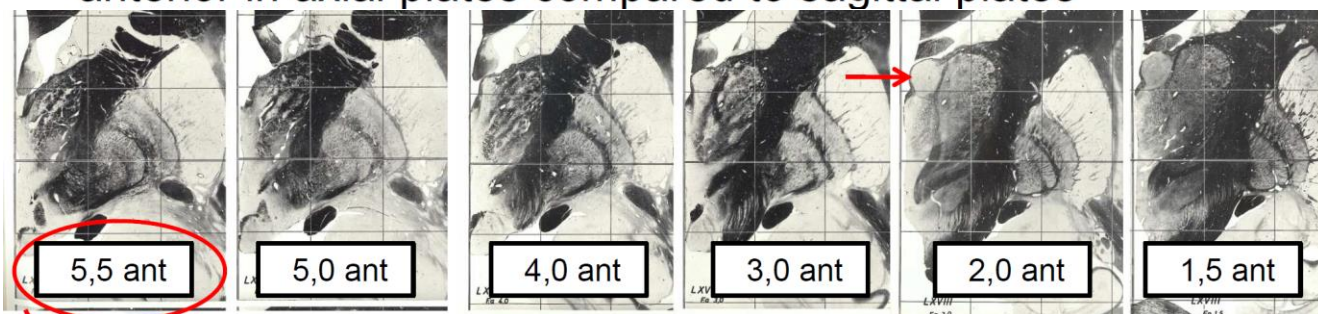
Schaltenbrand-Warren atlas:

ANT: 12 mm superior, 5-6 lateral, 0-2 anterior to MCP





ANT (anterior CSF border or mtt junction) is 4-5mm more anterior in axial plates compared to sagittal plates

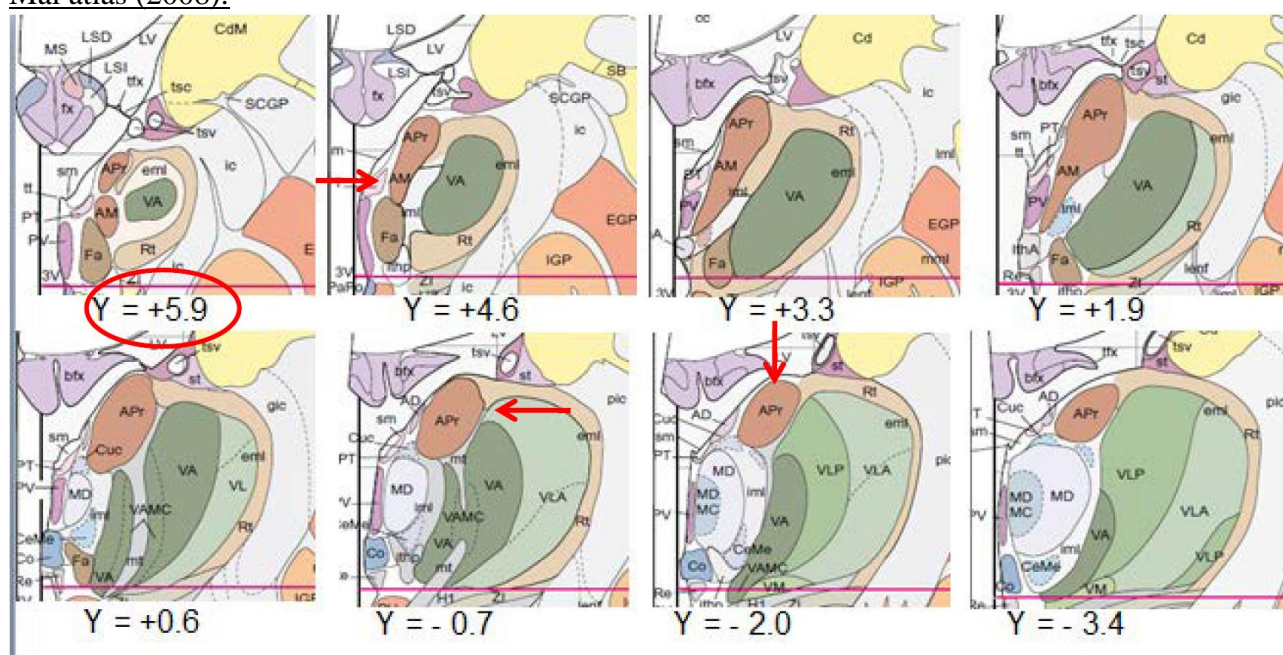


Coronal plates correlate with sagittal plates in Y axis

ANT is more medial in coronal plates compared to sagittal plates

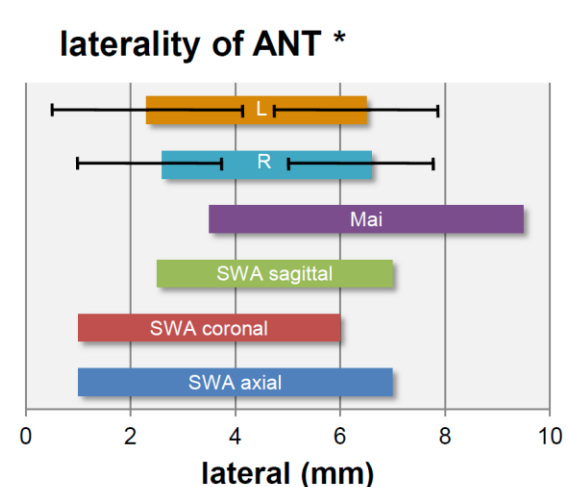
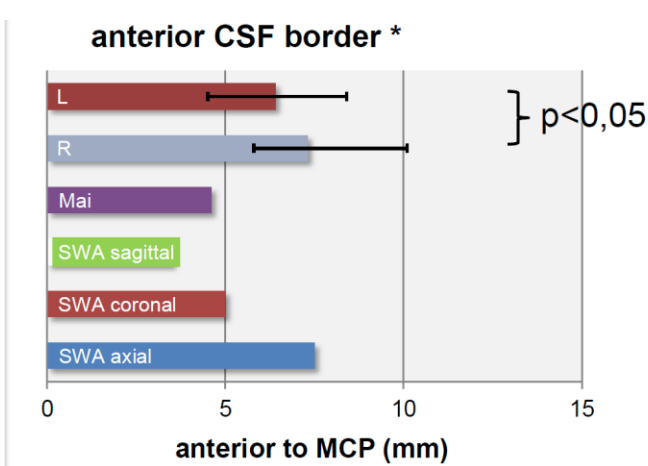
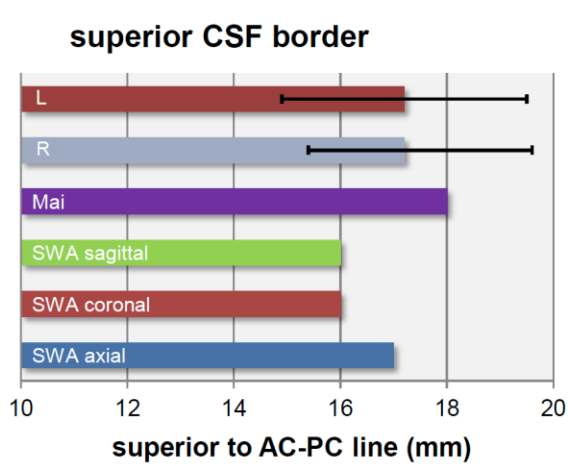
Lehtimäki (2018)

Mai atlas (2008):



Correlates relatively well with schaltenbrandt atlas sagittal plates (anterior border ≈ 5mm anterior to MCP, mamillothalamic tract at midcommissural plane)

Lehtimäki (2018)

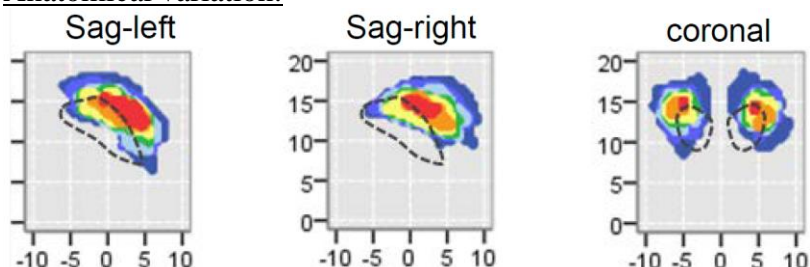


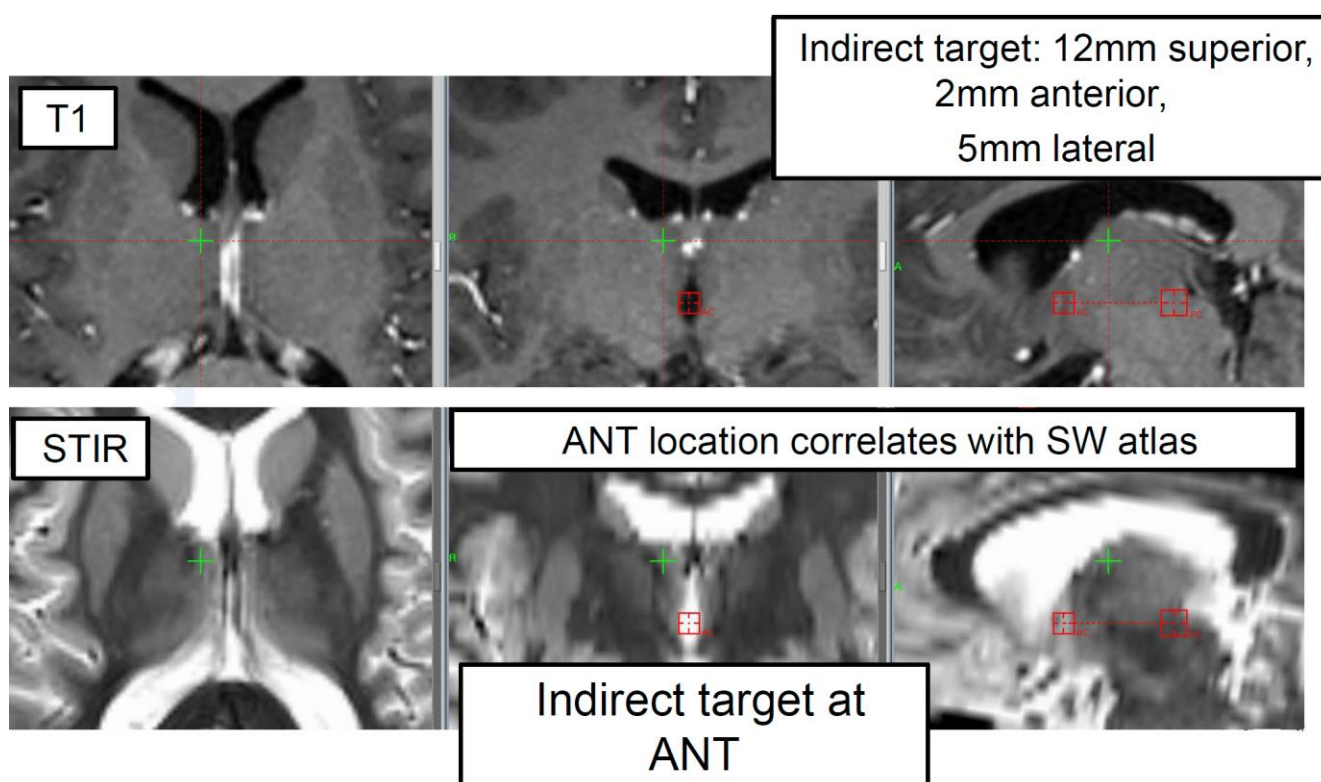
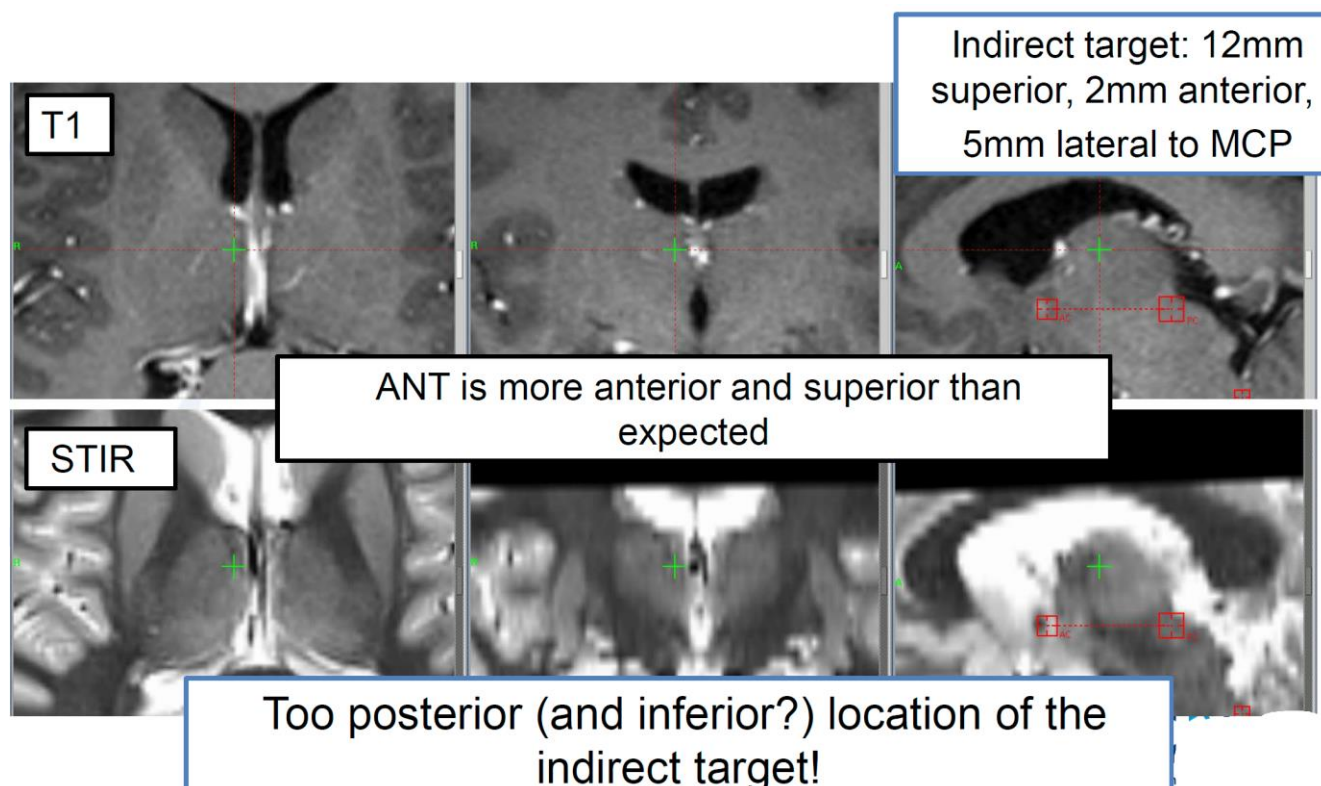
*measured 5mm below the superior border

Axial plates of SWA seems to be the most realistic approximation of ANT location compared to patient data!

Lehtimäki K, unpublished

Anatomical variation:





Lehtimäki (2018)

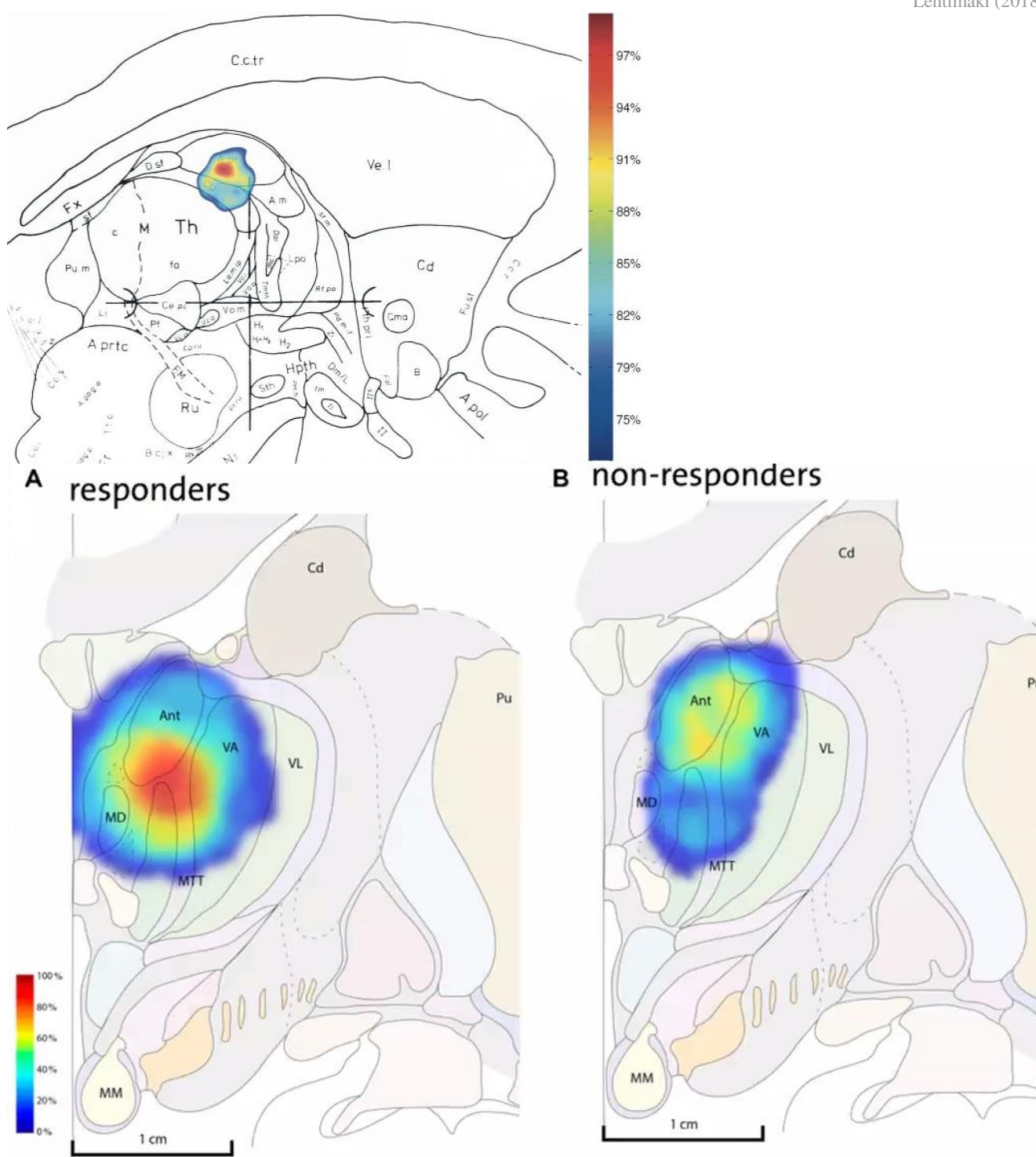


FIGURE 5. Stimulation heat maps superimposed on an adaptation of the Mai atlas 3rd edition (12,0 mm - coronal plate 31) to visualize the activation scores (range of 0%-100%) in anatomic space. The hot-spot (intersection of VTAs with the highest activation score) of responders **A** is located at the medio-ventral ANT in close vicinity to the ANT-MTT junction in contrast to no evident hot-spot in non-responders **B**.

Schaper et al. Neurosurgery (2020) epub

DIRECT TARGETING

ANT is commonly located more anterior and superior in 3T MRI compared to the target based on SW atlas sagittal data!

Target - within the anteroventral subdivision of the ANT, superior and slightly posterior to the entry of the MTT into the ANT.

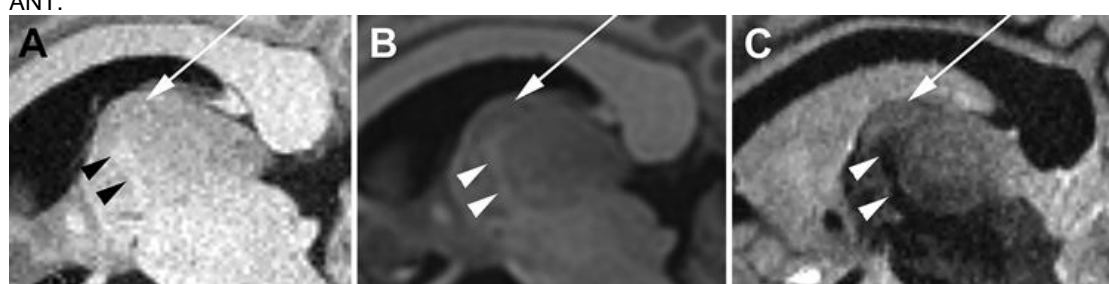
- MTT/ANT junction is slightly anterior to the midpoint of ANT in the anterior-posterior axis;
- MTT/ANT junction is close to the border between anterior principal and anteromedial subnucleus according to the Schaltenbrand-Wahren atlas.

3T MRI with transmit-receive coil:

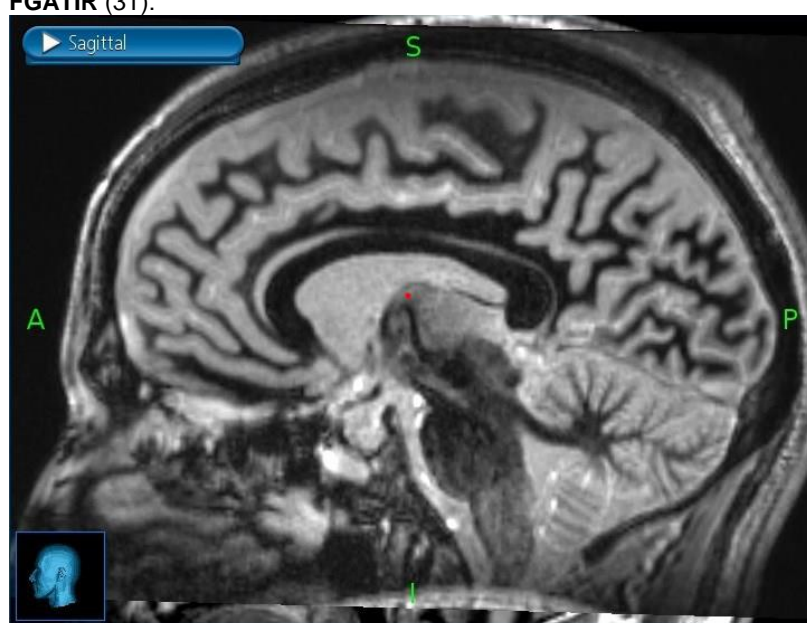
- STIR
- FGATIR (better and faster than STIR) – needs at least on 3T scanner
- DTI – some experts say it does not add extra value to FGATIR

Comparison of three imaging protocols in delineating the mammillothalamic tract (*arrowheads*) and ANT (*arrow*):

- A. **MP-RAGE** acquired at 0.8 mm₃ - poor delineation of the mammillothalamic tract and ANT.
- B. **MP-RAGE** acquired at 1.2 mm₃ - better illustrates the mammillothalamic tract and ANT.
- C. **FGATIR** acquired at 0.8 mm₃ - superior delineation of the mammillothalamic tract allowing more precise definition of the ANT.

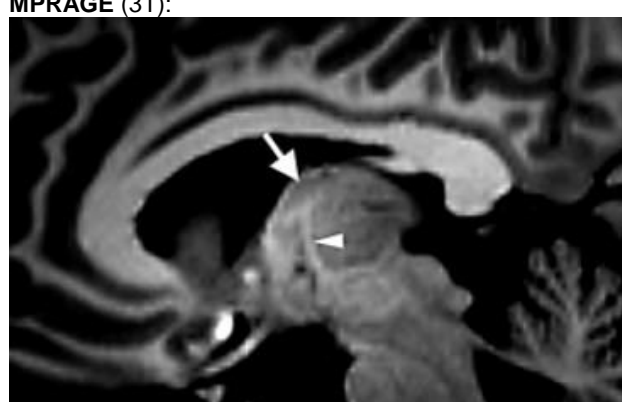


FGATIR (3T):



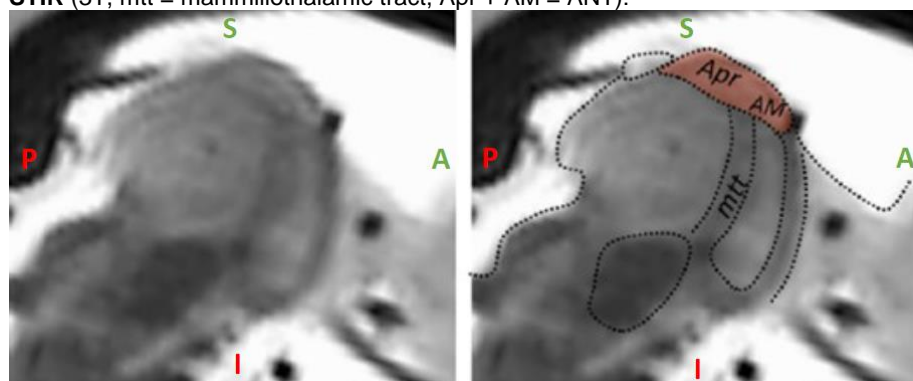
Source of picture: Medtronic

MPRAGE (3T):



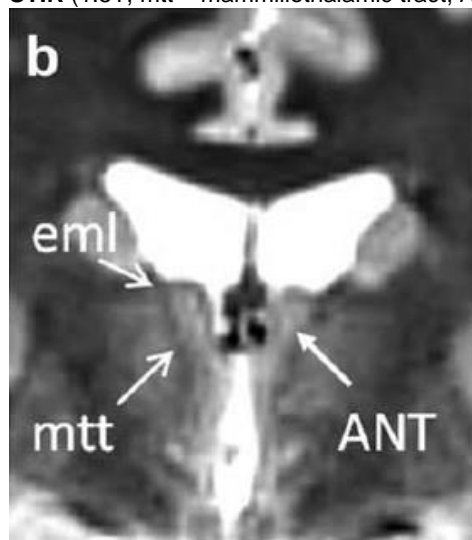
Source of picture: Buentjen L et al. Direct targeting of the thalamic anteroventral nucleus for deep brain stimulation by T1-weighted magnetic resonance imaging at 3T. *Stereotact Funct Neurosurg.* 2014; 92:25-30

STIR (3T, mtt = mammillothalamic tract, Apr + AM = ANT):



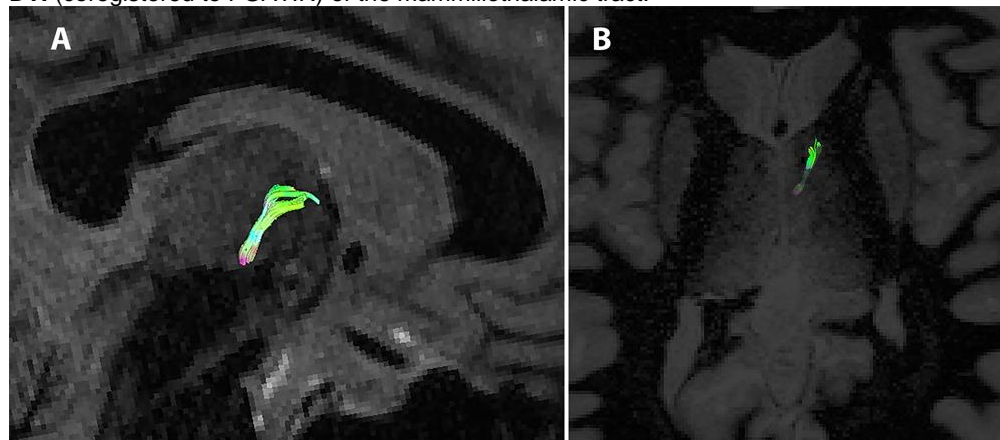
Source of picture: Lehtimäki K et al. Outcome based definition of the anterior thalamic deep brain stimulation target in refractory epilepsy. *Brain stim.* 2016; 9: 268-275

STIR (1.5T, mtt = mammillothalamic tract, ANT = Anterior nucleus of the thalamus, eml = external medullary lamina):



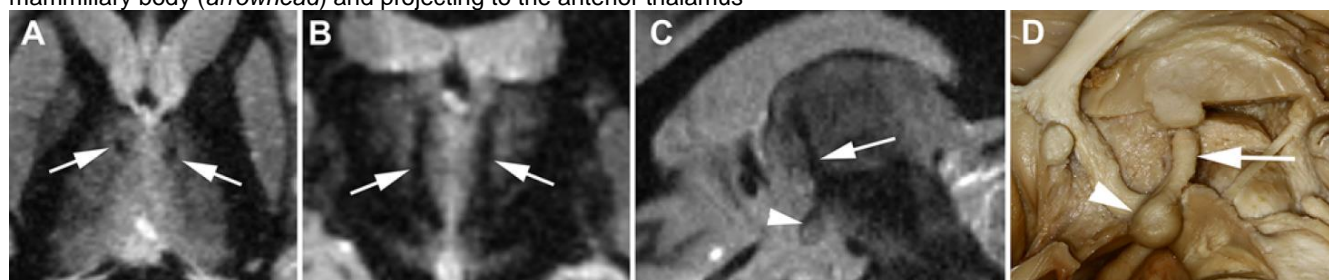
Source of picture: Jiltsova E et al. Imaging of anterior nucleus of the thalamus using 1.5 T MRI for deep brain stimulation targeting in refractory epilepsy. *Neuromodulation.* 2016; 19(8):812-817

DTI (coregistered to FGATIR) of the mammillothalamic tract:

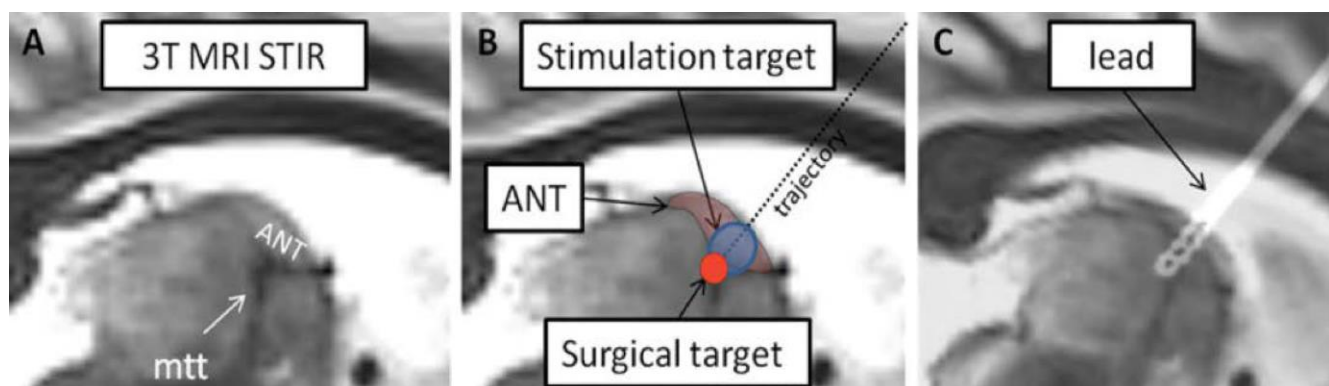
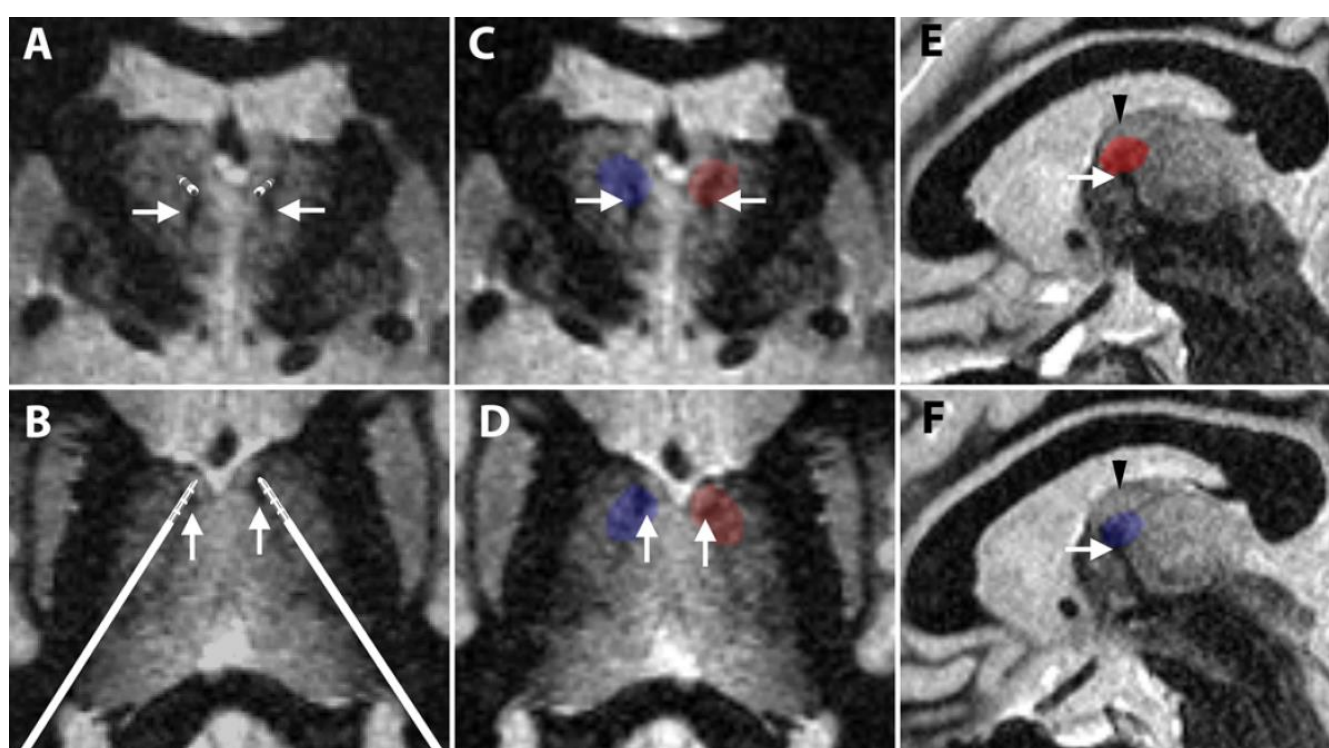


FGATIR MR images in the axial (A), coronal (B), and sagittal (C) planes. The mammillothalamic tract (*arrows*) is clearly visualized as a linear hypointensity extending dorsally from the mammillary body (*arrowhead*) to the anterior thalamus.

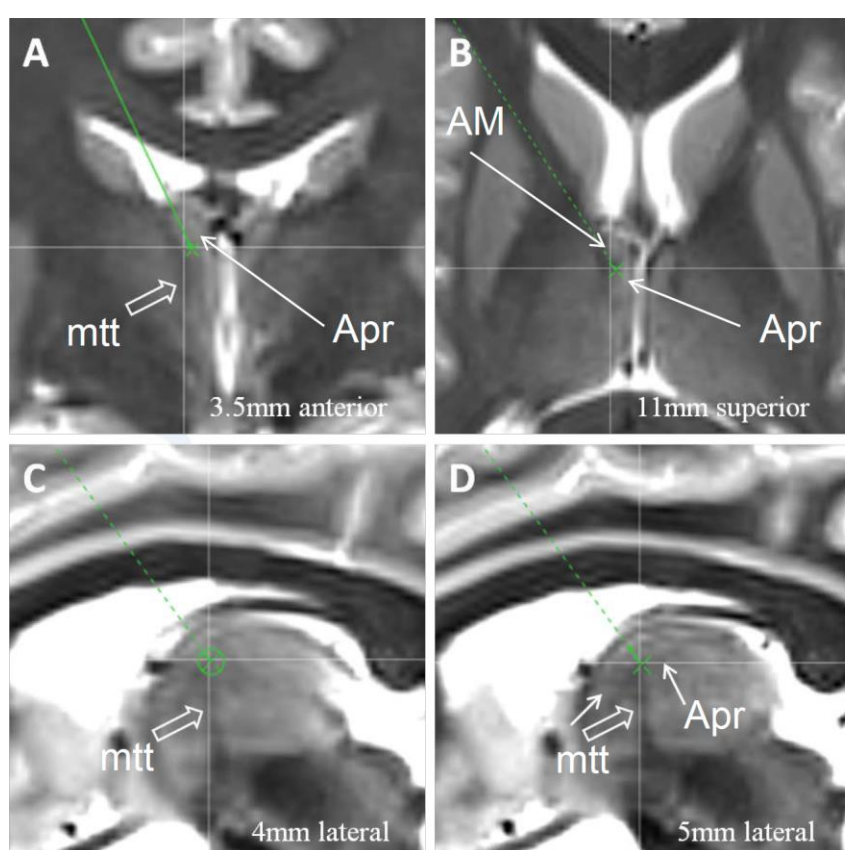
Cadaveric dissection in the sagittal plane (D) illustrates the course of the mammillothalamic tract (*arrow*) originating in the mammillary body (*arrowhead*) and projecting to the anterior thalamus



ANT DBS electrode (Medtronic 3389) localization coregistered to the preoperative FGATIR MR image. Final electrode localization is shown relative to the mammillothalamic tract (*arrows*) in the coronal (A) and axial (B) planes. Coronal (C), axial (D), left parasagittal (E), and right parasagittal (F) images show VTAs for the right (*blue*) and left (*red*) ANT electrodes relative to the mammillothalamic tract (*arrows*) and ANT (*arrowheads*). The VTAs are closely localized to the junction of the mammillothalamic tract and ANT on both sides.



Source of picture: Cukierti, Lehtimäki (2017) >>

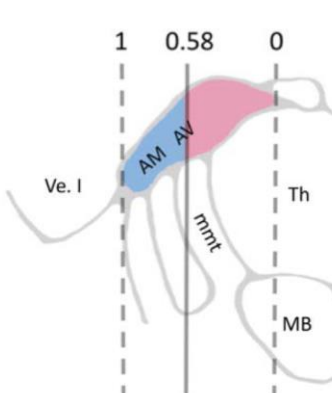


Surgical target
3,5mm from CSF
surface

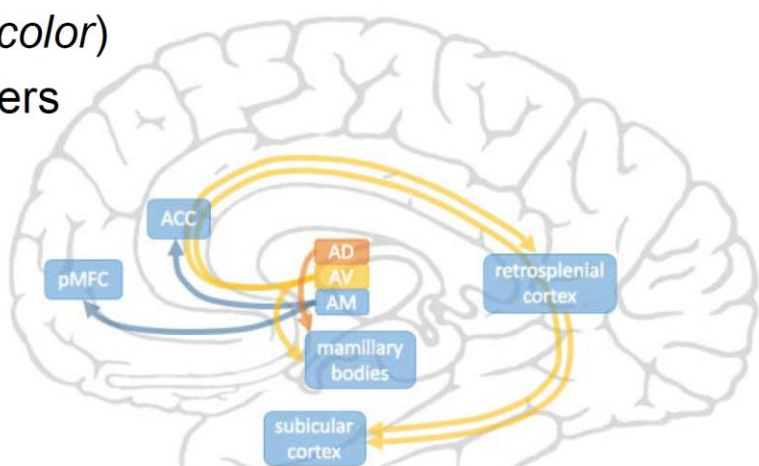
The centre of 3389
(interspace 1&2) to
target point

Two uppermost
contacts (3&2) in
ANT

74% of the contacts (blue color)



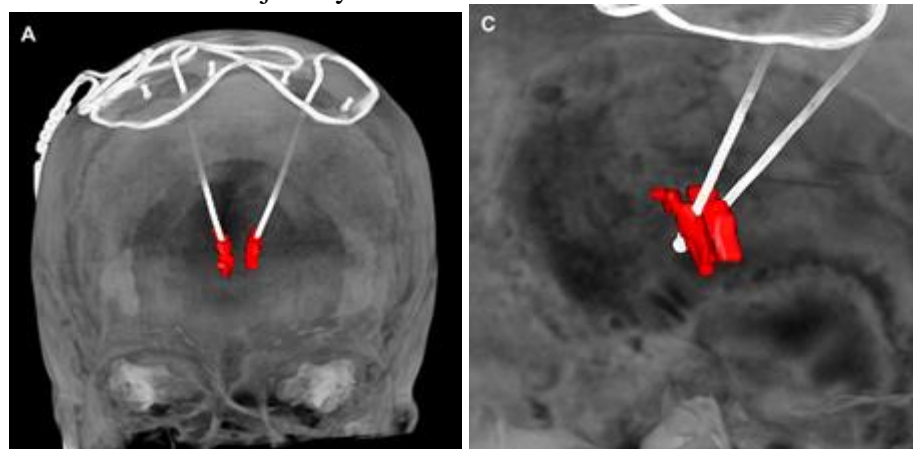
responders



83% of the contacts (red color)
non-responders.

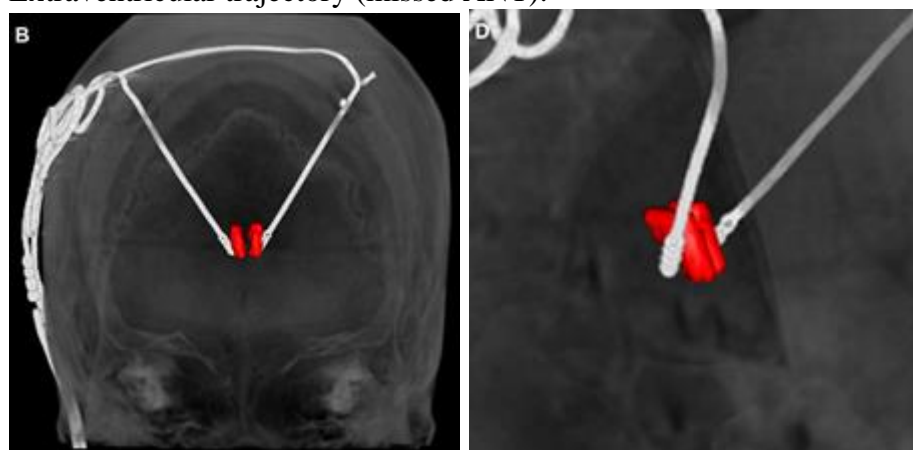
Järvenpää et al. Frontiers of Neurology
2018 | Volume 9 | Article 324

Transventricular trajectory:

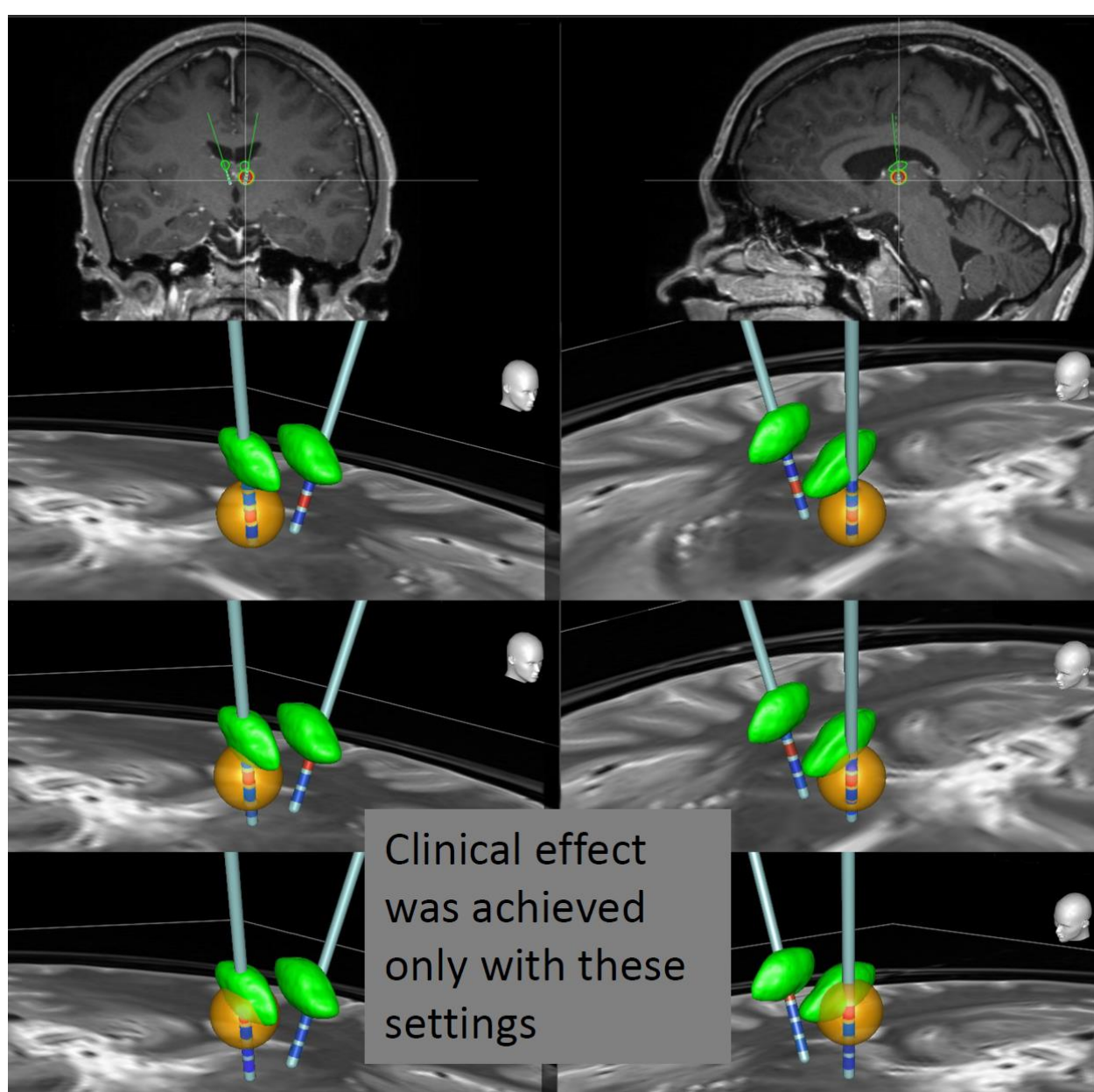


Source of picture: Lehtimäki et al. (2018) >>

Extraventricular trajectory (missed ANT):



Source of picture: Lehtimäki et al. (2018) >>



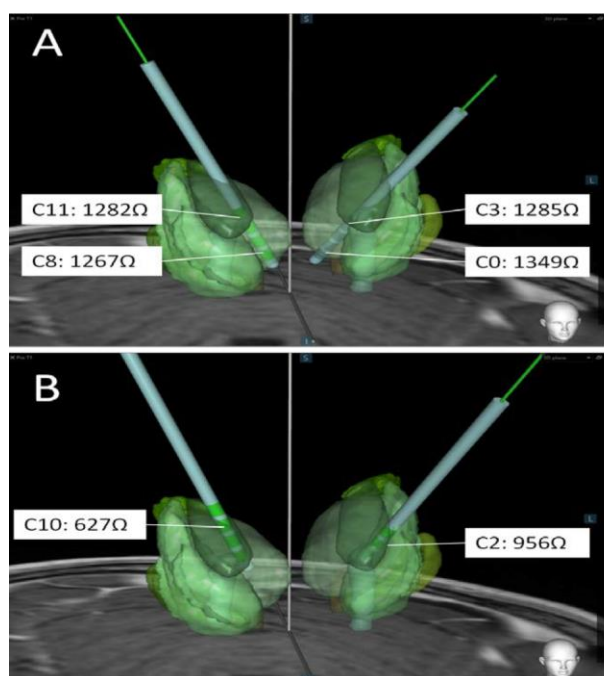
ELECTRODE VERIFICATION – HIPPOCAMPAL ELECTRODES

- hippocampal electrodes are placed, and the Medtronic Activa PC+S system used to record ANT stimulation-induced hippocampal evoked potentials as electrophysiological confirmation of appropriate placement of the ANT leads.

Van Gompel JJ, Klassen BT, Worrell GA, Lee KH, Shin C, Zhao CZ, et al: Anterior nuclear deep brain stimulation guided by concordant hippocampal recording. Neurosurg Focus 38(6):E9, 2015

ELECTRODE VERIFICATION – IMPEDANCES

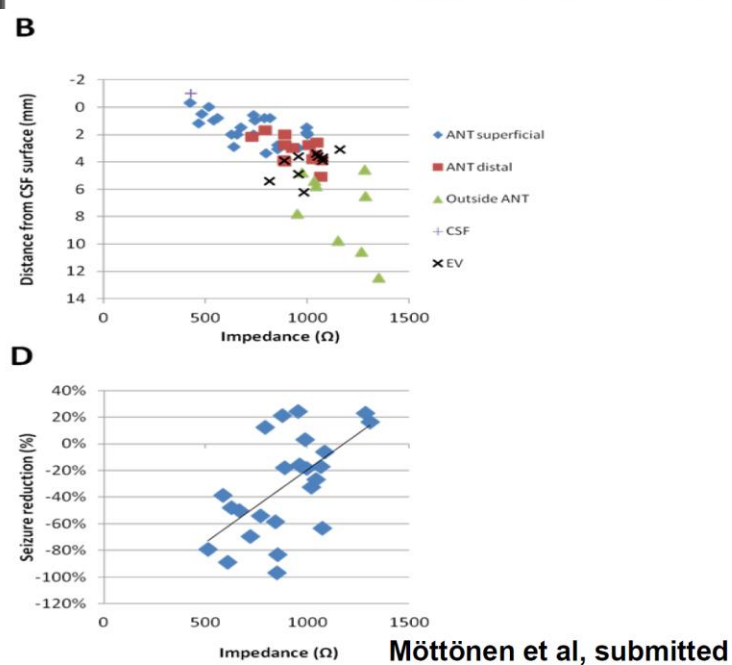
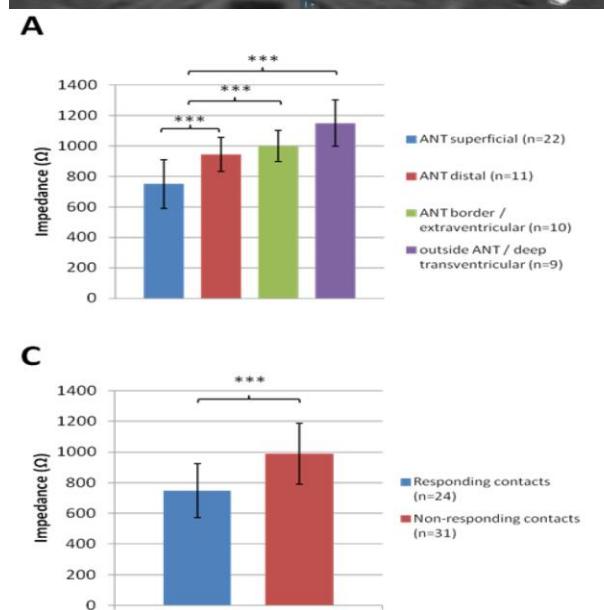
- impedances in CSF are lower than in parenchyma (“CSF wicking” effect – CSF tracks along DBS lead into brain parenchyma and impedances drop).
- impedance in CSF is 200-300 Ohm.



A. Transventricular leads implanted deeper than anticipated

B. Revision of the leads aiming most cranial contacts at the superior border of ANT

Möttönen et al, submitted

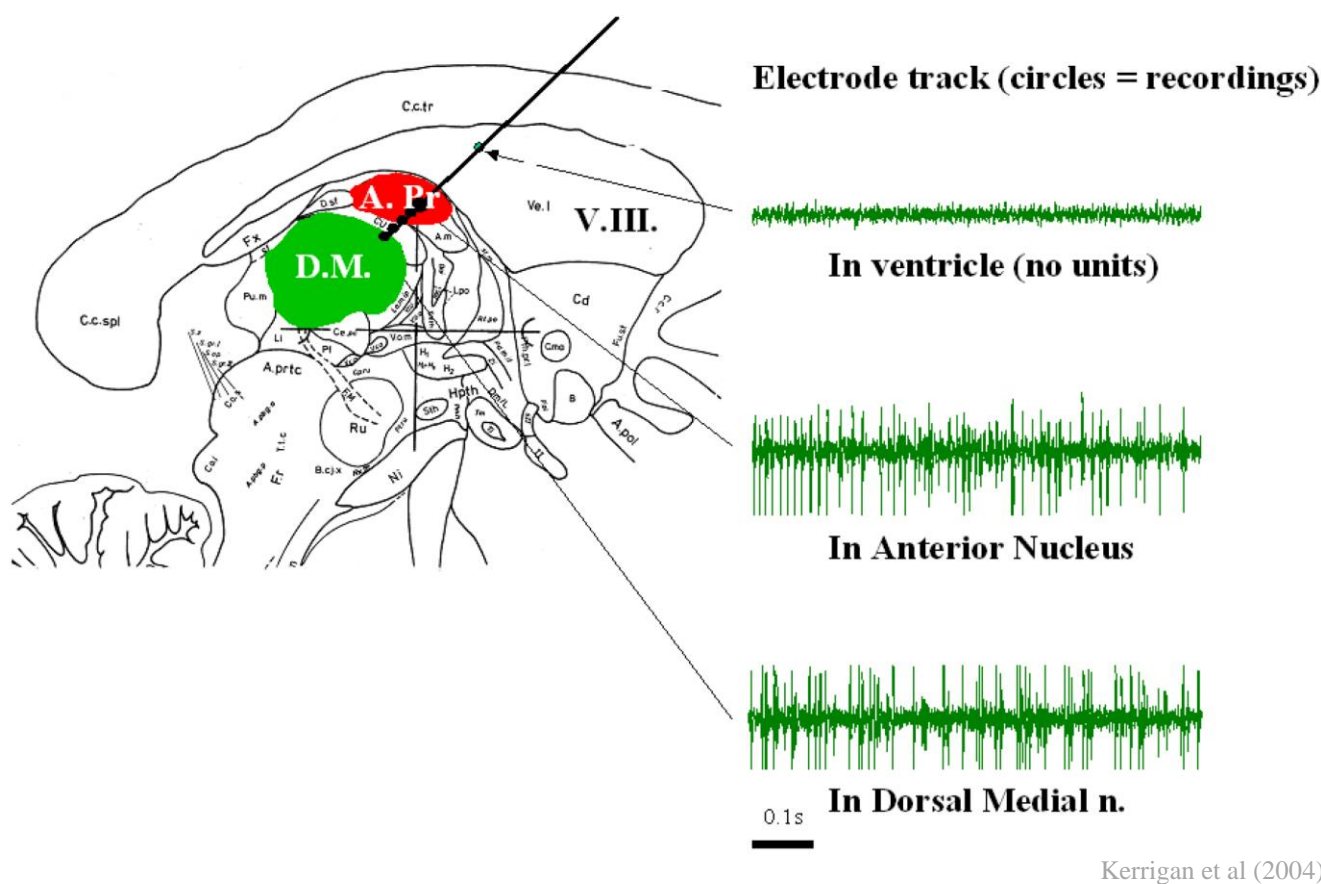
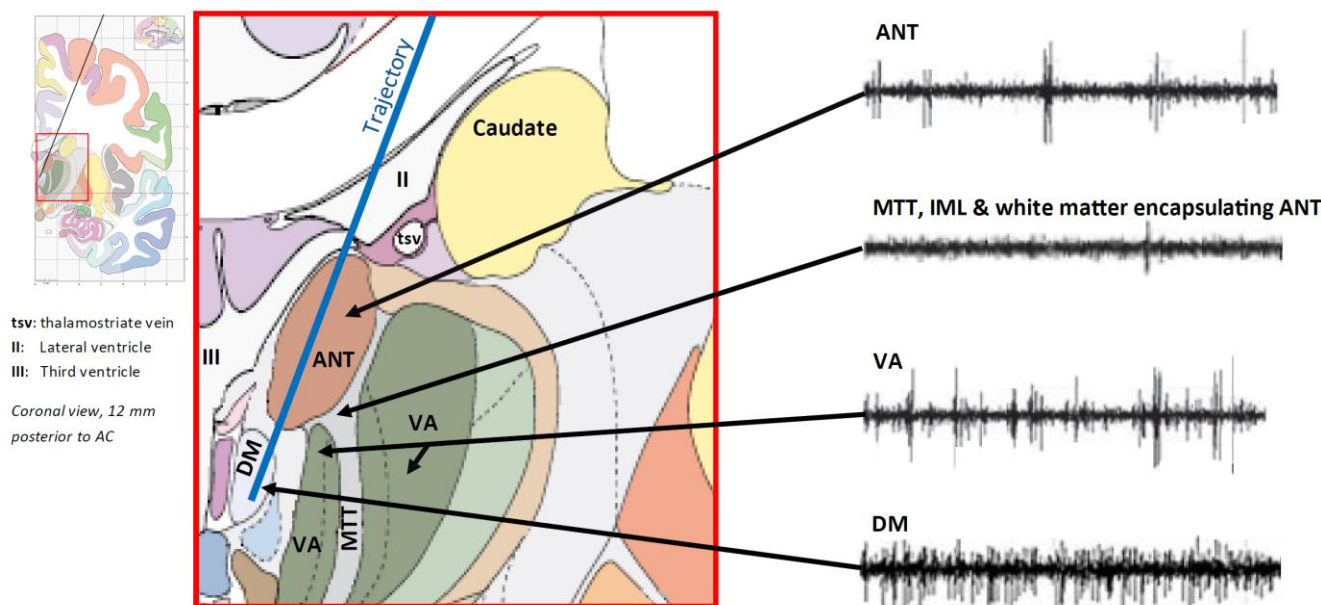


Möttönen et al, submitted

ELECTRODE VERIFICATION – MER

Unnecessary and dangerous (narrow vascular window) in transventricular trajectory.

Descending along the trajectory...	Lateral Ventricle	Quiet
	ANT	Low frequency spikes with low background activity and bursting cells present
	Internal Medullary Lamina	Spiking activity attenuates at the inferior aspect of the ANT when electrode passes into the IML (white matter)
	Dorsomedial (DM) Nucleus of the Thalamus	A slightly more medial trajectory may encounter the DM nucleus The DM exhibits more regular firing patterns than the ANT and with a lower spike amplitude
	OR	
	Ventral Anterior (VA) Nucleus of the Thalamus	A slightly more lateral trajectory may encounter the VA nucleus The VA exhibits higher frequency spiking activity than that observed in the ANT



Location too	MER observations
Posterior	Thinner MER cross-section if posterior to target region of ANT - Posterior to ANT = No neuronal activity (IML)
Anterior	Anterior to ANT = No neuronal activity (lateral ventricle) - Cells representative of ANT if within the nucleus but anterior to target region
Lateral	No neuronal activity (IML) - Spiking activity with higher frequency than ANT (VA nucleus)
Medial	No neuronal activity (IML) - Spiking activity with lower spike amplitude and more regular firing patterns than ANT (DM nucleus)
Inferior (along electrode trajectory)	No neuronal activity (IML) - Spiking activity with lower spike amplitude and more regular firing patterns than ANT (DM nucleus - inferomedial) - Spiking activity with higher frequency than ANT (VA nucleus - inferolateral)

TRAJECTORIES

- SANTE trial** – transventricular frontal (recommended for best accuracy without safety issues)
- MORE registry** – lateral extraventricular (fails to enter ANT most often of all approaches).
- Mayo Clinic** – posterior extraventricular.

Trajectory angle should be adapted to align with the individual shape of the ANT!

Data from MORE

Lehtimäki K, Coenen VA, Gonçalves Ferreira A, Boon P, Elger C, Taylor RS, et al: The surgical approach to the anterior nucleus of thalamus in patients with refractory epilepsy: experience from the international multicenter registry (MORE). Neurosurgery [epub ahead of print], 2018

- 73 ANT-DBS implants (146 leads) in 17 European centers participating in the MORE registry - 53.4% used an **extraventricular (EV) trajectory** and 46.6% used a **transventricular (TV) trajectory**.
- MER appears not to be a crucial factor in successful lead placement in the ANT, esp. if TV route is used.

	TV	EV
at least 1 contact at ANT	90%	71%
at least 1 contact at ANT bilaterally	84%	58%
leads missing the ANT	10%	30%
mean number of contacts at ANT	1.63	1.40

TRANSVENTRICULAR FRONTAL (PRECORONAL)

- ~ 60° posterior from an axial plane parallel to AC-PC plane, i.e. ~ 30° anterior from a coronal plane perpendicular to AC-PC plane.
- trajectory typically runs through the narrow vascular window between **superior choroidal vein** (medially) and **thalamostriate vein** (laterally, between caudate and ANT); blunt stylet advanced slowly pushes veins away.
- sometimes **choroid plexus** is on top of ANT (but it is a mobile structure so hemorrhage is rare – Dr. Lehtimäki goes through it).
- MORE study - two distinct types of **misplacements** were observed:
 - too deep position of the lead** in a trajectory through the ANT (placing of most superior contacts at MD or internal medullary lamina)
 - medial deviation of the lead** - 1 lead situated in structures bordering the third ventricle and 2 leads were positioned in CSF spaces - related to the penetration of the lateral ventricle.

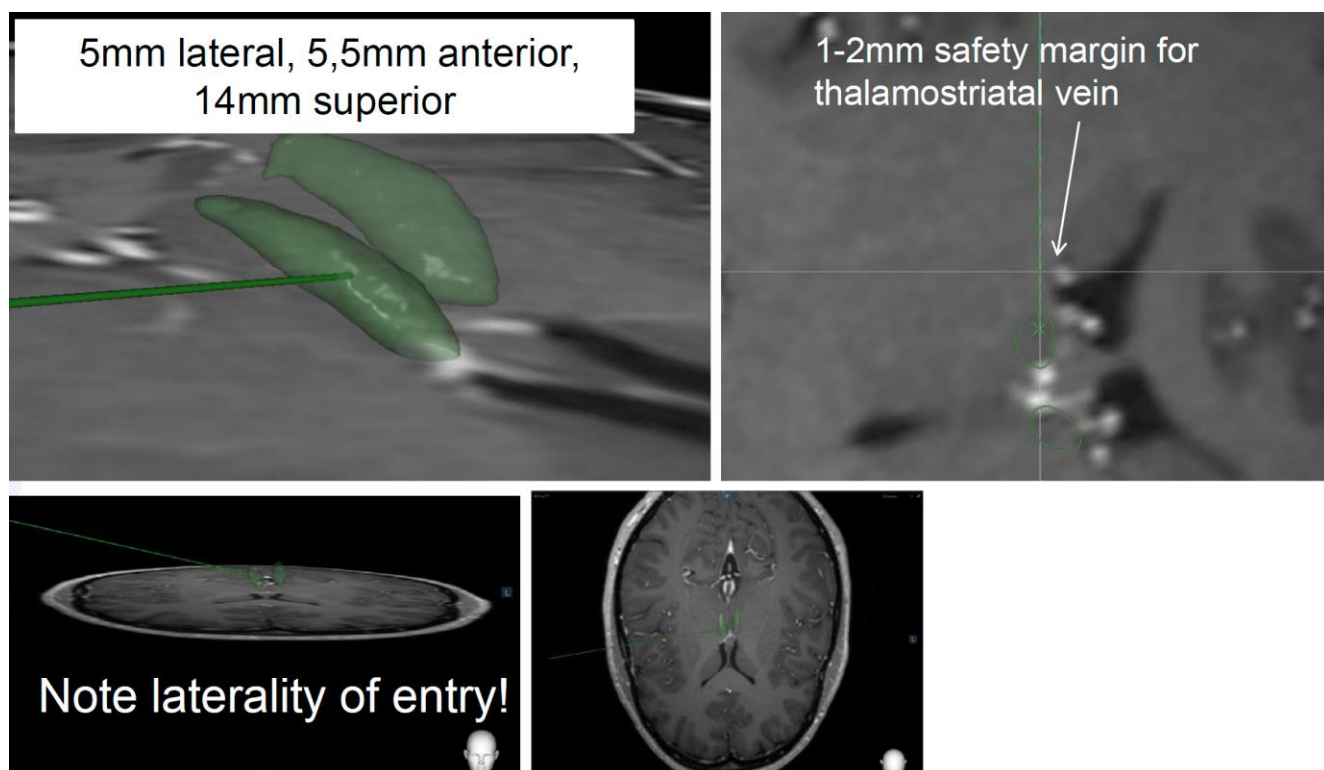
TV trajectory traverses ANT with at least 95% probability, the main surgical challenge being the correct depth of the lead!

The rate of ANT-miss using transventricular trajectory with 3389 lead is 17.2%

LATERAL EXTRAVENTRICULAR (TRASCORTICAL)

- passes through eloquent cortex, such as the operculum.
- provides improved mediolateral coverage.
- thalamostriate vein** runs at the anterior and lateral aspect of ANT - in order to reach ANT from frontal EV approach, a very lateral and posterior entry point is needed to pass the thalamostriate

vein, which is in contrast limited by frontal eloquent cortex; compromise between these anatomical limits is most likely achieved by adjusting the target inferiorly, laterally, and posteriorly, probably aiming to stimulate the MTT-ANT junction rather than ANT nucleus per se.

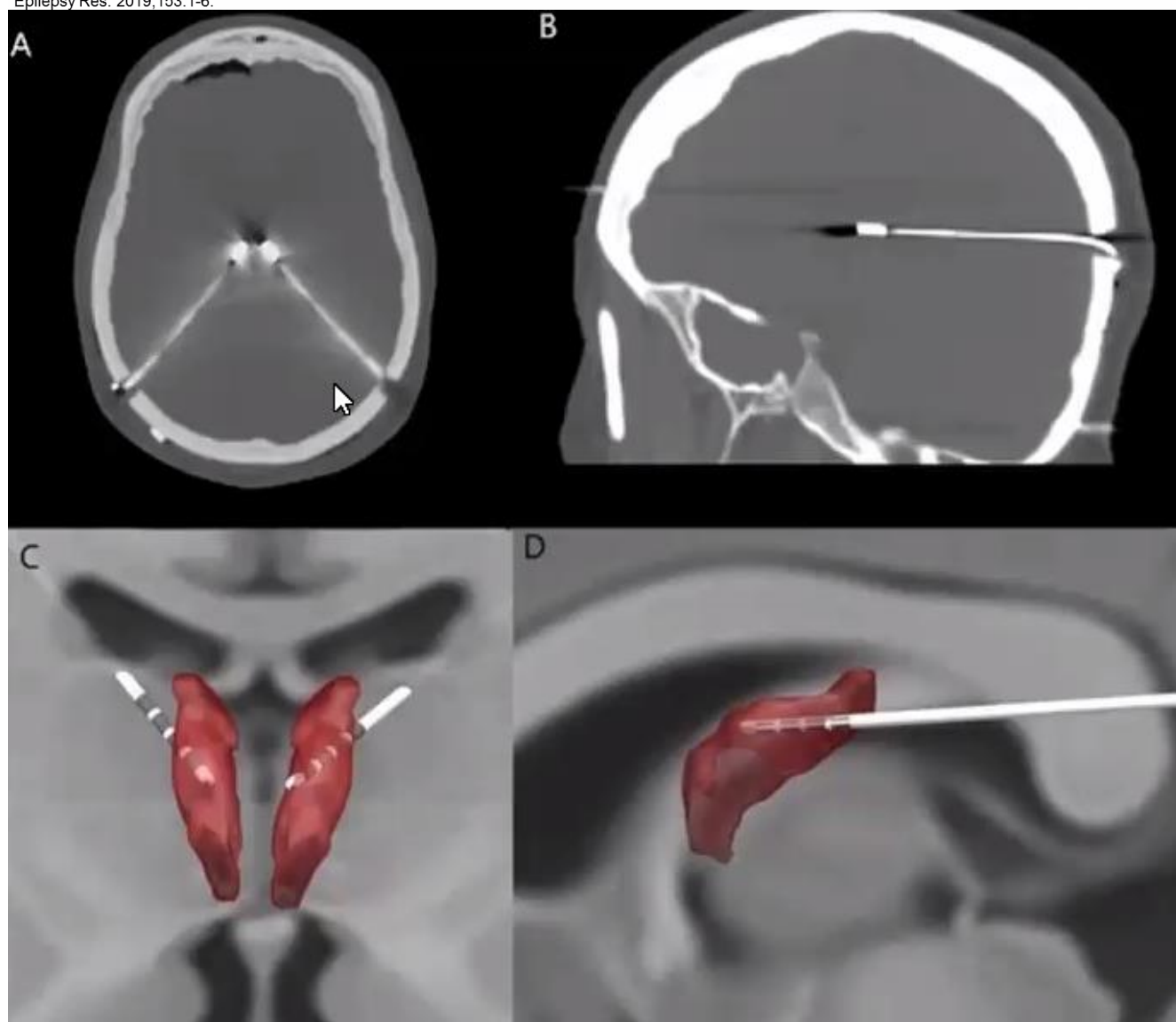


- **ANT-miss lead trajectories**, the leads were systematically more inferior and had their courses directed more posteriorly compared to **ANT-hit trajectories**
- with respect to MTT/ANT junction, **ANT-hit lead trajectories** were clearly located superior to the MTT/ANT junction and at the level or slightly posterior to the MTT/ANT junction, whereas **ANT-miss lead trajectories** had their courses systematically below and grossly posterior to the MTT/ANT junction.

POSTERIOR INFERIOR PARIETAL

- greatest anteroposterior coverage
 Van Gompel et al.: electrodes are placed along a posterior inferior parietal route, to avoid intraventricular hemorrhage and lead misplacement associated with transventricular and lateral transcortical approaches.

Wang Y, Grewal SS, Middlebrooks EH, et al. Targeting analysis of a novel parietal approach for deep stimulation of the anterior nucleus of the thalamus for epilepsy. *Epilepsy Res.* 2019;153:1-6.



POSTOP

- Wound care, MRI, electrosurgery, follow ups. see p. Op360 >>
- regular room 1 night postop after 1st stage; one day surgery for 2nd stage.

COMPLICATIONS, SIDE EFFECTS

Tröster AI et al. Memory and mood outcomes after anterior thalamic stimulation for refractory partial epilepsy. *Seizure.* 2017 Feb; 45:133-141.

1. 4.5% of the patients had asymptomatic **intracranial hemorrhage (ICH)** in SANTE ← more frequent than in DBS surgery for movement disorders specifically (2.16% of ICH)
2. **Exacerbating seizures / inducing new seizures** (0.5-13% with 74-86% of those occurring around the time of electrode placement or initiation of stimulation)
 - review of 2101 electrode placements across 16 reports revealed an incidence of new onset seizures in **up to 13% of patients**. At least 74% of seizures occurred around the time of electrode placement, with many patients experiencing intracranial hemorrhage.
 - others estimated that DBS is associated with < 2.4% (95% CI 1.7%–3.3%) risk of seizures and that postprocedural risk of seizures from chronic DBS was approximately 0.5% (95% CI 0.02%–1.0%).
 - separate report examined 161 patients (288 leads) - 4.3% experienced seizures - the vast majority (86%) of seizures occurred within 48 hours after lead implantation.
3. **Psychiatric** side effects
 - SANTE: **depression** 37.3% (vs 1.8% in controls) – patients need to be watched closely!
 - changing stim contacts almost always helps.
4. **Cognitive** side effects
 - SANTE: **subjective memory impairment** 27.3% (vs 1.8% in controls); all resolved with no group differences on **objective** neuropsychological testing.

At 7 years: no significant cognitive declines or worsening of depression scores were observed through the blinded phase or at year 7.
Improved scores were observed at 7-years on measures of executive functions and attention.

5. **Sleep** disruptions with vivid dreams.

Neuropsychological monitoring of memory and mood + slow titration are recommended in ANT DBS!

There are case series that have suggested neuropsychological and cognitive effects with chronic ANT stimulation:

- 1) decreased response inhibition
Hartikainen KM et al. Immediate effects of deep brain stimulation of anterior thalamic nuclei on executive functions and emotion-attention interaction in humans. J Clin Exp Neuropsychol. 2014;36(5):540-550
- 2) sleep disruption
Voges BR, Schmitt FC, Hamel W, et al. Deep brain stimulation of anterior nucleus thalami disrupts sleep in epilepsy patients. Epilepsia. 2015;56(8):e99-e103.
- 3) psychiatric adverse effects
Jarvenpaa S, Peltola J, Rainesalo S, Leinonen E, Lehtimaki K. Reversible psychiatric adverse effects related to deep brain stimulation of the anterior thalamus in patients with refractory epilepsy. Epilepsy Behav. 2018;88: 373-379

PROGRAMMING

Feature	Description	Percept™ PC + SenSight™ Lead	Percept™ PC + 1x4 Lead	Activa™ PC/RC + SenSight™ Lead	Activa™ PC/RC + 1x4 Lead
Segment Mode (Monopolar Only)	Enable and disable directional lead segments	✓		✓	
OptiStim™ Control	Adjust the amplitude of a single electrode without impacting the amplitude of other electrodes in the configuration	✓	✓		
ShapeLock™ Control	Create a unique field shape, including relatively dissimilar amplitude contributions from various electrodes, then grow and shrink that shape	✓	✓		
Multiple Rates	Program multiple rates within a group or lead	✓	✓		
CC / CV Capabilities	Amplitude Mode: Constant Current (CC) or Constant Voltage (CV)	CC	CC	CV	Either

BRAINSENSE

BrainSense™ Setup: for LFP recordings


- BrainSense™ LFPs are differentials – calculation requires 2 sensing contacts for data collection with at least 1 of these contacts situated in grey matter
- Sensing contacts must surround stimulation contact(s)
- 3 Programming options to choose from

3 sensing configurations possible:

Sensing Setup - Electrode Configuration

Tap Save Sensing or Thresholds to update electrodes for both therapy and sensing.

Left ANT



BrainSense™ Setup:

- BrainSense™ LFPs are differentials – calculation requires 2 sensing contacts for data collection with at least 1 of these contacts situated in grey matter
- Sensing contacts must surround stimulation contact(s)
- 3 Programming options to choose from

- epilepsy signature LFP peaks are typically located in 8-12 Hz range (Percept PC can records only in 5 Hz wide band) – look for those recorded (upon patient triggered events) and also during programming session.
- turn LFP detection right after battery implantation (POD 0) – will obtain baseline LFP peaks while still *off stim*.

STIMULATION

Differences from DBS for movement disorders

- 1) intermittent (vs. continuous) stimulation – “cycling”
- 2) contact is programmed to be a cathode (negatively charged electrode) and case as anode* – to cause depolarization block.

*patients may feel tingling at battery site

Parameter	Typical Starting Value
Amplitude	5 V <i>*In clinical practice clinicians may start at a lower amplitude and titrate up slower as they assess patient response and tolerability.</i>
Pulse Width	90 μs
Rate	145 Hz
Electrode Configuration	Unipolar Mode: Single electrode or two adjacent electrodes negative, case positive (all patients in the SANTE clinical trial were in unipolar mode)
Cycle of Therapy	Cycling mode ON: 1 minute on, 5 minutes off
SoftStart™ Stop	programmed to 8 seconds

Phase I (start 2-3 weeks postop) – **increasing output**

Amplitude – start at 0.5 mA (old way - 1.5-2.0 V) and increase q2-4 weeks by 0.5 mA (0.5 V) (or even longer intervals – analogy with adjusting AEDs) up to 4 mA (4.5-5.0 V, up to 9.0 V); **most patients need 2-3 mA.**

- gradual amplitude increase helps to minimize occurrence of psychiatric side effects
- keep symmetrical between sides.
- corresponds to 4-7 mA (some experts recommend current-based programming to mitigate impedance effects that maybe very asymmetric)

Pulse width 90 msec (this is invariable*)

Frequency 145 Hz (this is invariable*)

*hardware allows to change it but in studies it did not make any difference

Duty cycle: 1 min on, 5 mins off.

Monopolar

- typically not the deepest contact
 - usually most centrally located contact
 - do not use contacts with **low impedances** – electrical current will shunt into CSF (not into parenchyma).
 - contacts in thalamus but outside ANT cannot stimulate ANT as white matter capsule creates barrier.
 - alternative – wide bipolar stim (anode most distal).
- N.B. bipolar stimulation is used to limit current spread into surrounding structures.

Phase II – changing cycling

Decreasing off time from 5 to 3 min.

N.B. directional stim is available only in monopolar mode.

OUTCOMES

- best effects are on disabling, multifocal epilepsy as well as temporal lobe epilepsy (involvement of Papez circuit).
- it takes time for efficacy to build up (vs. DBS in movement disorders).
- seizures may intensify upon initiation of stimulation.

ROLE OF PREVIOUS VNS

SANTE data – see below >>

There is a putative association between VNS and DBS responses

- in 10/11 patients, the response to VNS seemed to be similar to the response to DBS; progressive response to VNS was likely to correlate with a progressive response to DBS in 3/3 patients; partial response to VNS was associated with a fluctuating response pattern to DBS in 2 patients; 5/6 nonresponders to VNS were also nonresponders to DBS (one of the VNS nonresponders obtained progressive response to DBS).

Toni Kulju et al. Similarities between the responses to ANT-DBS and prior VNS in refractory epilepsy. Brain Behav. 2018 Jun;8(6):e00983. doi: 10.1002/brb3.983. Epub 2018 May 8.

STIMULATION OF THE ANTERIOR NUCLEUS OF THALAMUS FOR EPILEPSY (SANTE) TRIAL

Complete set of trial data >>

Fisher RS, Salanova V, Witt T et al. and the SANTE Study Group. Electrical stimulation of the anterior nucleus of thalamus for treatment of refractory epilepsy. Epilepsia. 2010 May; 51(5):899-908

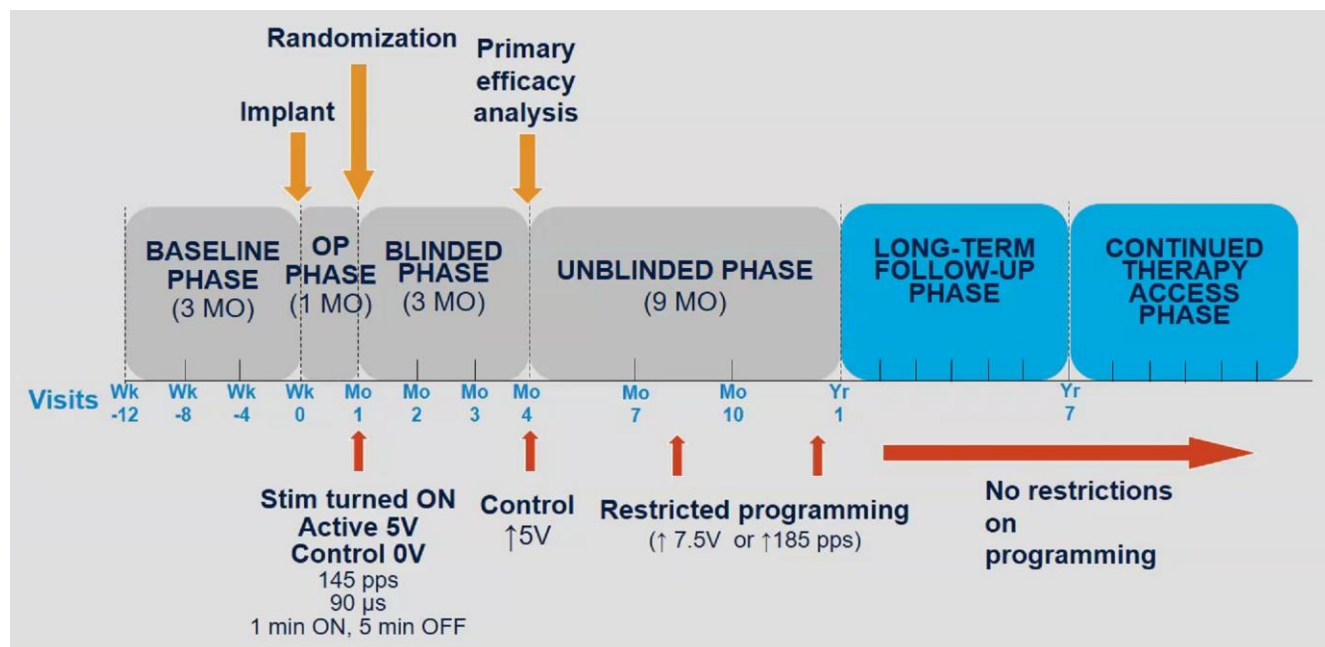
5-year outcome:

Salanova V et al. Long-term efficacy and safety of thalamic stimulation for drug-resistant partial epilepsy. Neurology. 2015 Mar10; 84(10):1017-25.

7-year outcome:

Sandok E et al. Long term outcomes of the SANTE Trial: 7-Year Follow-Up. American Epilepsy Society Annual Meeting. 2016 Abst. 1.298.

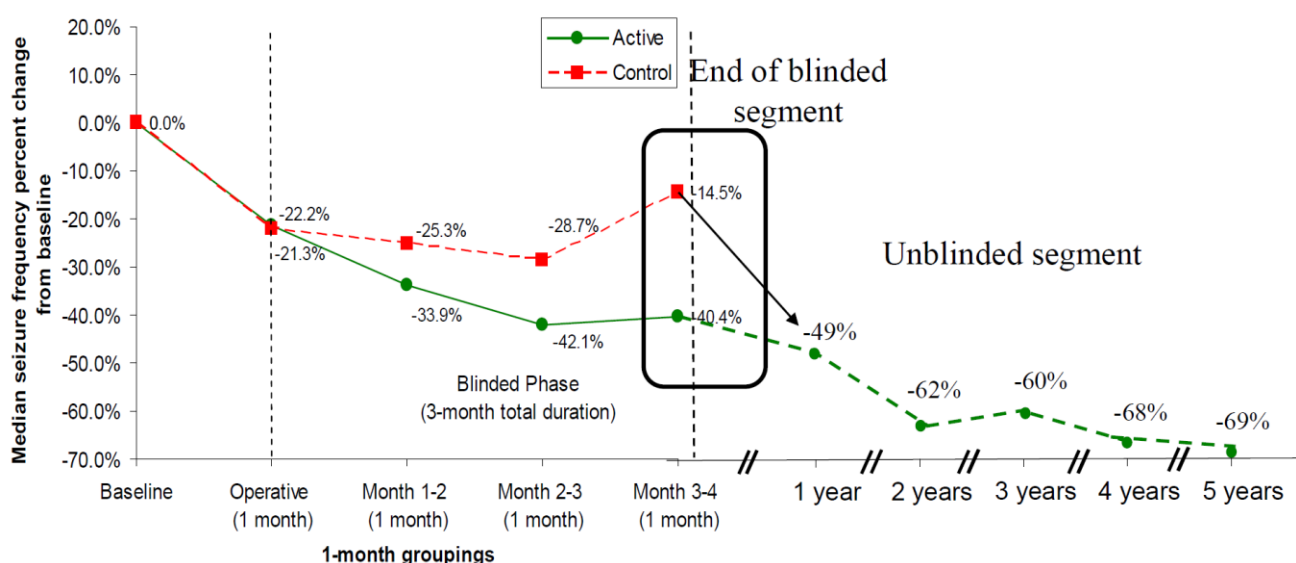
- level I evidence for medically refractory partial seizures with or without secondary generalization - positive effects of bilateral stimulation appear to be long-lasting + patients had improved quality of life.
- multicenter, prospective, randomized, double-blind, parallel groups pivotal study – high quality data.
- 110 patients who were implanted with a Medtronic DBS system at 17 centers located in the U.S.
- blinded phase – 3 months.



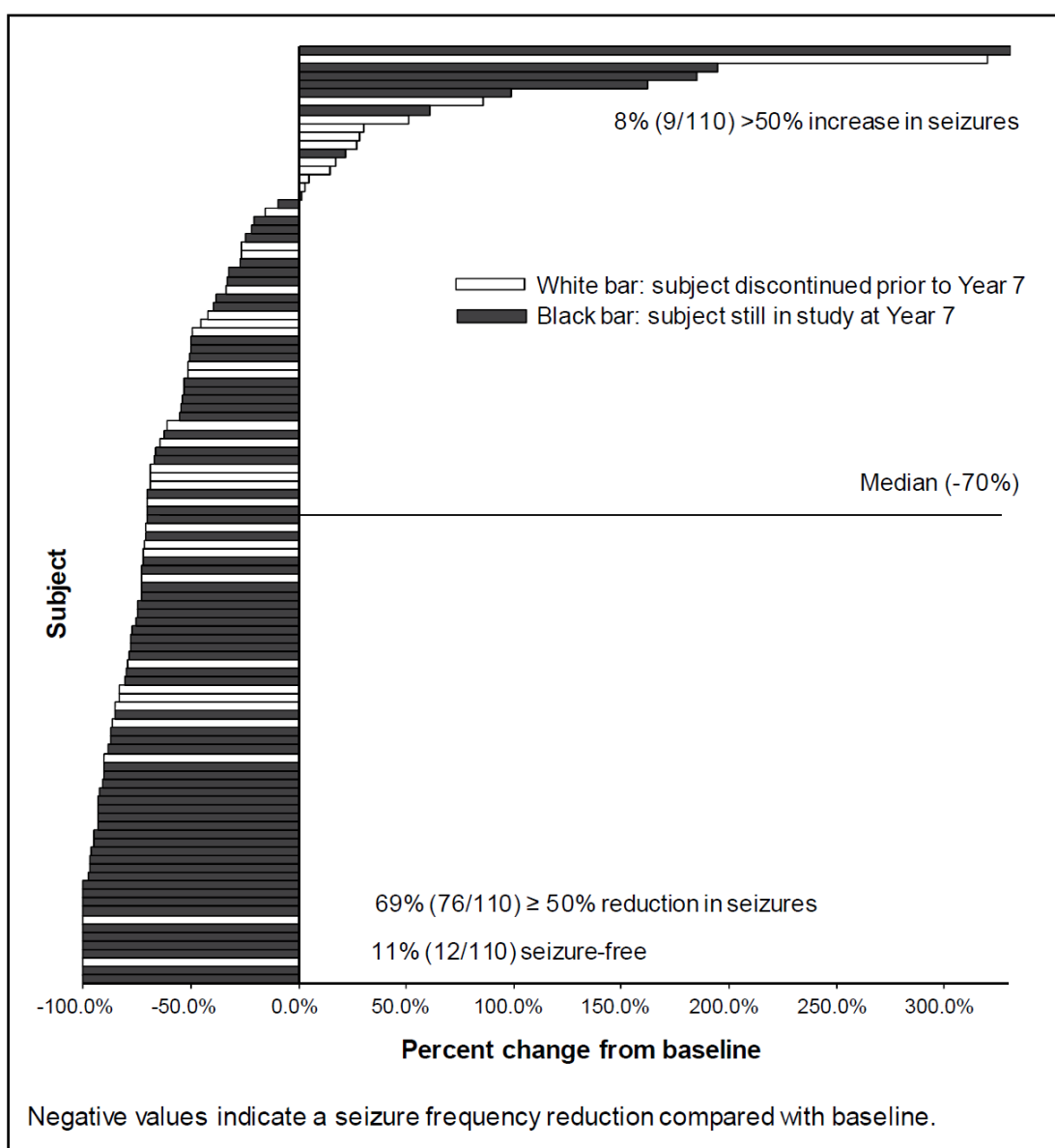
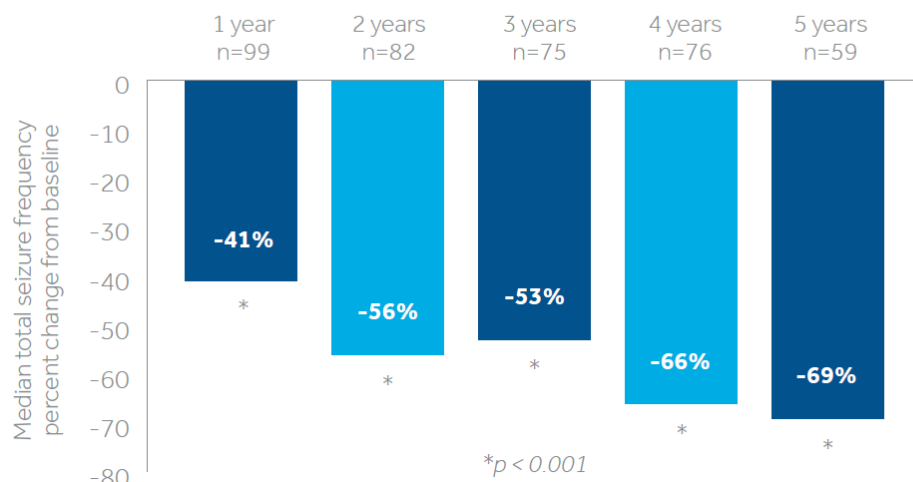
- patients with ≥ 50% reduction in seizures (median seizure reduction numbers are very close):

3 months	40.4%	vs. 14.5% in placebo
13 months	43%	(n=99)
25 months	54%	(n=81)
37 months	67%	(n=42)
5 years	68%	
7 years	74%	(18% experienced at least one 6-month seizure-free period, 7% were seizure-free for the preceding 2 years)

- in real life may expect better results than in SANTE, as SANTE investigators did not know the exact target location.



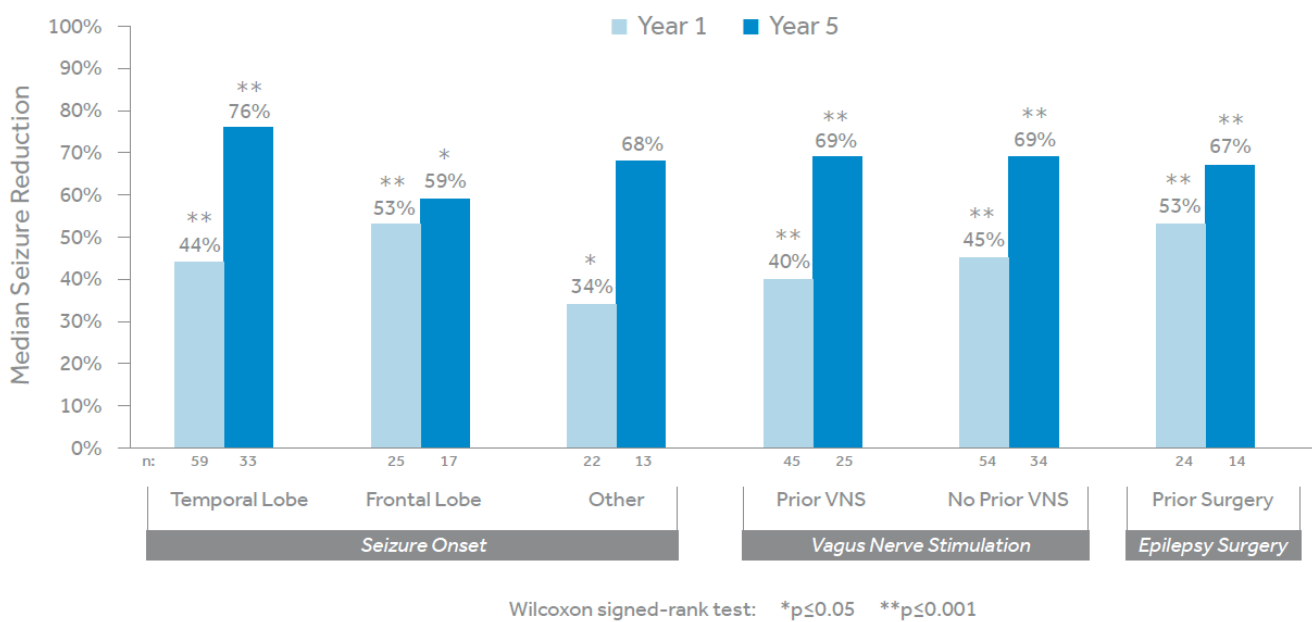
Seizure reduction for those subjects who had at least 70 days of diary in the 3 months before each annual visit.



Subject total seizure frequency percent change from baseline to most recent 3 months of follow-up.

- statistically significant reduction in seizure frequency only in **temporal epilepsies** - 44.2%, (vs. controls - 21.8%).
- complex partial seizures** were significantly reduced compared to simple partial and partial to generalized seizures.
- patients previously implanted with a **VNS device*** or who underwent **resective surgery** prior to DBS had outcomes that were not different from previously nonoperated patients.
*for SANTE trial, patients had VNS explanted because VNS was ineffective

Median seizure reduction for various subgroups.



- side effects – see above >>
- analysis revealed **placement outside the ANT in 8.2%** of electrodes (vs. 3.6% in DBS for movement disorders).
- of note, **one outlier subject in the trial whose seizures dramatically worsened** (210 seizures in 3 days compared to their baseline seizure rate of 19 seizures per month) necessitated outlier analysis to satisfy primary endpoints and played a role in delaying FDA approval for years, until long-term data demonstrated clearer benefit.

MEDTRONIC REGISTRY FOR EPILEPSY (MORE)

>>

- multicenter international registry conducted since October 2011 in 13 countries and using an open label observational study design to evaluate the long-term effectiveness, safety, and performance of ANT-DBS .

EPAS

- FDA-mandated postapproval DBS trial

EPAS Study Overview: Study Design, Geography, Enrollment, Duration

Global, interventional, prospective, multicenter open-label, post-market study

- 25 investigational centers in the US and Europe (sites currently selected)
- Enrollment of 216 patients to implant 140 subjects to obtain 112 subjects with follow-up data at 3 years
- Inclusion and exclusion criteria similar to SANTE
- 3-Month prospective baseline for CMM Phase
- Neuroimaging collected pre/post implant
- Setting DBS programming parameters based on standard of care
- AEDs tracked and can be changed anytime during the study
- The follow-up for subjects who meet implant criteria for the DBS for Epilepsy System is 3 years and 4 months
- For subjects who do not meet the implant criteria is 3 months, or less in the case of subjects who enroll with pre-existing diary data
- Total study duration for each subject is 3 years and 4 months (39 months)
- Overall duration for the study is approximately 10 years

CENTROMEDIAN NUCLEUS OF THALAMUS (CMT, CMN)

Read:

Seizure outcome during bilateral, continuous, thalamic centromedian nuclei deep brain stimulation in patients with generalized epilepsy: a prospective, open-label study

Arthur Cukiert*, Cristine Mella Cukiert, Jose Augusto Burattini, Pedro Paulo Mariani

- Cukiert et al. Seizure 18 (2009) 588–592
- Son et al. 2016

ANATOMY

- CMN is largest of the intralaminar nuclei - spheroid-shaped nucleus approximately 10 mm in diameter.
- CMN is in **posterior group of the intralaminar nuclei** of the thalamus (together with parafascicular (PF) and central lateral (CL) nuclei).
- CM has sparse neuronal cell density of ~ 2200/mm³ (vs. mediodorsal, PF and pulvinar nuclei ~ 3200–5000/mm³)

CONNECTIONS

N.B. CMT has much more widespread connections than ANT (ANT - “only” Papez).

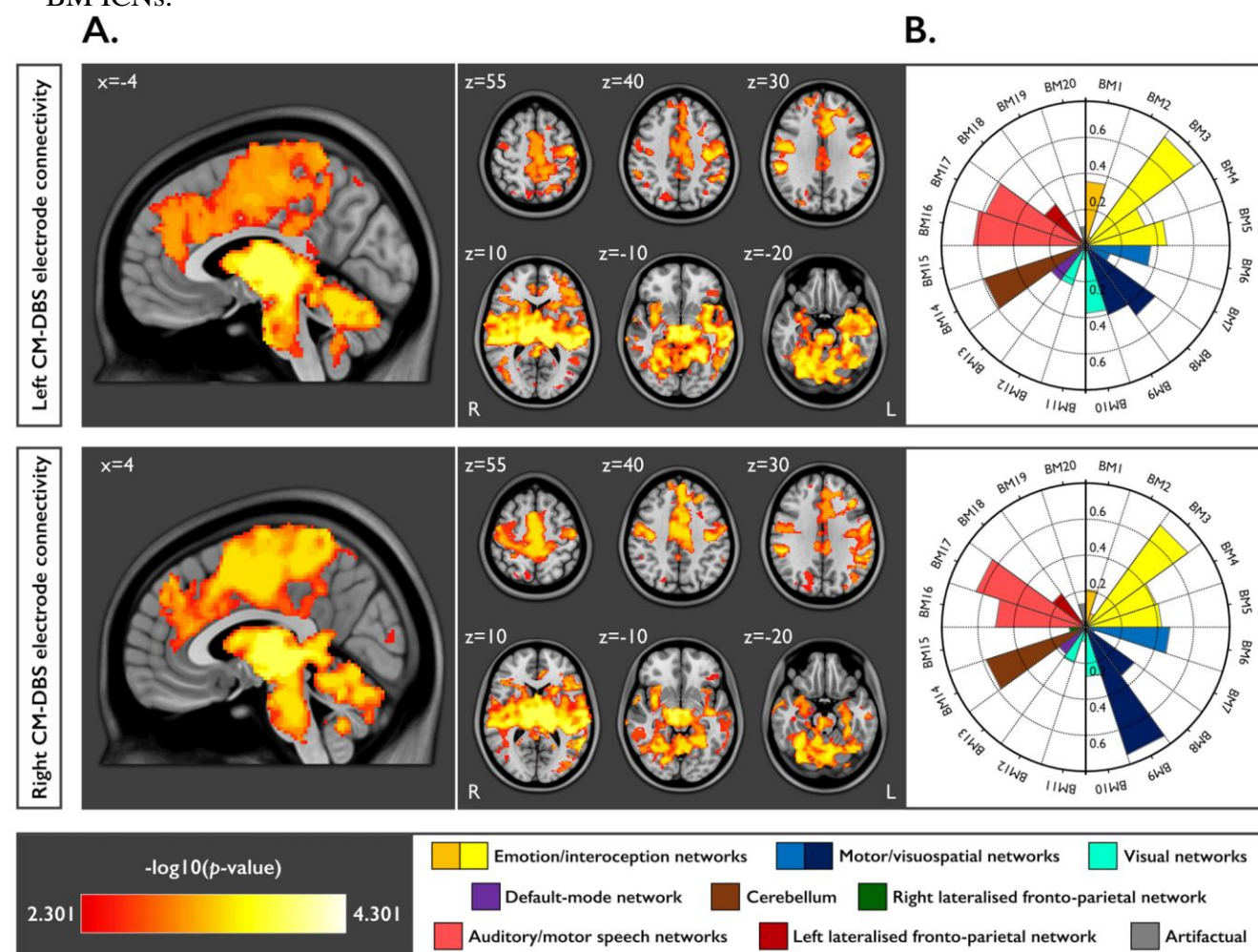
- motor cortex provides input to the CMT, as do the globus pallidus interna (GPi).
- CMT projects back to the motor cortex as well as the striatum with particular preference for the putamen and the head of the caudate nucleus proximal to the internal capsule.
- CM’s connectivity is theorized to play a key role in a range of arousal, cognitive and sensorimotor processes.

fmRI resting-state - functional connectivity calculated from positions of implanted DBS electrode contacts within the centromedian nucleus (CM):

(A) Sagittal and axial brain maps showing areas of significant positive mean functional connectivity strength ($p < 0.005$, corrected for family-wise error after threshold-free cluster enhancement) 19 calculated separately for the left (upper row) and right (lower row) DBS electrode contacts within the CM from 16 patients. Connectivity maps are coloured using a $-\log_{10}$ transformation of voxel-wise p values. The x and z coordinates indicate axial and sagittal voxel positions (mm) in Montreal Neurological Institute 152 2009b template space, respectively.

(B) Polar plots quantifying spatial similarity between the connectivity maps in (A) and each of 20 intrinsic connectivity networks (ICNs) derived from the ‘BrainMap’ (BM) meta-analytic database of >1800 prior task-related neuroimaging studies. Spatial similarity is expressed as a value ranging from 0 to 1 (larger wedges in the plot indicate high similarity with the BM ICN; smaller wedges indicate low similarity). Each wedge is coloured according to the hypothesised functional role(s) of the BM ICN, as indicated by the figure legend in the lower right.

Interpretation: connectivity from CM-DBS electrode positions is maximal with BM ICNs that normally support **emotional/interoceptive, motor/visuospatial, cerebellar and auditory/motor speech processing**; in contrast, connectivity is less apparent with **frontoparietal, default mode and visual** BM ICNs.



Source of pictures: Aaron E L Warren et al. 2020 >>

INDICATIONS

- majority of available data support the use of CMT DBS for the treatment of **generalized epilepsy**, including from Lennox-Gastaut syndrome.
- current data is only from level III-IV studies.

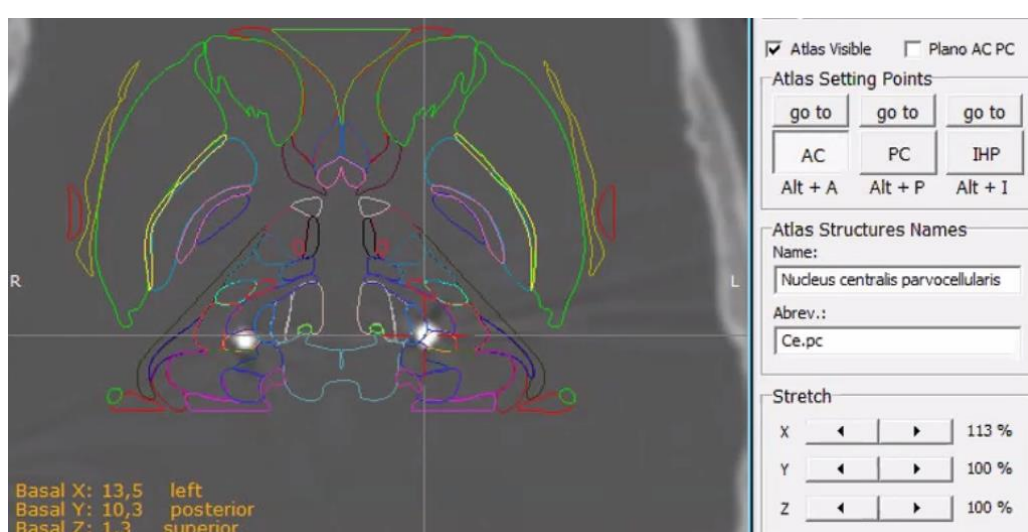
TARGETING

INDIRECT TARGETING

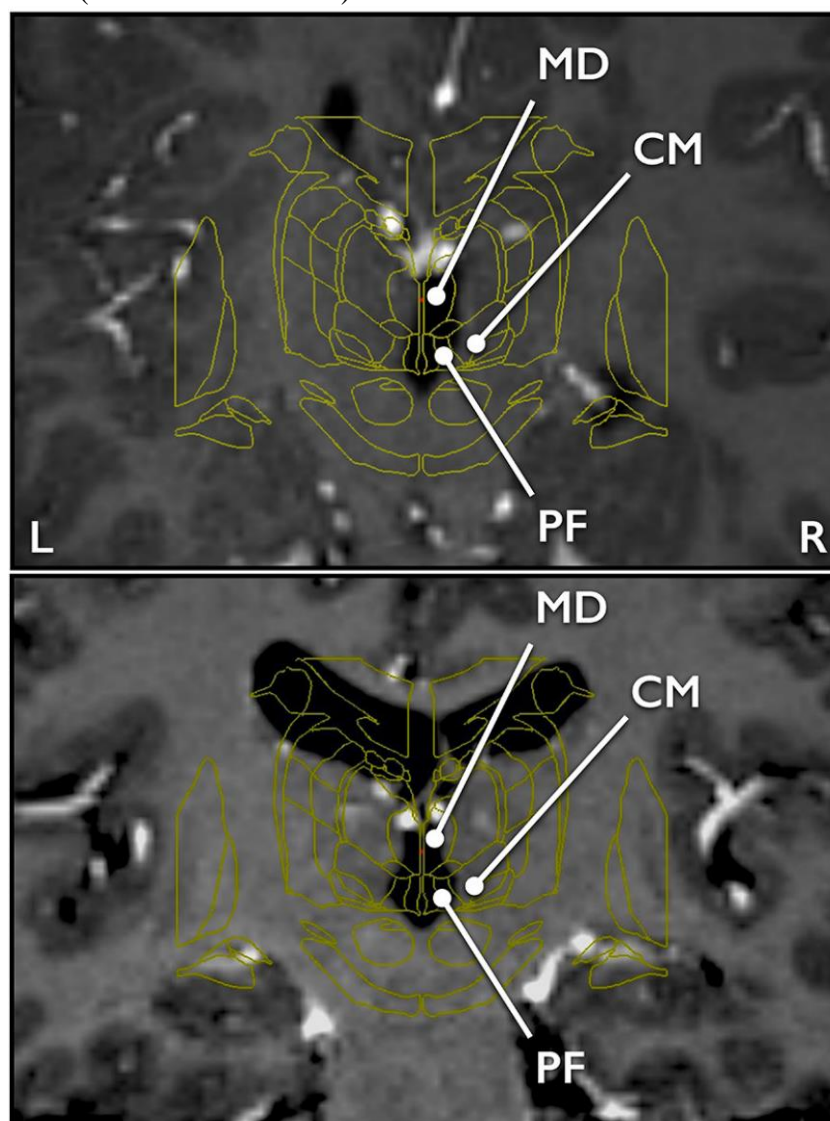
10 mm lateral to **PC**
 3 mm superior to **PC**
 ~ 6 mm anterior to **PC**

Warren et al 2020 case series:

8.1 mm lateral (range 6.7–10.6) to **midcommissural point**
 9.8 mm posterior (range 2.4–12.6) to **midcommissural point**
 1.1 mm superior (range -4–2.9) to **midcommissural point**



Examples of coronal images and **Schaltenbrand and Wahren atlas** – 2 different patients with structural brain abnormalities due to malformations of cortical development – shows **potential inaccuracies** (some nuclei in CSF):



Source of pictures: Aaron E L Warren et al. 2020 >>

DIRECT TARGETING

IMAGING

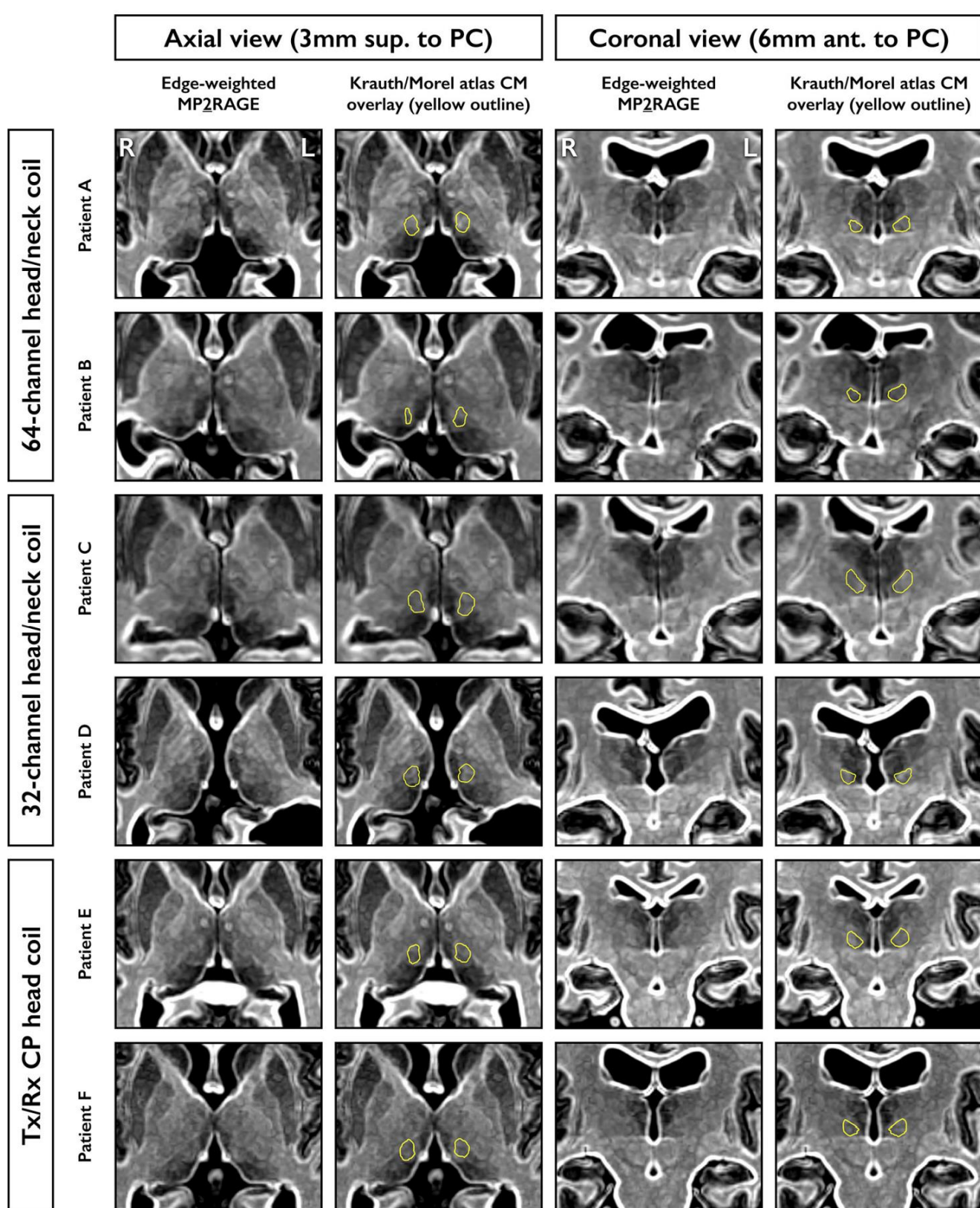
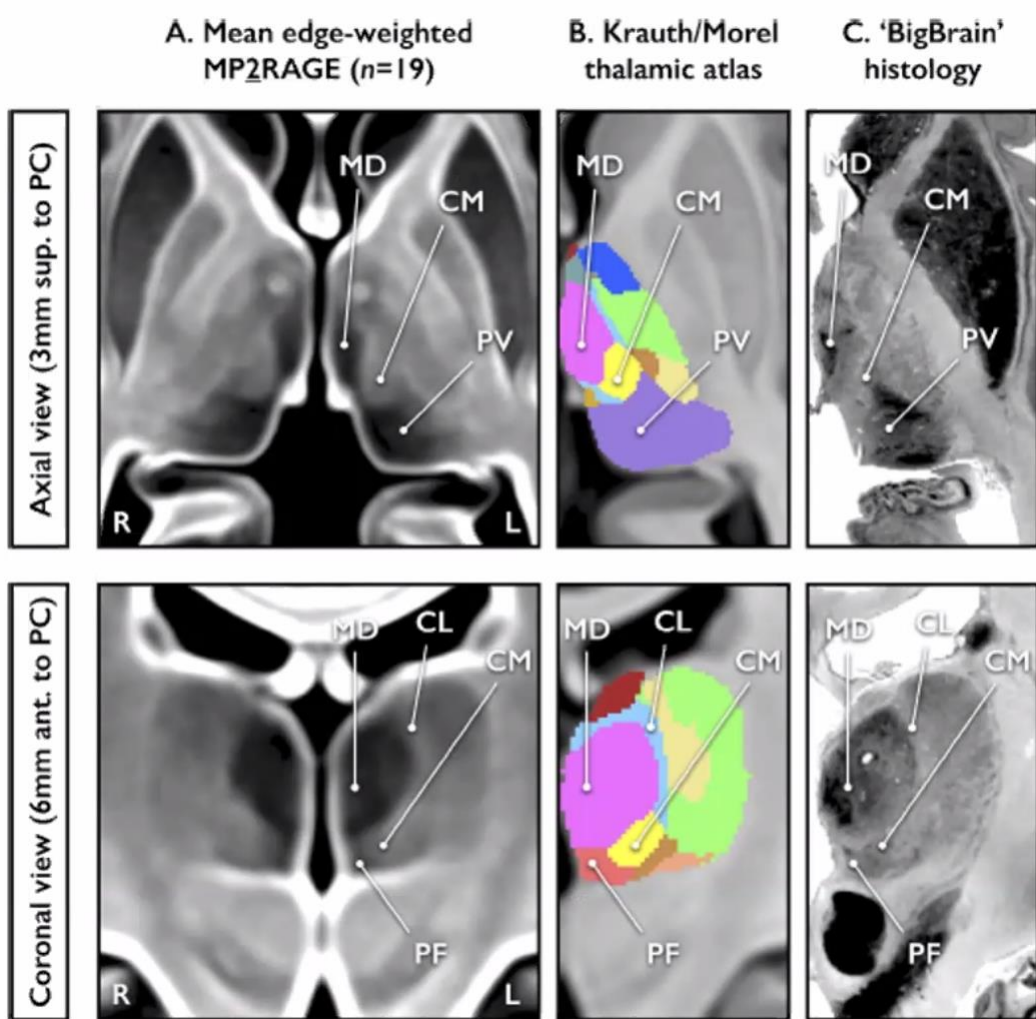
- CMT **cannot be seen even on 7T MRI** (vs. ANT).
- A. **Magnetization-prepared 2 rapid acquisition gradient echoes (MP2RAGE)** sequence; MP2RAGE differs from MPRAGE by acquiring two volumes with different inversion times that are combined into a unified volume that shows improved grey/white matter image contrast.
- edge-detection method (Sobel operator)** can highlight intrathalamic borders visible on MP2RAGE.
 - Sobel operator computes the gradient magnitude at each image point (ie, change in signal intensity from one voxel to the next), where areas of high gradient indicate likely 'edges'.
 - voxel intensities within each of the MP2RAGE and Sobel-processed images are converted to z-scores, and then a novel 'edge-weighted MP2RAGE' image is calculated by summing together the two z-score images: this weighted each MP2RAGE voxel by its likelihood of indicating a border between areas of differing signal intensity (ie, border voxels became 'brighter' in the summed image, whereas non-border voxels became 'darker').
 - Warren et al. 2020 found that SWI has worse visualization than MP2RAGE.

Edge-weighted MP2RAGE following spatial warping to Montreal Neurological Institute (MNI) 152 2009b template space.

Axial (upper row), CM appears as a hyperintense region bordered medially by hypointense mediodorsal nucleus (MD) and posteriorly by hypointense pulvinar nucleus (PV).

Coronal (lower row), CM is bordered superiorly by MD and medially by hypointense parafascicular (PF) nucleus, while CM's approximate lateral extent is suggested by thin line of relative hyperintensity consistent with centrolateral nucleus (CL). It is best appreciated ~3 mm superior and ~6 mm anterior to the posterior commissure (PC)

(B and C) Atlas comparisons - location of the CM on edge-weighted MP 2 RAGE shows good correspondence with the CM's position determined by the Krauth/Morel and BigBrain thalamic atlases:

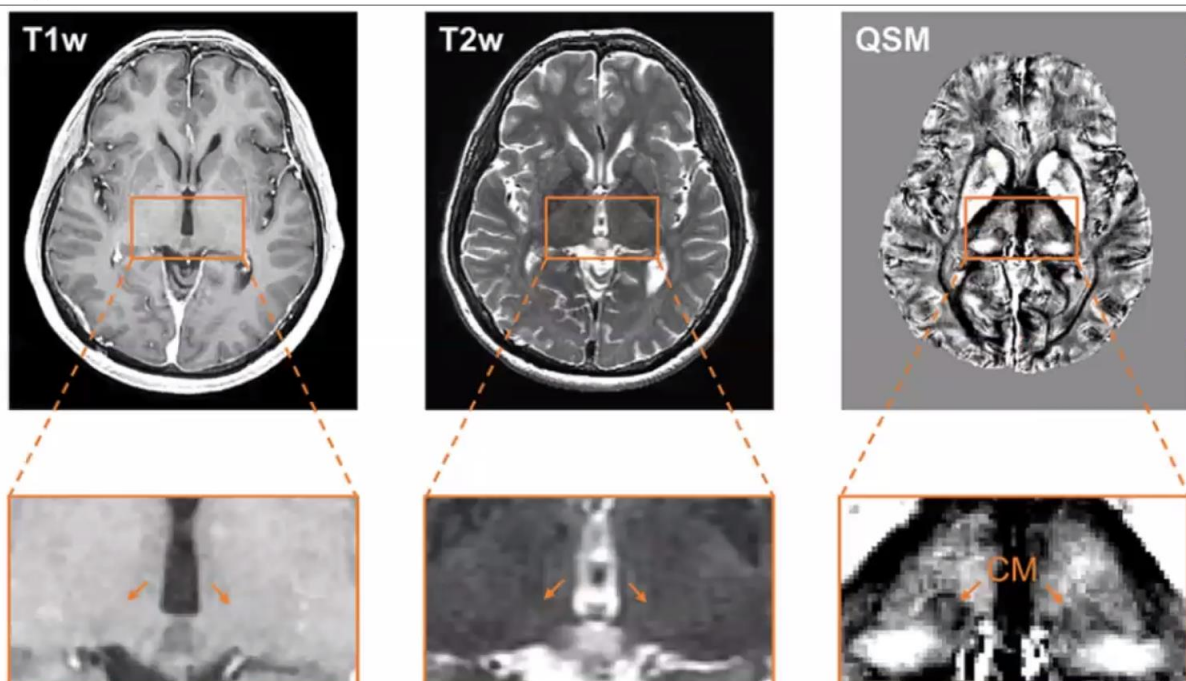


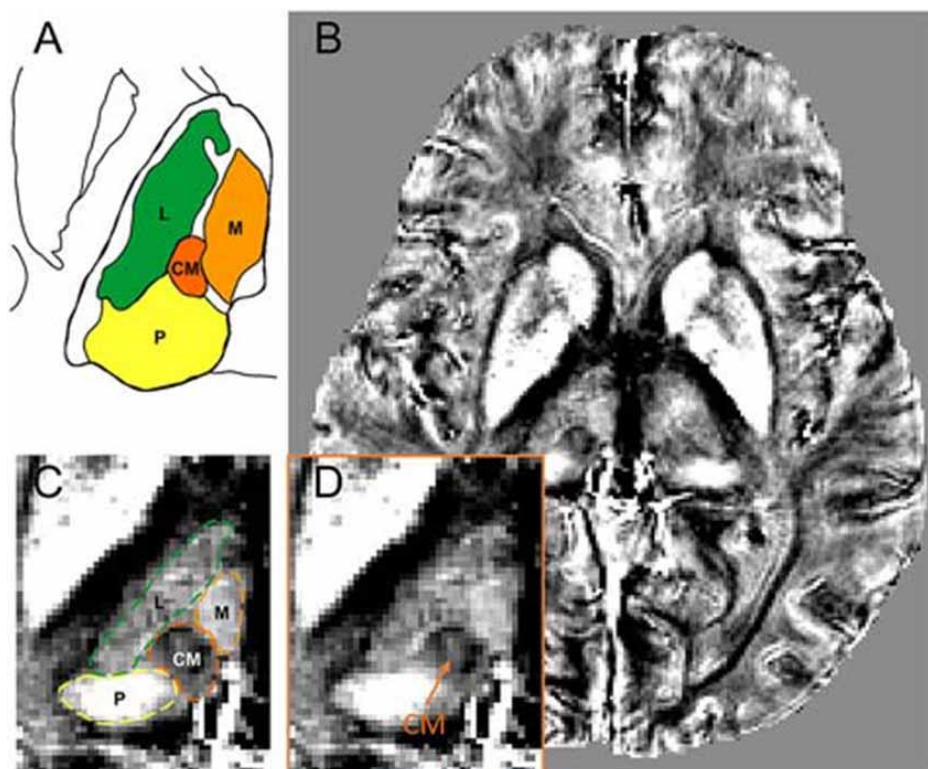
Source of pictures: Aaron E L Warren et al. 2020 >>

B. **Quantitative susceptibility mapping (QSM)** is promising.

- QSM is reconstructed from 3D gradient recalled echo (GRE)

Parameter	3D T1w	2D T2w	3D GRE
Imaging plane	Axial	Axial	Axial
Field of vision (mm)	240 × 240	240 × 240	240 × 240
Matrix	320 × 320	320 × 320	320 × 320
Resolution (mm)	0.75 × 0.75 × 1.5	0.75 × 0.75 × 1.5	0.75 × 0.75 × 1.5
Time of repetition (ms)	7.04	3,000/4,000	32.80
Time of echo (ms)	3.47	128.60/106.03	11.00
Scan time (s)	172	346	528



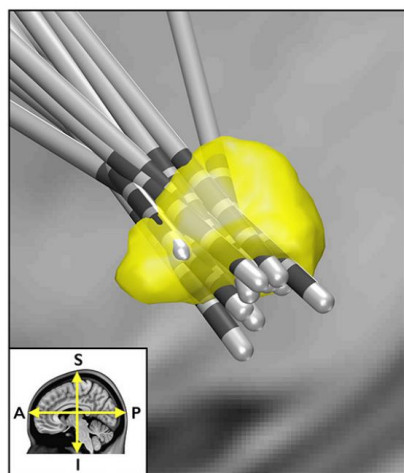


Source of pictures: Jun Li et al. 2020 >>

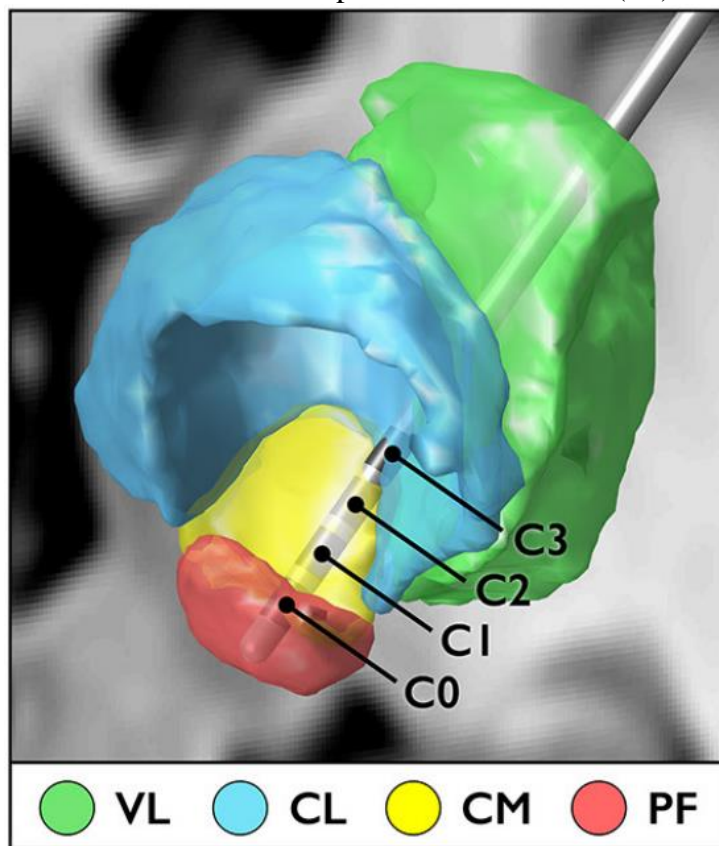
MER, STIMULATION

- **MER** cannot guide reliably;
 - Waren et al. 2020: *reduced spike firing rate and background noise* in CM (posterior intralaminar nuclei are neurophysiologically ‘quieter’ than adjacent structures during spontaneous recordings while under general anesthesia).
 - Waren et al. 2020 performed **microelectrode stimulation** at target depth (130 Hz, 60 μs) - to determine the stimulation threshold for clinical motor effects (clinically detectable movement or change in muscle tone) – internal capsule effects:
 - < 4 mA – no motor response.
 - 4–6 mA – motor response in 9.4% patients
 - 9–10 mA – motor response in 58% patients
- N.B. no target positions were adjusted as a result of these test stimulations!

TRAJECTORY



- typical trajectory enters thalamus at the level of ventrolateral nucleus (VL) and passes through centrolateral nucleus (CL).
- at least 2–3 stimulation contacts within the CM, with the most inferior contact (C0) positioned near the border between CM and parafascicular nucleus (PF).



Source of pictures: Aaron E L Warren et al. 2020 >>

PROCEDURE

- placed under general anesthesia with recruiting response.
- if electrode is too lateral → sensory side effects (paresthesias)
- if electrode is too deep (pretectal area) → upward gaze deviation.

PROGRAMMING

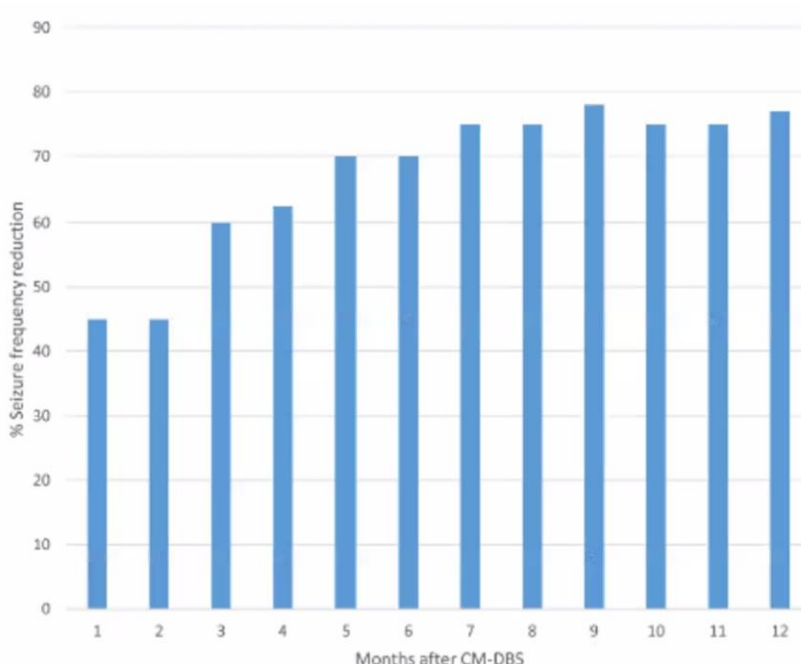
Dr. A. Cukiert:

- 130 Hz, 300μsec, bipolar (0-3 & 4-7).
- Upper limit: ~ 5V
- 0.5V increment every week.
- Common complain at higher intensity: paresthesias (last minutes-hours).

OUTCOMES

- response rates from **0%** (Andrade et al. Neurology 2006;66:1571–1573) to **100%** (Cukiert et al. Seizure 18 (2009) 588–592)

- Son et al. 2016: **79% response rate** (11 of 14 patients), with a mean seizure frequency reduction of 68%; they did not find any correlation between lead positioning and the magnitude of seizure reduction on regression analysis.
- Cukiert et al. 2020:



- best responders more anterior and lateral in CM, concentrated in parvocellular portion.
- less effective in focal epilepsies although it did help with secondary generalization.
- causes no change in neuropsychological tests; benefit - improved attention.

Study	Velasco et al	Cukiert et al	Andrade et al	ESTEL trial (Dalic et al)
N	13	4 pts s/p CC	2	20
Pathology	LGS	IGE 2 LGS 2	SGE 1 Multifocal 1	LGS
Targeting	Recruiting response	Recruiting response		
Stim parameters	130 Hz, 450 μ s, 2-3 v	130 Hz, 300 μ s, 2v	100-185 Hz, 90-120 μ s, 1-10v	
Outcome	Sz free 2 87-95% 6 50-80% 3 < 50% 1	100% RR Av 78%	Initially worsened, no clear diff in on and off	Median seizure reduction 46.7% (interquartile range [IQR] = 28-67%) for diary-recorded seizures and 53.8% (IQR = 27-73%) for electrographic seizures
Neuropsych outcome	Improvement related to Sz Outcome	Improved alertness (SNAP IV)	N/A	
Comments	Anterolateral nucleus in parvocellular best response	Improvement in alertness at 0.5 V, sz control at 1.5 V		

PULVINAR

- pulvinar is the most posterior nucleus of the thalamus.
- subnuclei project extensively to vast areas of cortex:
 - mesial temporal (medial pulvinar, PuM)
 - visual-processing parietal regions (lateral pulvinar)
- some studies have suggested that seizures arising from the lateral temporal lobe more rarely interact with PuM directly; rather, PuM may be involved in the propagation of seizures between mesial and lateral temporal cortices. vs. others have suggested that preferential pathways interconnect PuM with various cortices including the temporal neocortex, TP junction, and insulo-opercular region.

HIPPOCAMPUS

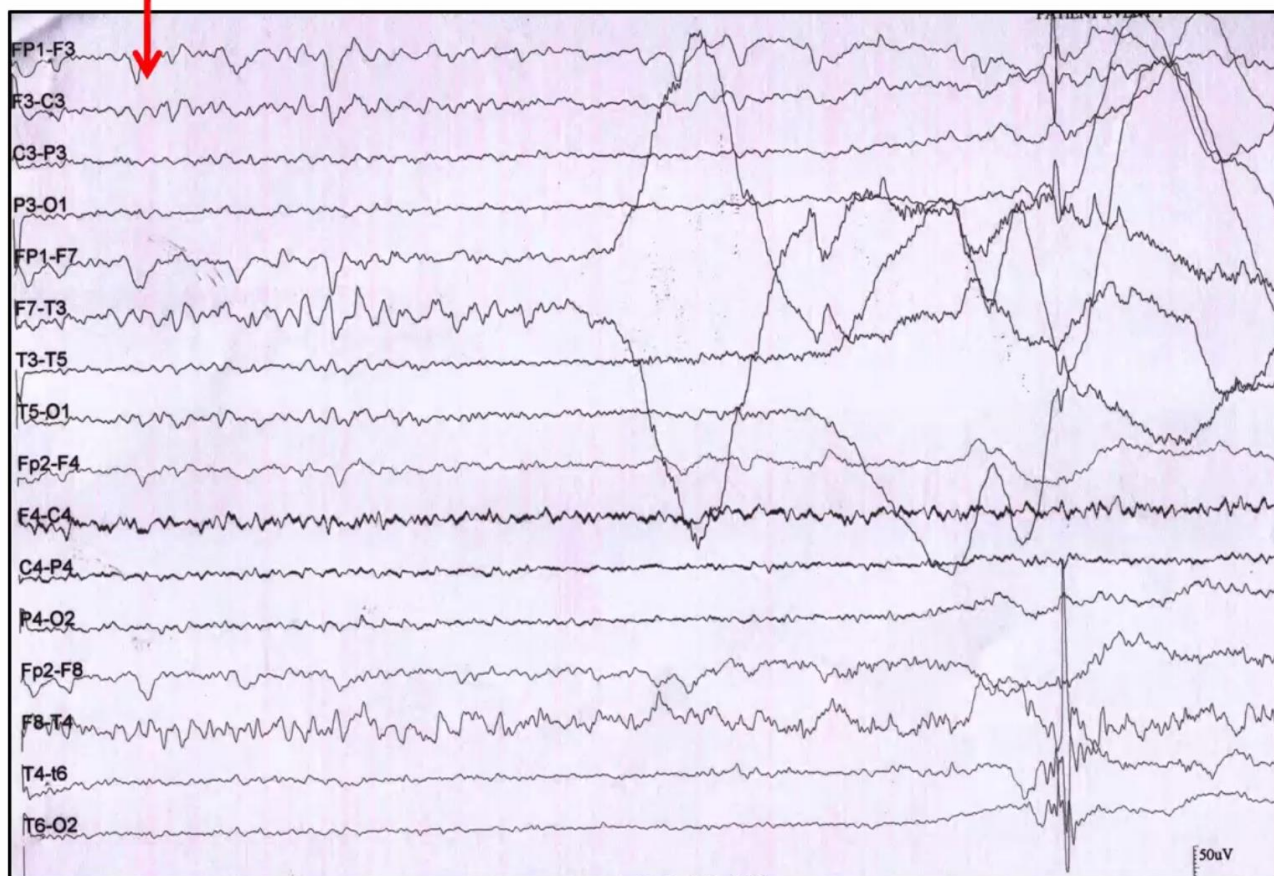
- patients selected from population undergoing invasive electrodes: diagnostic electrodes replaced with stimulation electrodes at site of seizure focus.
- need Medtronic 3391 lead with longer distance between contacts (approved for OCD indication) or Boston Scientific DBS lead.
- 60-100% response rates (some become seizure free!) – some experts believe that DBS is better than RNS (so far DBS is not FDA approved for hippo).
- causes no change in neuropsychological tests.

Programming

Dr. A. Cukiert

- 130 Hz, 300 μ sec, bipolar (0-3 & 4-7).
- Upper limit: ~ 4.0 V
- 0.5V increment every week.
- Common complain at higher intensity: none.

DBS is able to trigger patients typical seizures



Outcomes

Study	n	Randomization	Stim Param	Seizure Outcome	Neuro-psych	Comment
Velasco et al Epilepsia '07	9	Immediate on vs 1 mo delay	130 Hz 450 us cyclic	100% RR 4/9 sz free	No decline	Absence of MS on MRI predicts success
Boon et al Epilepsia '07	10	no	130 Hz 450 us cont	70% RR 1/10 sz free (+MS)	No decline	Pts selected based on dec in spikes with stim
Telez-Zellento et al Neurol '06	4	Alternating 1 mo blocks over 6 mo	190 Hz 90 us cont	25% RR ¼ sz free	No decline	Design of randomiz not optimal

Cukiert et al (2017) - the results of a prospective, double-blind, randomized controlled trial evaluating the efficacy of unilateral and bilateral HCP DBS in 16 patients with refractory TLE:

- 2 months after surgery, all patients were randomized to stimulation on or off for a 6-month blinded period.
- of the 8 patients randomized to the on-stimulation group, 4 became seizure free and 7 were defined as responders, whereas 1 patient did not respond to DBS therapy.
- the experimental group experienced significantly fewer simple partial and complex partial seizures than the control group throughout the blinded period.

Vonck et al. - 11 patients who underwent bilateral HCP DBS electrode implantation, with stimulation laterality applied based on seizure localization.

- after 2.5–3 years of follow-up, patients who were initially started on unilateral stimulation were converted to bilateral stimulation if seizure reduction of > 90% had not been achieved.
- at final follow-up, and after switching to bilateral stimulation as necessary, 6 patients achieved ≥ 90% seizure reduction, 3 patients achieved seizure reduction rates ranging from 40% to 70%, and 2 patients achieved < 30% seizure reduction.
- switching from unilateral to bilateral stimulation further improved seizure outcomes in 3 of 5 patients with unilateral ictal onset.
- implementing day-night cycling after attaining treatment stability did not affect seizure control.
- no changes in neuropsychological testing were noted after DBS therapy.

STN

Author	N	Localization of epilepsy	Outcome
Benabid/Chabardes 2002	3	sensory motor cortex	67-87%
	2		< 50%
	1		0
Shon (Seoul) <i>Stereotact Funct Neurosurg</i> 2005;83:84–90	2	FLE s/p failed resection	87-89%
Handforth (UCLA) <i>Epilepsia</i> 47(7):1239–1241, 2006	1	Bitemporal epilepsy	50%
	1	Frontal encephalomalacia	33%
Neme (Santiago)	1		> 50%
	3		< 50%

CEREBELLUM

- while the cerebellum (hemispheres) has the longest history in DBS for the treatment of epilepsy, results have been mixed. Therefore, stimulation of the cerebellum has fallen out of favor.

NUCL. ACCUMBENS

POSTERIOR HYPOTHALAMUS

Viktor's NotesSM for the Neurosurgery Resident
Please visit website at www.NeurosurgeryResident.net