FUNCTIONAL NEUROSURGERY

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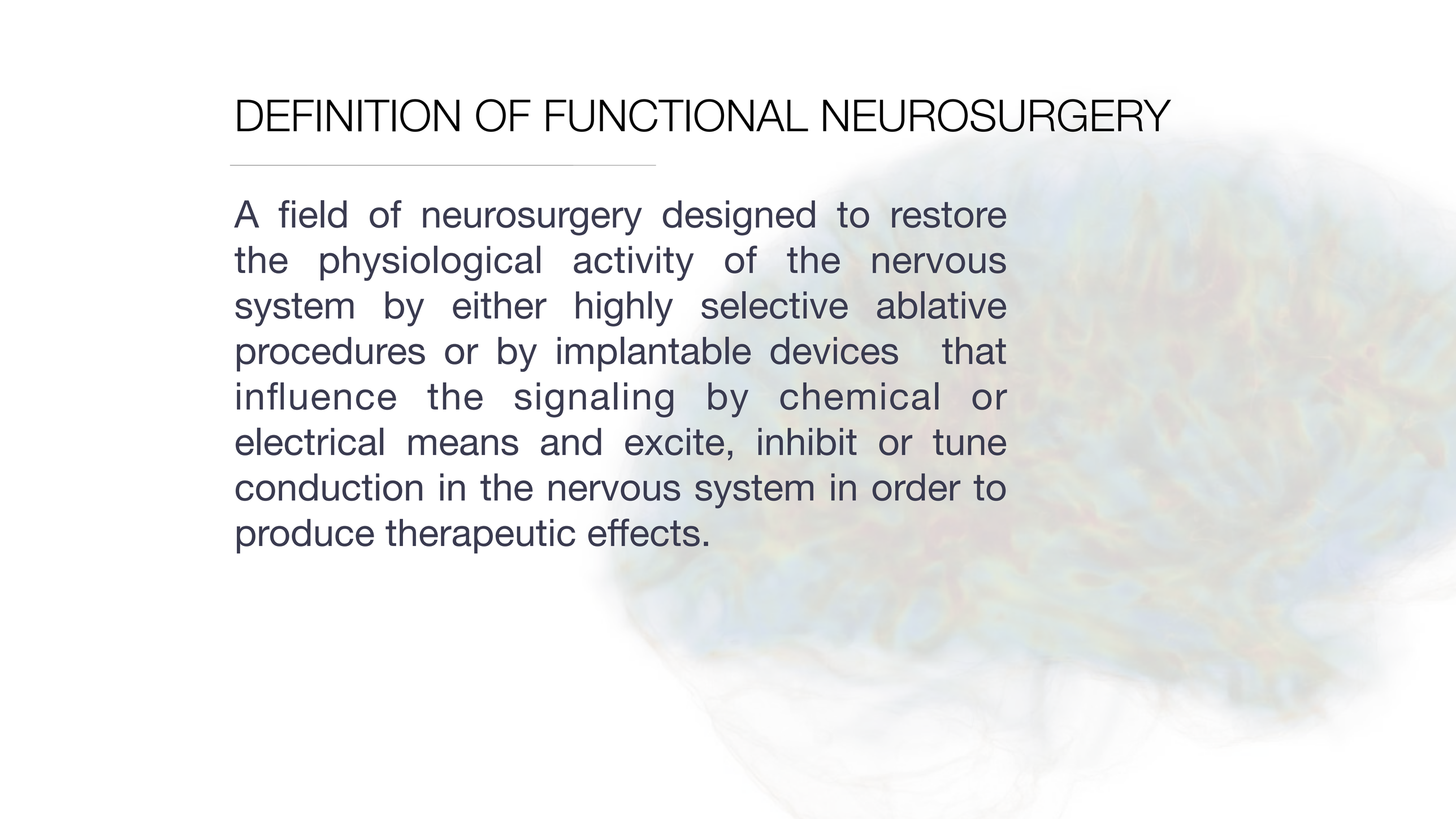
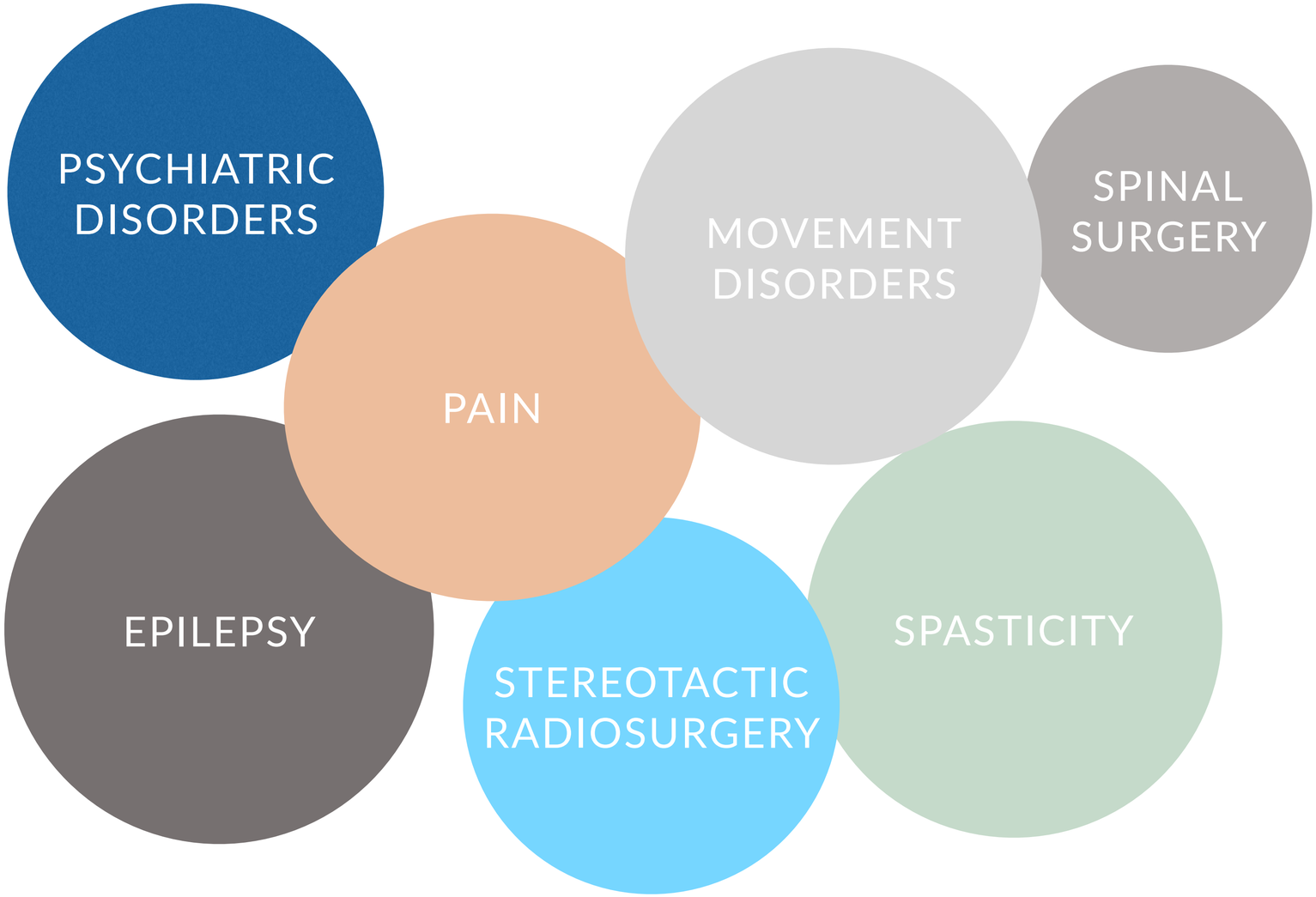
DEFINITION OF FUNCTIONAL NEUROSURGERY

A field of neurosurgery designed to restore the physiological activity of the nervous system by either highly selective ablative procedures or by implantable devices that influence the signaling by chemical or electrical means and excite, inhibit or tune conduction in the nervous system in order to produce therapeutic effects.

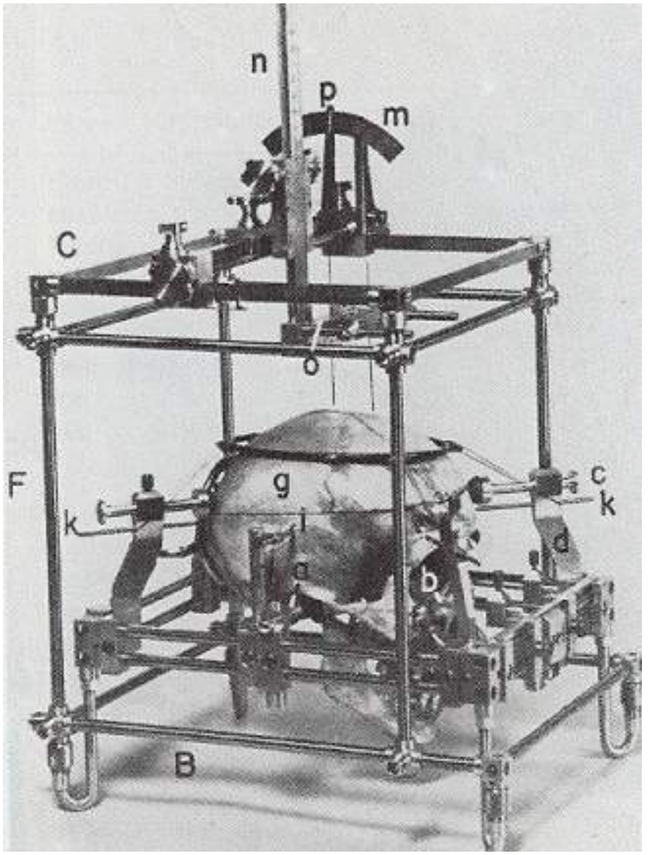


FUNCTIONAL NEUROSURGRY



HISTORY OF FUNCTIONAL NEUROSURGERY

- 1907 Horsley, Clarke stereoencephalotom
- 1947 Speigel és Wycis human stereotactic surgery
- 1950 Spiegel, pallidotomy, Huntington
- 1952 Cooper ant. choroid. art. Ligation in PD, GP infarct
- 1952 Hassler, Riechert VL thalamotomy
- 1953 Mérei , Pécs – Hulay, Debrecen
- 1960 Szabolcs Tóth, Budapest
- 1964 microrecording in deep brain surgery
- 1968 introduction of levodopa
- 1970’s Lindvall fetal dopamine (adrenal medulla graft) implantation into the striatum
- 1980’s pallidotomy for levodopa dyskinesia, complikation (bilateral lesion)
- 1980 Brice és McLellan SM thalamic stimulator
- 1993 Benabid subthalamic nucleus (STN) stimulation



NEUROMODULATION

- Neurostimulation PNS, GGS, DBS, SCS, MCS
- Intrathecal chemical neuromodulation (pumps)
- Pulse radiofrequency procedures
- Neurovascular decompression
- Introduce the advanced functional neurosurgical practice for pain

ABLATIVE, PALLIATIVE

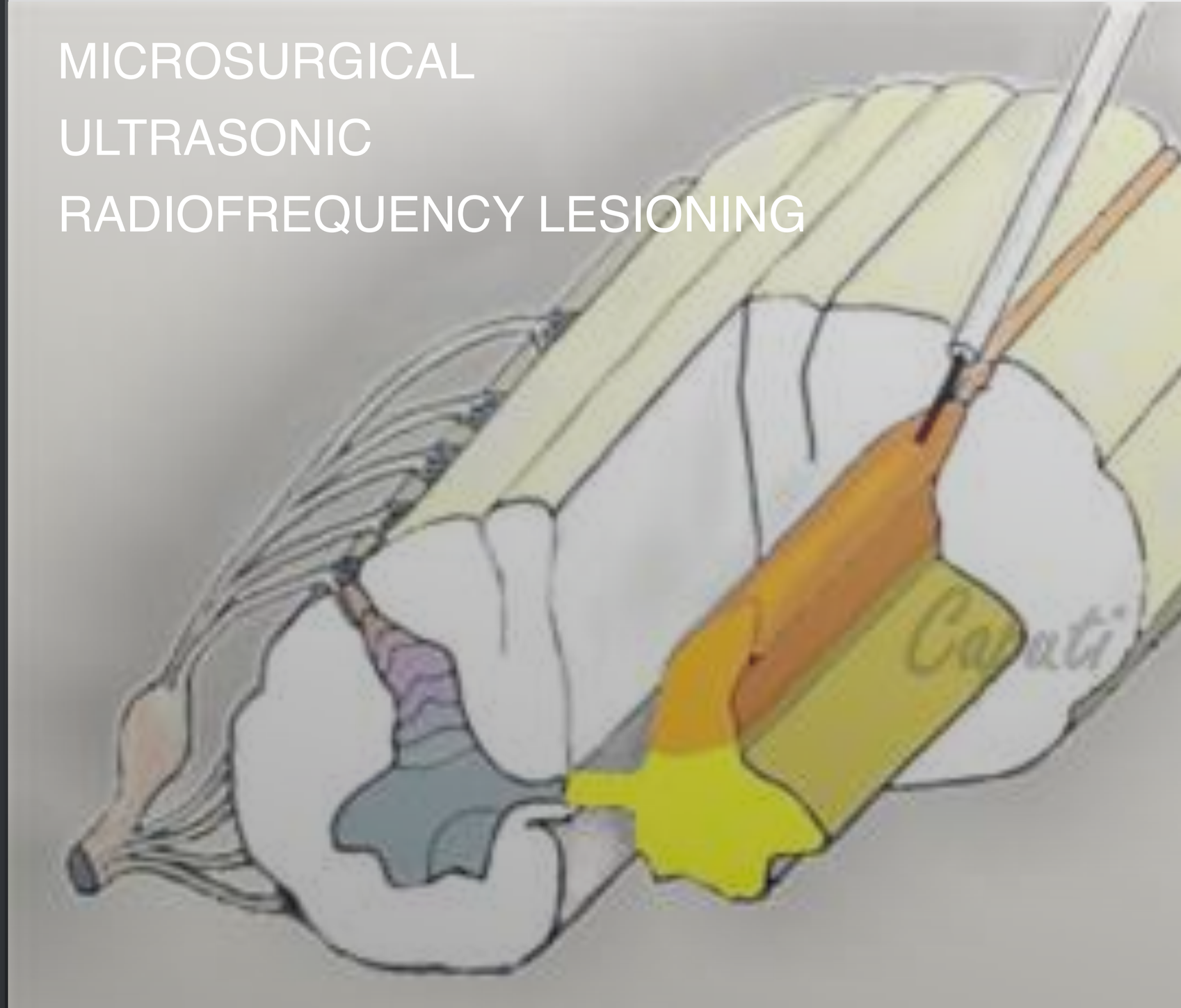
- Neurectomy/neurolysis
- Ganglionectomy/Rhizotomy
- DREZ
- Sympatectomy
- Cordotomy/myelotomy
- Mesencephalotomy
- Nc.Caudalis DREZ, Trigeminal tractotomy/nucleotomy
- Medial thalamotomy
- Cingulotomy
- Percutan RF/chemical/balloon compression for trigeminal neuralgia
- Gamma-knife radiosurgery?

DORSAL ROOT ENTRY ZONE LESION

MICROSURGICAL

ULTRASONIC

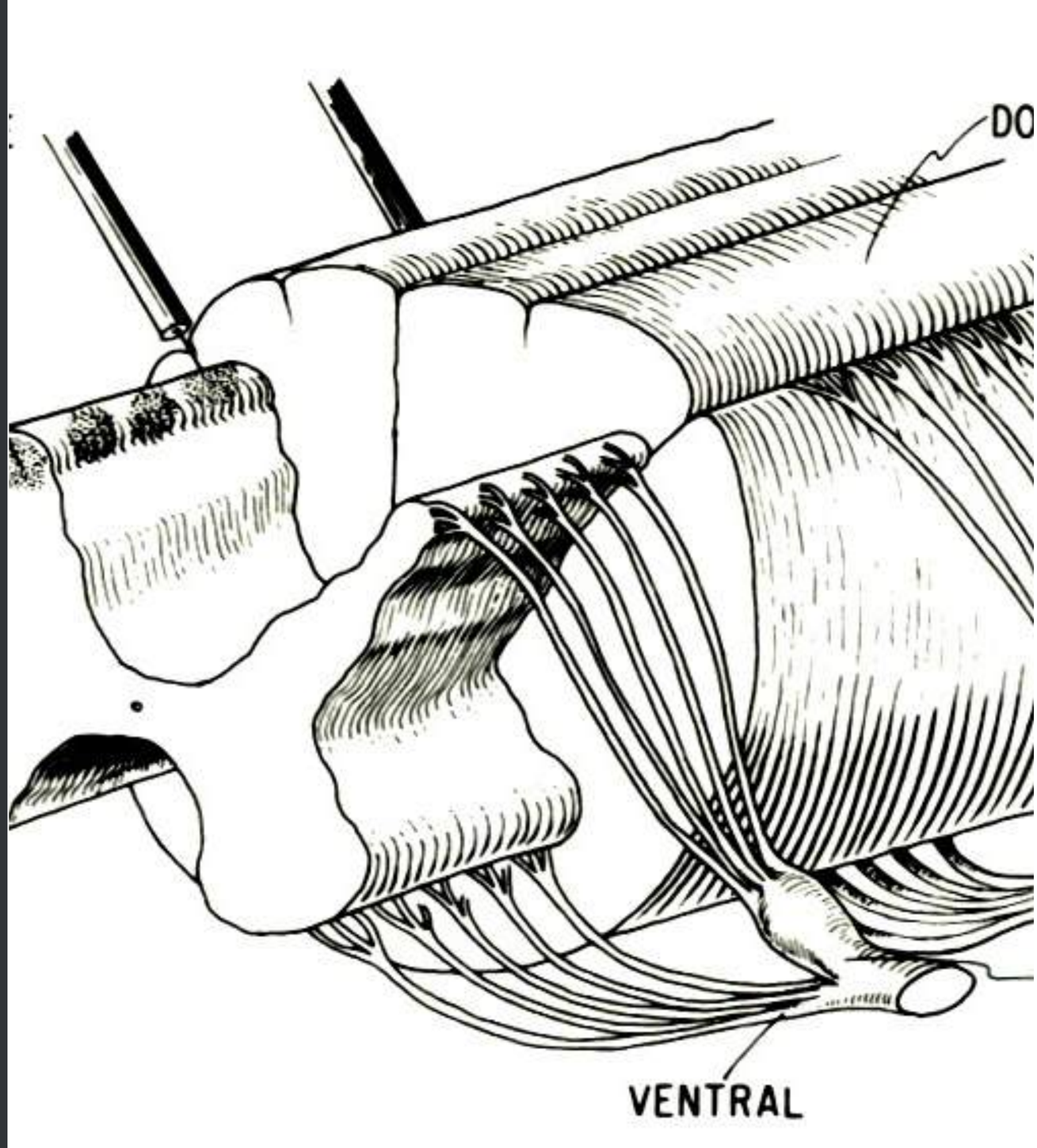
RADIOFREQUENCY LESIONING



MICROSURGICAL DREZOTOMY

Indications:

- Cancer pain limited in extent (Pancoast tumor)
- Unresectable intrinsic benign tumors of periferal nerves
- Persistent neuropathic pain due to brachial plexus avulsion
- Spinal cord lesion/trauma (segmental pain)
- Periferial nerve injuries (paroxysmal type and/or allodynia,hyperalgesia)



DREZ RESULTS

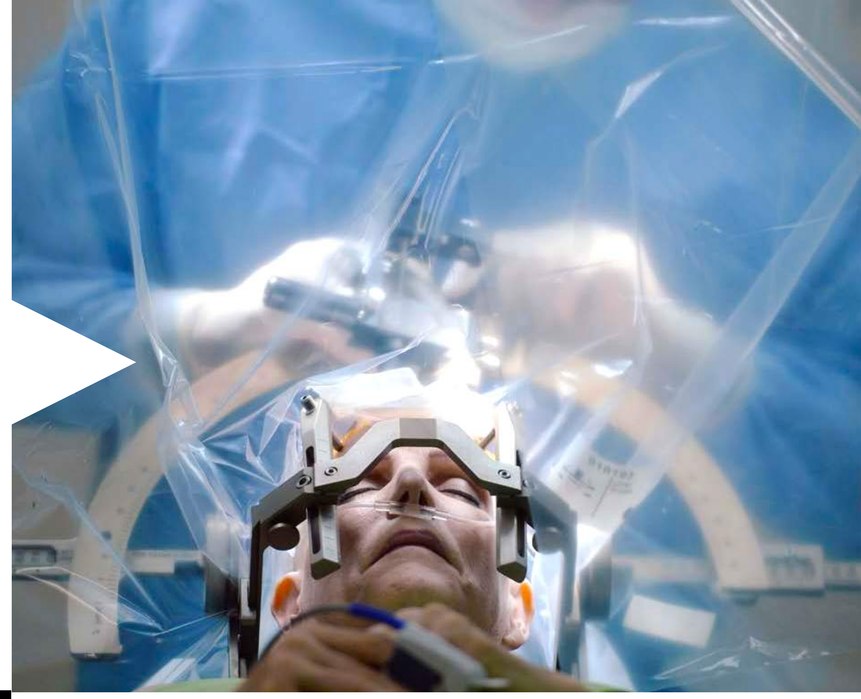
- Cancer pain cervical or C/Th level 87% (46 pts)
- Cancer pain: lumbar DREZ 78% (35pts) success
  - (survival 1mo-4years) – (Sindou)
- Brachial plexus avulsion pain:
  - Duke University 54% of 39pts. (RF)
  - Queen Square 68% of 44 pts. (RF)
  - Dreval 87% of 127 pts.(ultrasonic)
  - Sindou 79% a/d, 65%at 1y (35), 66,5% 4y (27)
- Spinal cord/cauda lesions 68% (Nashold)

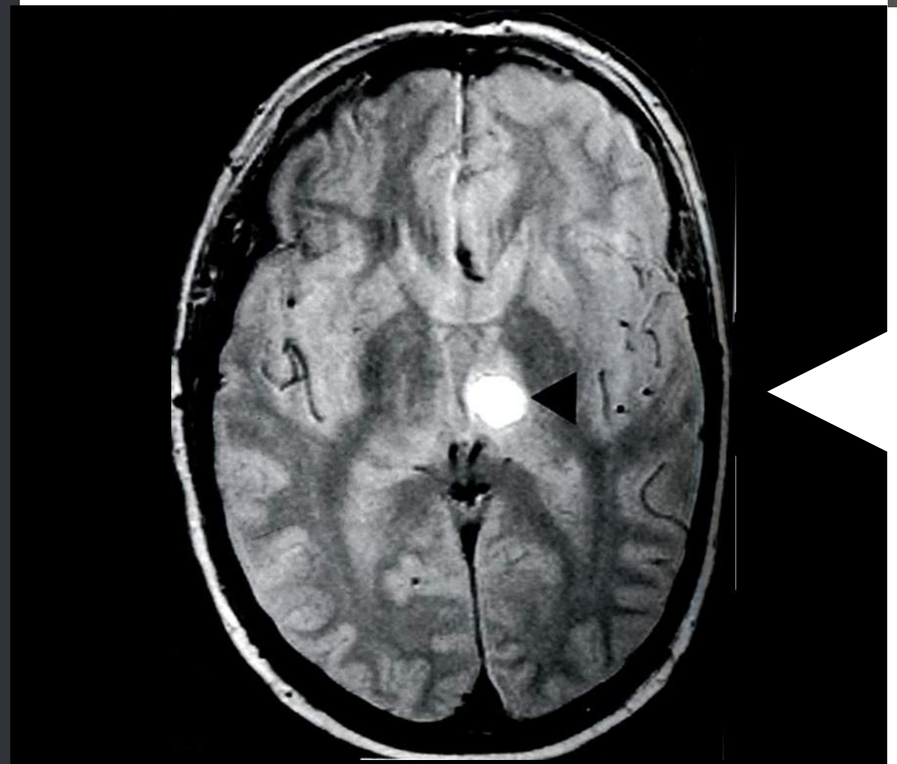
CORDOTOMY

- Aim: to interrupt the the spinothalamic tract contralateral to the painful side
- Procedure for nociceptive pain
- Cervical cordotomy: percutan
- Bilateral PC: abdominal, pelvic,lower extremity pain (upper extr.- respiartory failure!)
- Thoracic cordotomy:open
- CT guided percutan cordotomy (Kanpolat,1987)

MEDIAL THALAMOTOMY

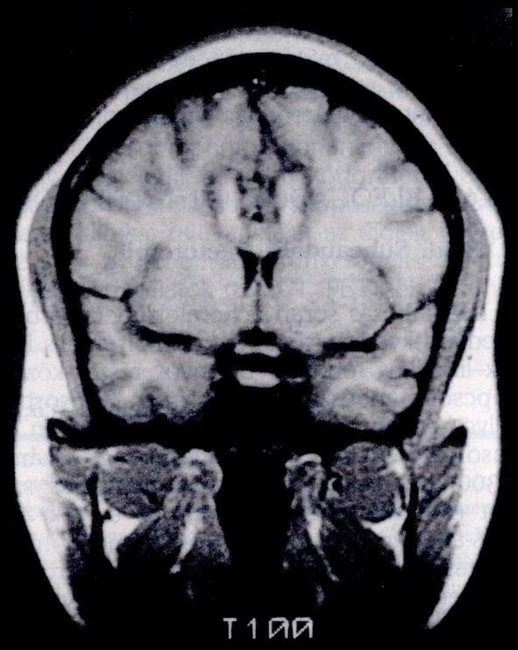
- Nociceptive > neuropathic
- Mesencephalotomy > MT
- Low risk procedure (9%)





- 70% initial pain relief Best response for: pain attacks, tactile allodynia, pins and needles and electric pain
- 30% response in continous tearing, compressive deep pain, proprioceptive allodynia

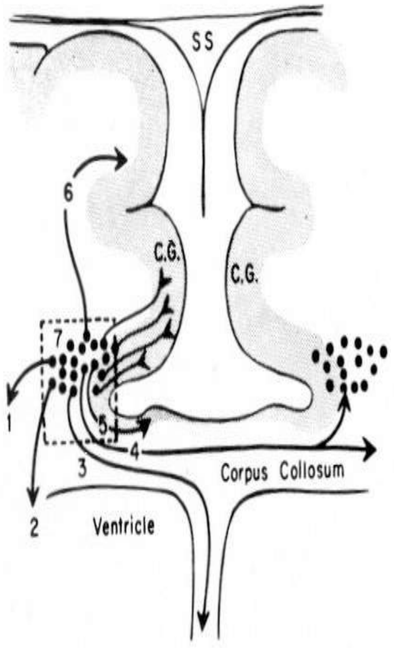
STEREOTACTIC CYNGULOTOMY FOR CHRONIC PAIN



394 patient in the literature
53% useful vs.47% non useful (Burchiel 2005)

Bortis AG et al .Historic evolution of open cingulectomy and stereotactic cingulotomy in the management of medically intractable psychiatric disorders, pain and drug addiction

Stereotacttic . And Funct Neurosurg 2009;87(5):271-91. doi: 10.1159/000226669. Epub 2009 Jul 3.



FRONTAL CINGULUM

1. Lat. subcallosal
2. Vent. subcallosal
3. Vent. callosal
4. Medial trans-callosal

5. “Medialmost”
6. Dorsal

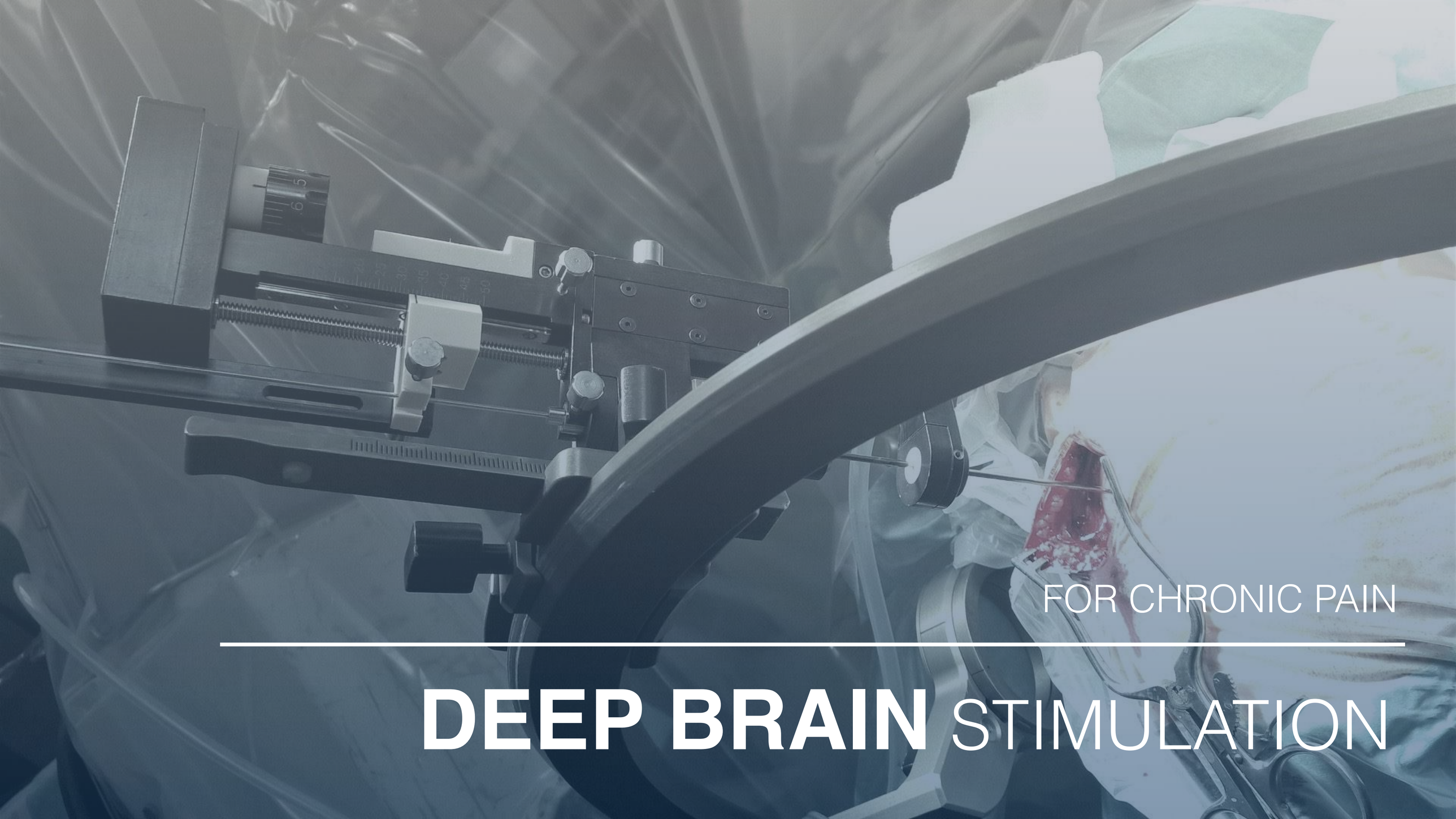
7. Cingulum

FIBER RADIATIONS:

Striatum
Ant. thalamus & striatum
Septal region
Contralat. ant. thalamus & contralat. striatum

Induseum
“Supralimbic” cortex

Uncinate fasciculus & Area 23 & 24 & Hippocampus



FOR CHRONIC PAIN

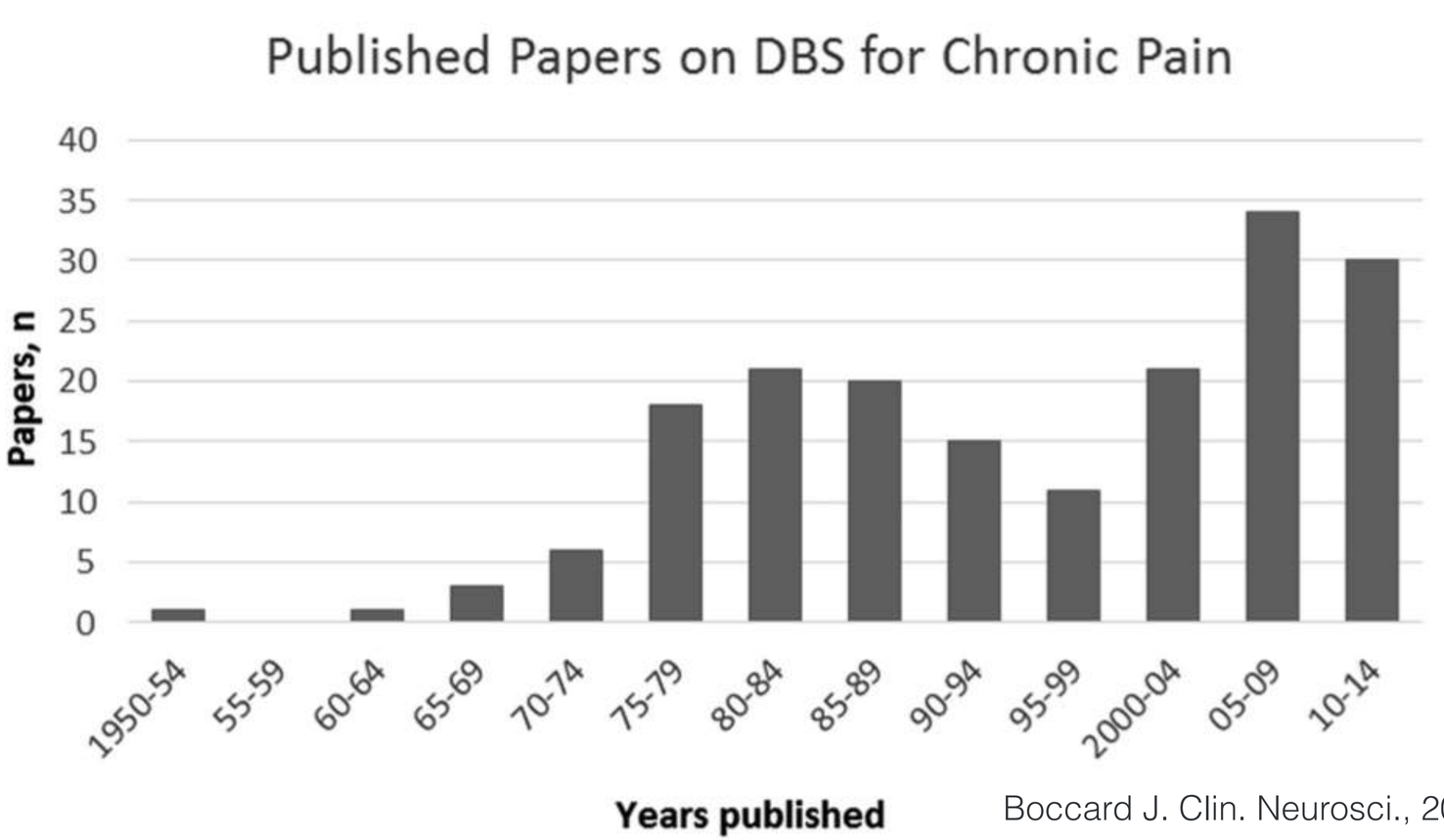
DEEP BRAIN STIMULATION

TARGETS FOR DBS

- Periventricular grey periaqueductal grey 10Hz
- Somatosensory nuclei (VPL and VPM) 132Hz
- Centromedian – parafascicular complex
- Cyngular cortex

THALAMOTOMY

- nucleus anterior
- nucleus dorsomedialis
- nucleus limitans
- primary somatosensory nuclei (VPL and VPM)
- centromedian-parafascicular complex
- nucleus centrolateralis
- periventricular grey
- pulvinar



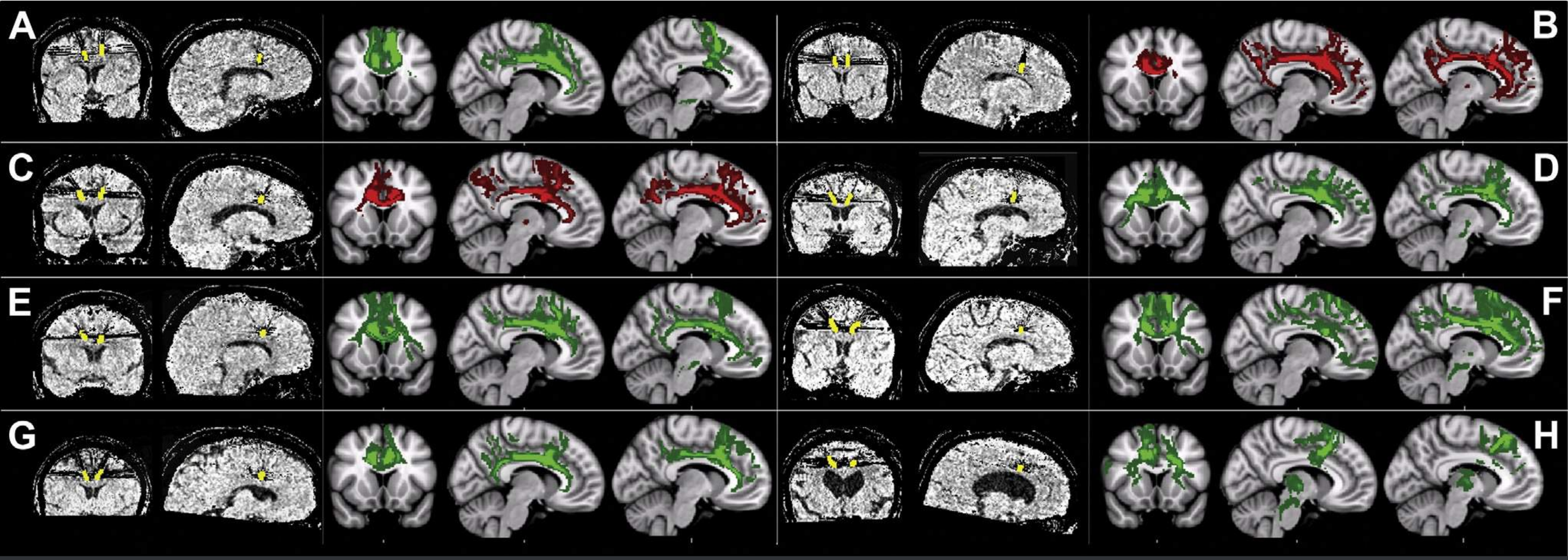
Boccard J. Clin. Neurosci., 2015

DBS FOR CHRONIC PAIN

RESULTS OF 6 STUDIES (1977-1997), LONG TERM SUCCESS

- Periventricular | Periaqueductal grey matter - 79%
- PVG | PAG + Sensory thalamus or internal capsule - 87%
- Sensory thalamus alone - 58%

Bittar J. Clin. Neurosci., 2005

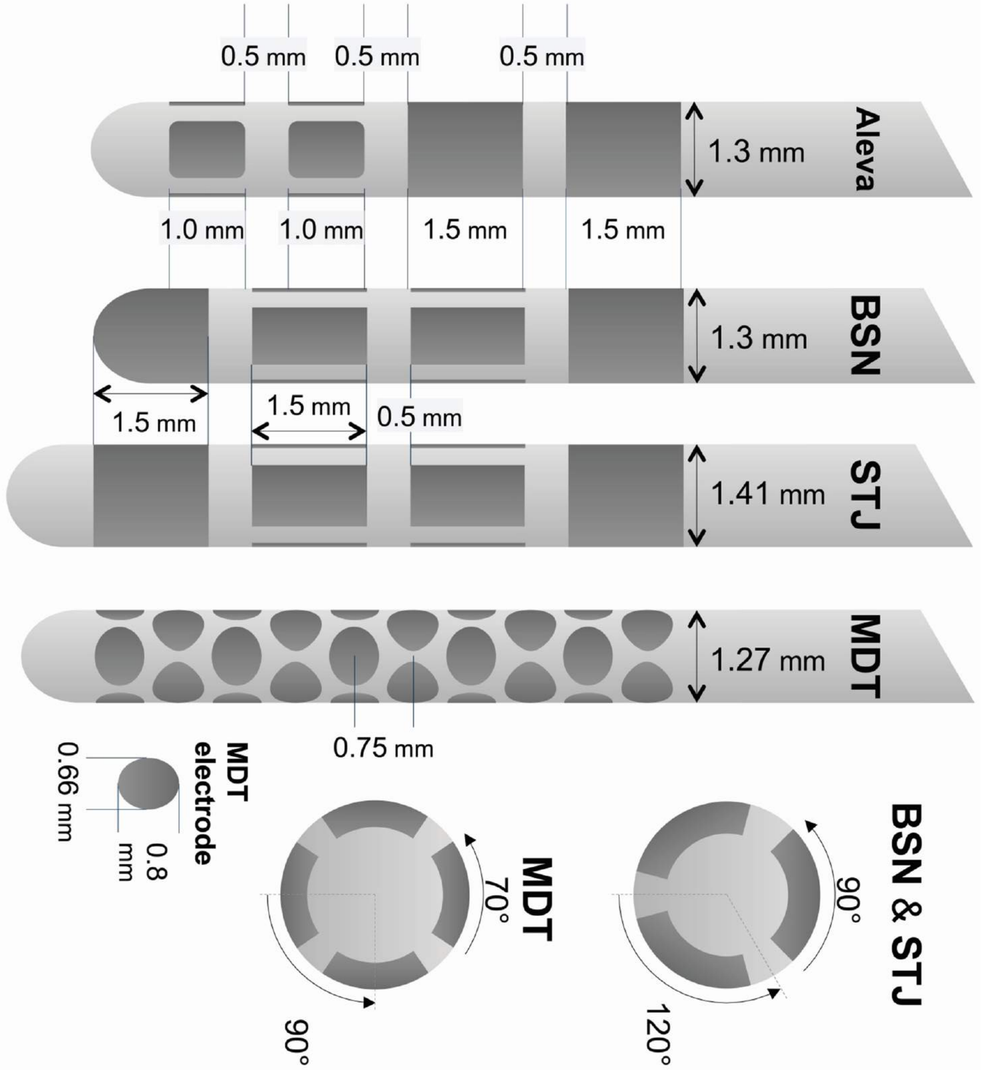


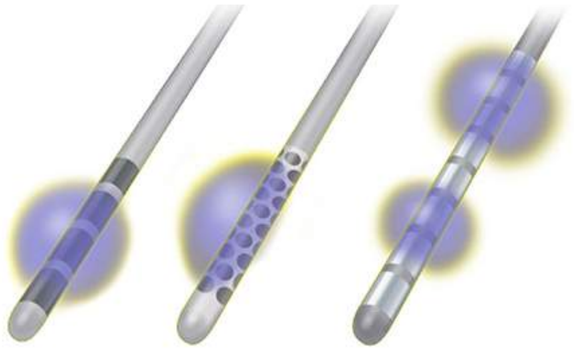
TECHNICAL ADVANCEMENTS IN DBS

- Localizing precise targets using probabilistic tractography
- Stimulating portion of the **ANTERIOR CINGULATE CORTEX** that has strong connectivity to the **PRECUNEUS** results in **WORSE OUTCOME (2)**
- Stimulating portion of the **ANTERIOR CINGULATE CORTEX** that has strong connectivity to the **BRAINSTEM** and the **THALAMUS** results in **GOOD PAIN RELIEF (6)**

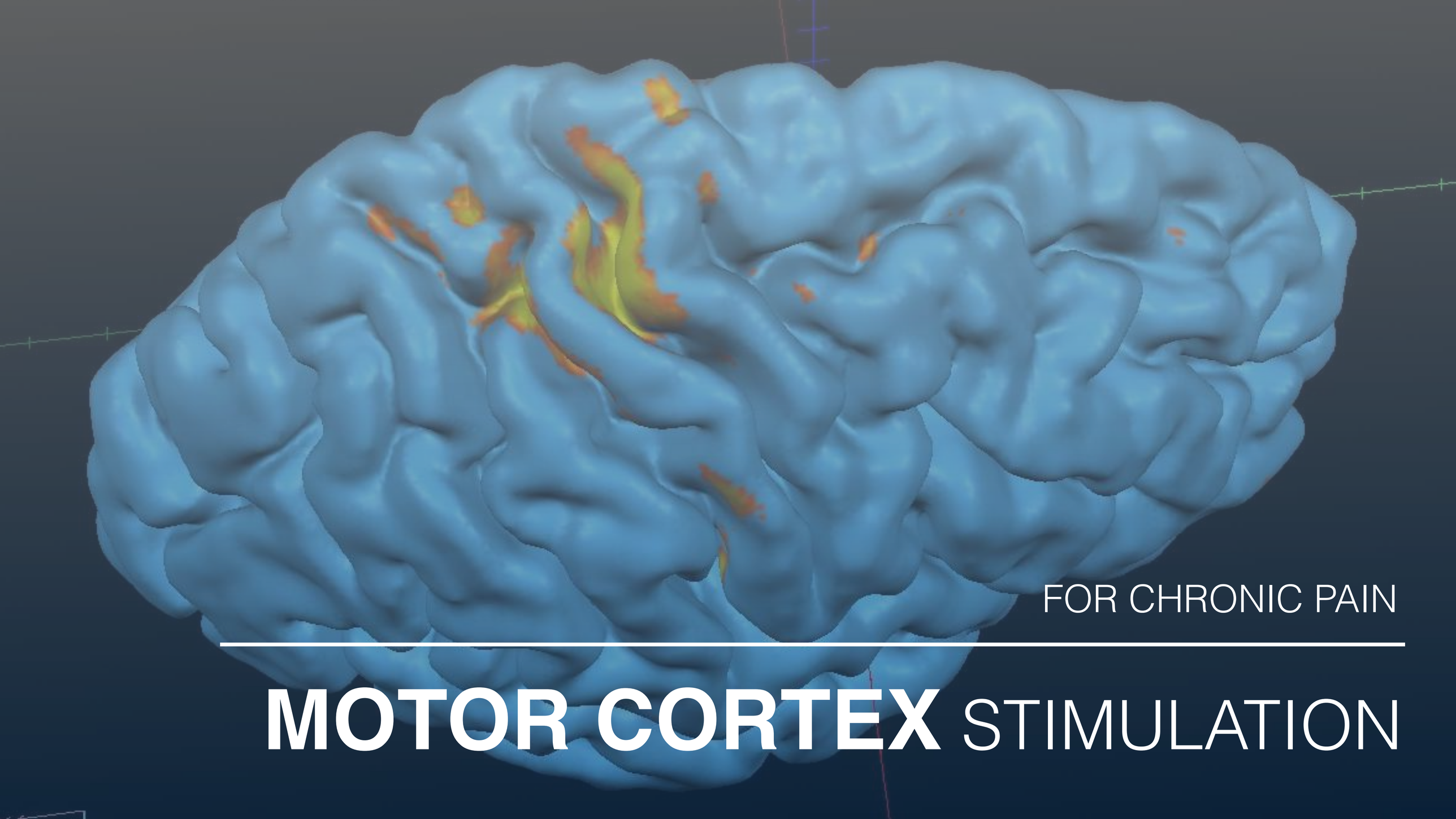
Boccard et al. World neurosurgery, 2016

TECHNICAL ADVANCMENTS IN DBS





- Current steering with directional electrodes (Pollo et al Brain 2014)
- Dual stimulation in different target structures in the brain (Sims-Williams et al. 2013 Streotact Funct Neurosurger)
- New stimulation paradigms



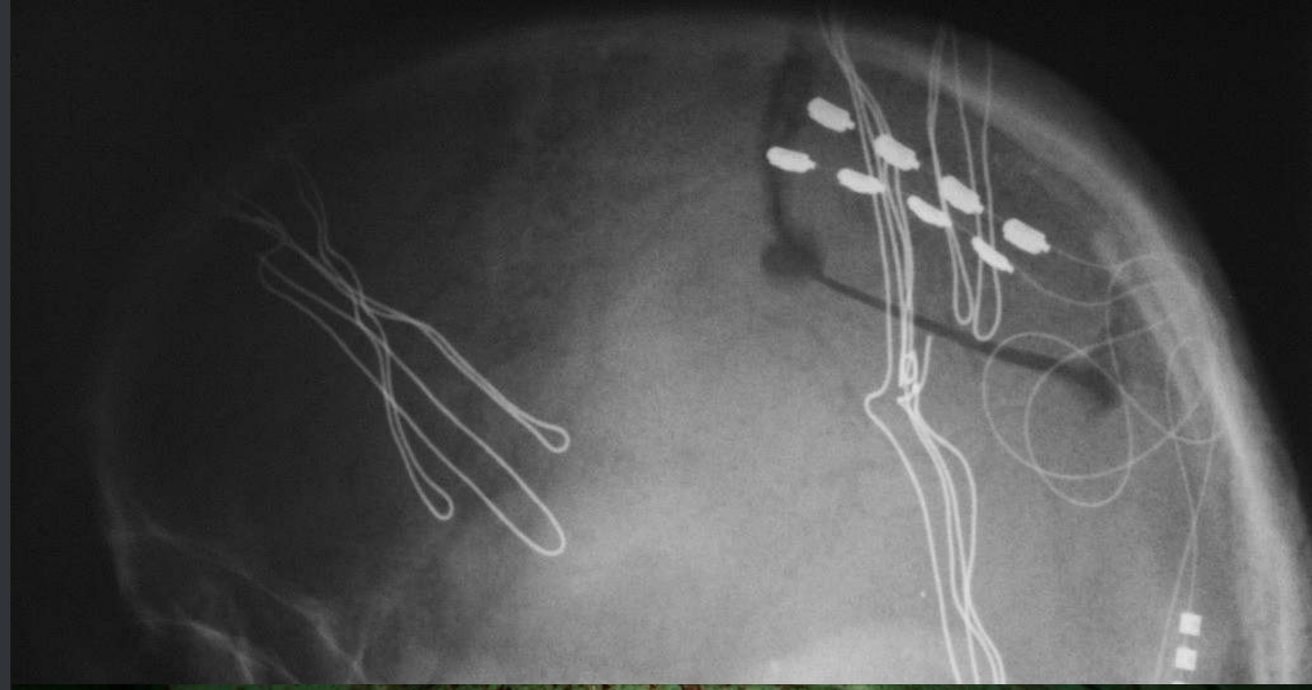
FOR CHRONIC PAIN

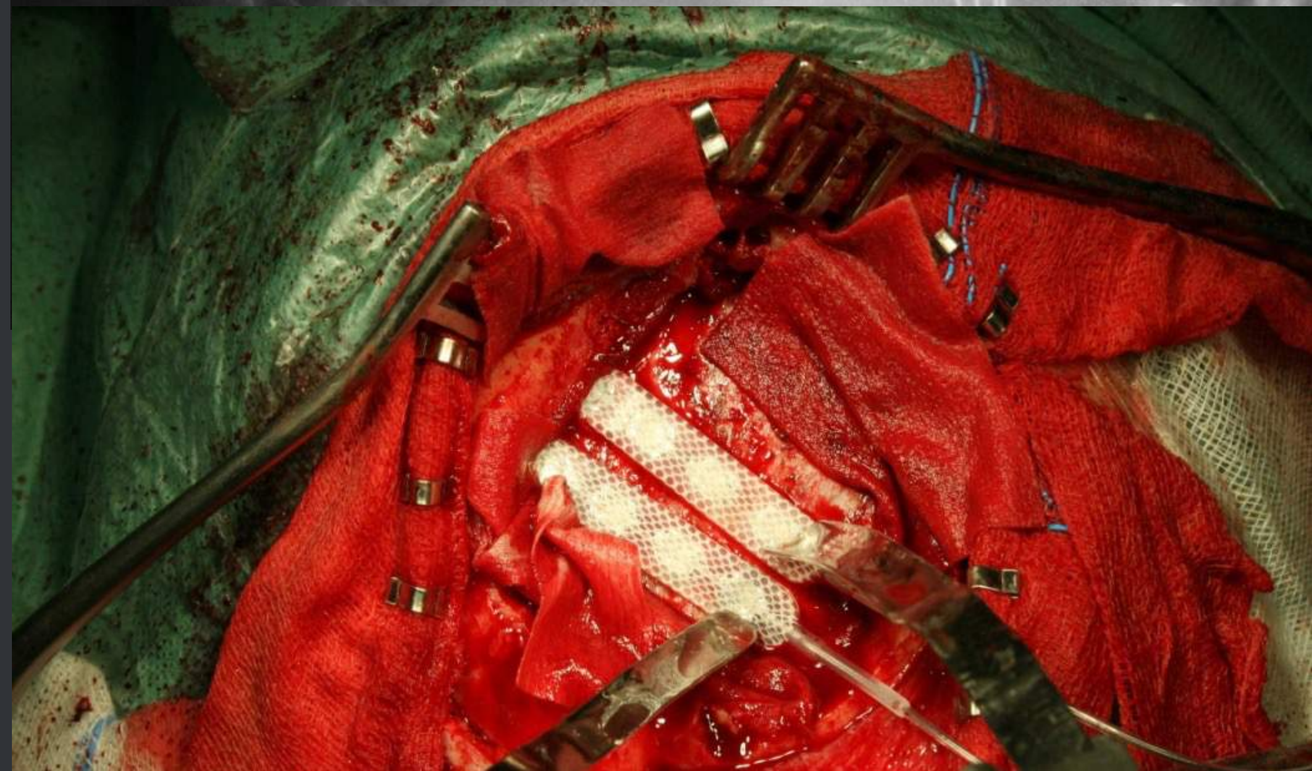
MOTOR CORTEX STIMULATION

PRIMARY MOTOR CORTEX STIMULATION

„PANACEA OR PLACEBO”

R.LEVY NEUROMODULATION 2014 JUNE





Tsubokawa 1991 central deaferentation pain

Meyerson 1993

N’Guyen 1997, developed the technique

Since 1991, 800 cases reported in the literture

No controled double-blind studies

CONCEPT: „multicenter,prospective, randomised,double blinde, crossover clinical trial” (12 European center, 104 patints, 2,5 years) failed

PRIMARY MOTOR CORTEX STIMULATION

INDICATIONS

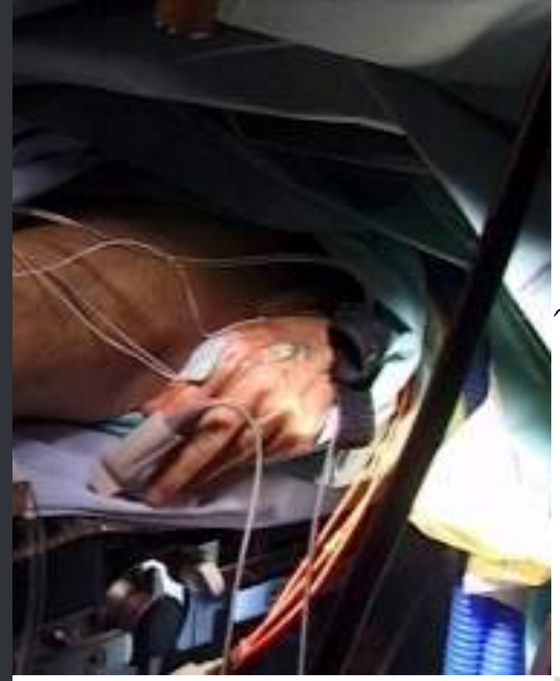
NEUROPATHIC PAIN

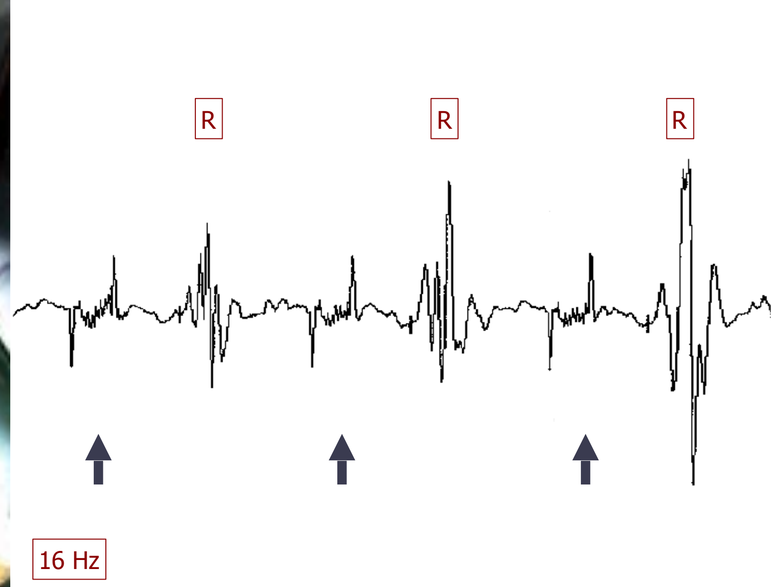
Central : 67% of published cases

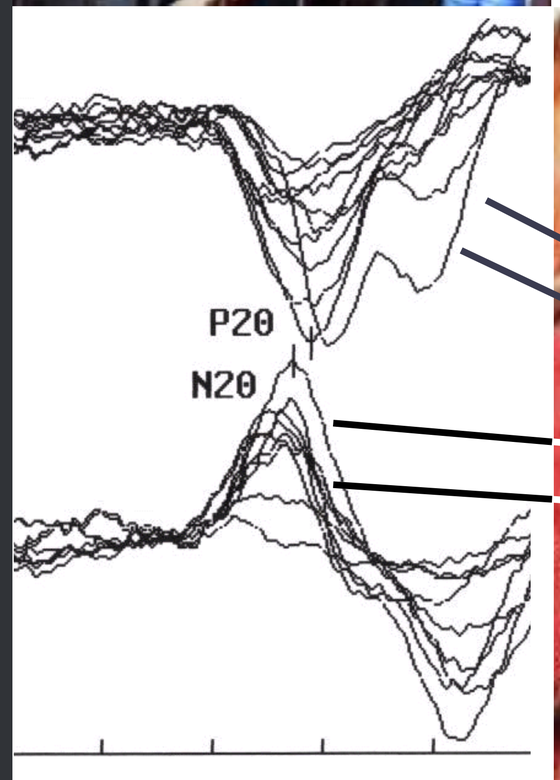
- Post stroke
- Spinal cord injury
- Others

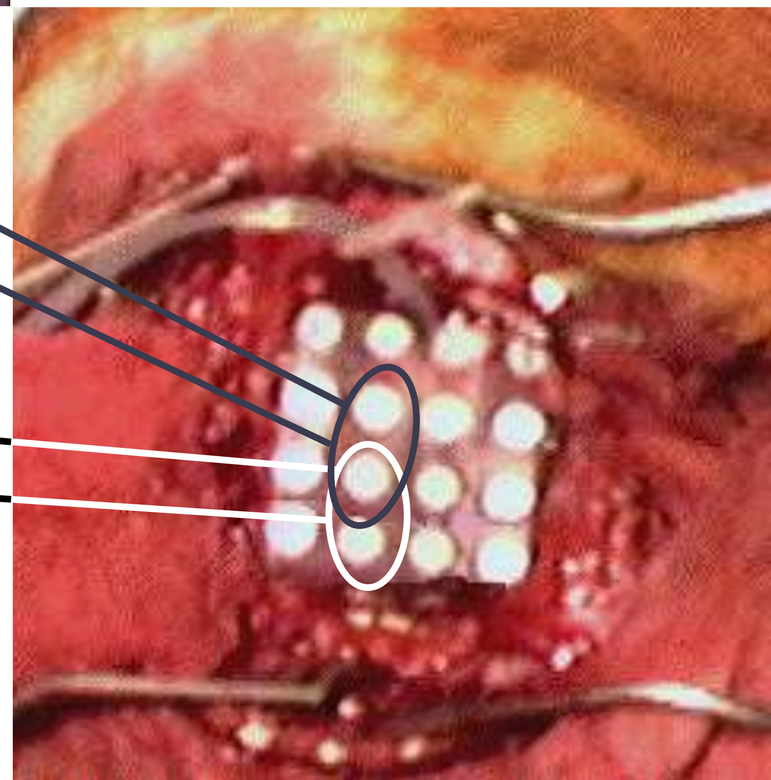
Peripheral : 31% of published cases

- TGN / facial pain
- Peripheral nerve injury
- Plexus avulsion
- Phantom pain









PRIMARY MOTOR CORTEX STIMULATION
RESULTS

	Results on VAS
fMRI + navigation	69,2% (2005)
Navigation	30,7%
Anatomy (burr hole)	12,5% (1991)

N'Guyen

	Year	Indication	EFNS level
Cruccu	2007	CRPS, neuropathic facial pain	**III, IV**
Levy	2015	Thalamus pain, neuropathic facial pain	**IV**

PAIN RELIEF >40% IN VAS SCORE

- Central pain 80%
- Trigeminal neuropathic pain 75,7%
- Paraplegic pain 55,5%
- Brachial plexus avulsion 34% (literature 44%)
- Phantom limb pain 53%

N'Guyen (2005)

“

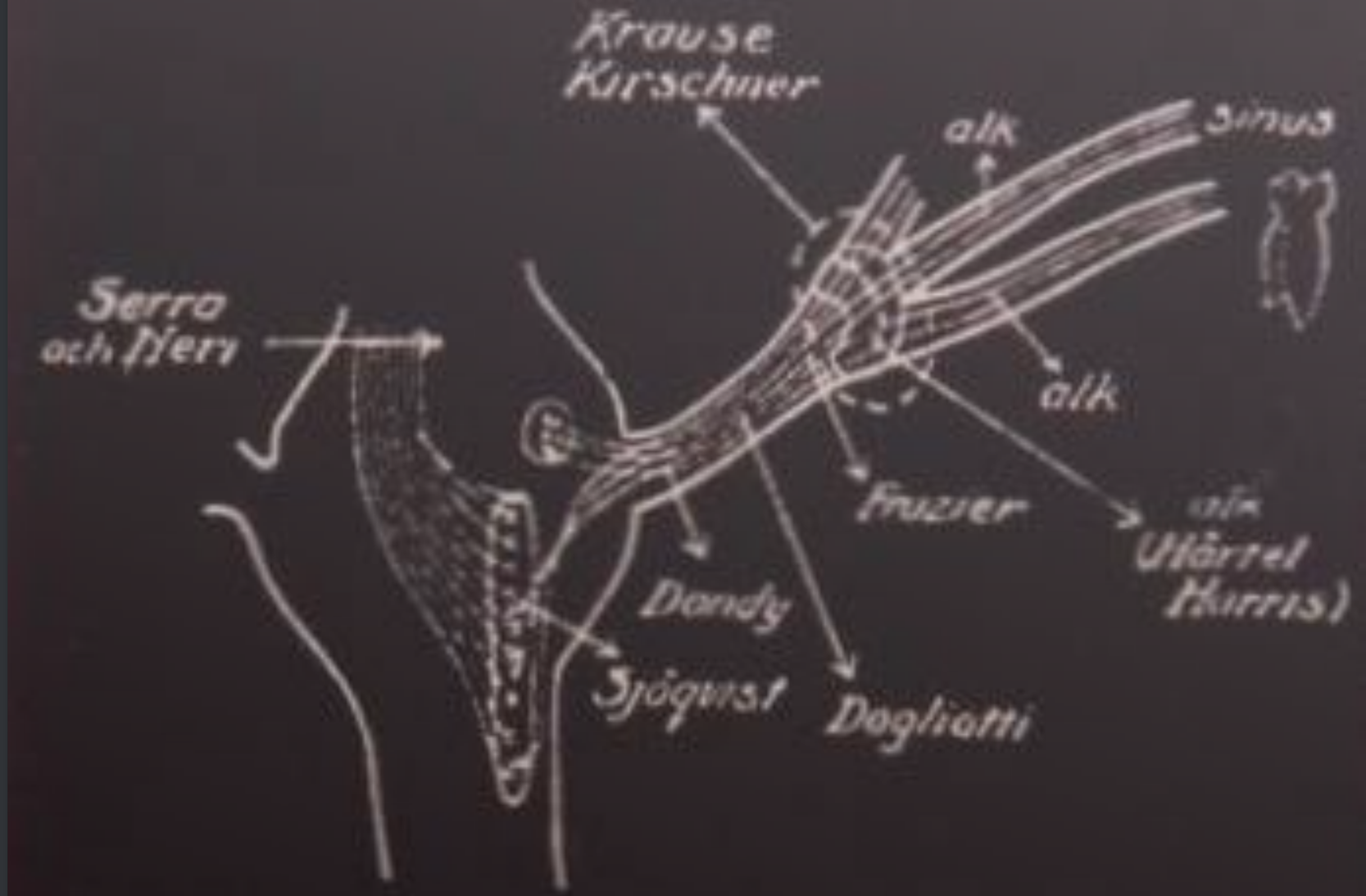
Is MCS a placebo or a panacea? It is likely neither. The literature suggests that MCS holds promise for patients with trigeminal neuropathic pain, poststroke pain, and pain that has failed to respond to others therapies.
At the present time, it is unlikely that we can make any definitive conclusions as to the efficacy of MCS for chronic neuropathic pain.

R.Levy Neuromodulation 2014 June

TREATMENT OPTIONS

TRIGEMINAL NEURALGIA

NEUROSURGICAL TREATMENT OF TRIGEMINAL NEURALGIA



OLOF SJÖQUIST: TRIGEMINAL NEURALGIA. A REVIEW OF ITS SURGICAL TREATMENT AND SOME ASPECTS OF ITS ETIOLOGY.

Acta chir.Scand 1938;82:201-217

PERCUTANEOUS TECHNIQUES FOR TRIGEMINAL NEURALGIA

Thermocontrolled radiofrequency lesioning (since 1950’s)

Pulse radiofrequency (Slujter 1996)

Glycerol rhyzotomy (Hakanson 1981)

Balloon compression (Mullan 1983)

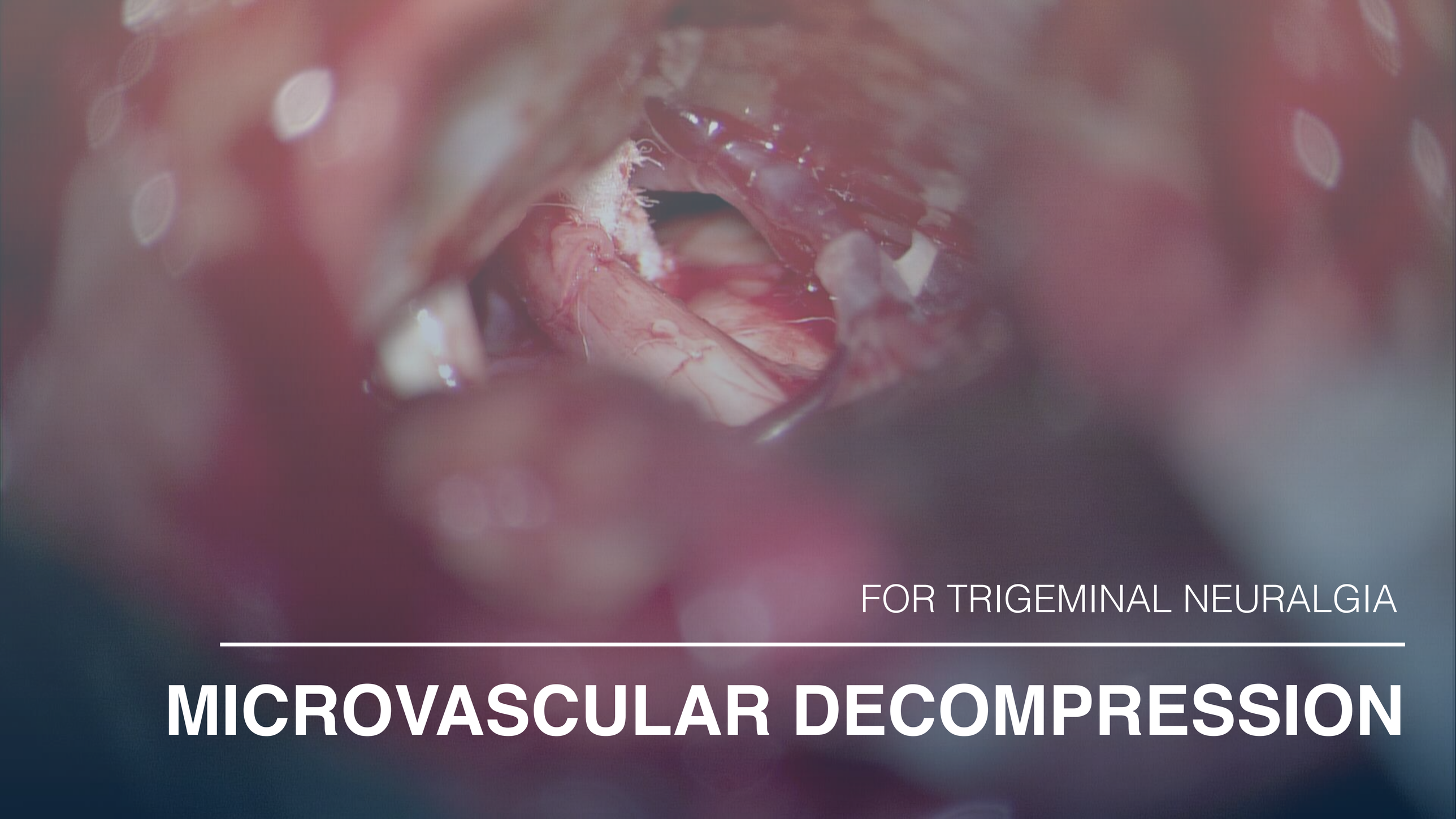
PERCUTANEOUS TECHNIQUES FOR TRIGEMINAL NEURALGIA

Avoid the risk of craniotomy
Repeated easily
Much less expensive than microvascular decompression or radiosurgery

PERCUTANEOUS TECHNIQUES FOR TRIGEMINAL NEURALGIA

COMPARSION OF TECHNIQUES

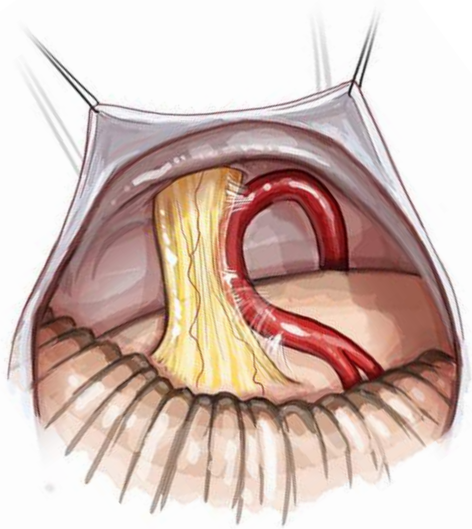
	RF	Glycerol	Baloon
Techn.success	**97,4-100%**	**94%**	**93-99%**
Initial pain relief	**98%**	**72-96%**	**89,9-100%**
Recurrence	**15-20%(5y-10 y)**	**54% (4y)**	**25-77,4%(3y)**
Facial numbness	**98%-3mo 10%perm.**	**60%**	**61-72%**
Motor deficit	**24%**	**1,7%**	**19-66%**
Corneal reflex:0	**7%**	**3,7%**	**1,5%**
Anaesth.Dolor.	**0,3-4%**	**0-2%**	**1,8%**

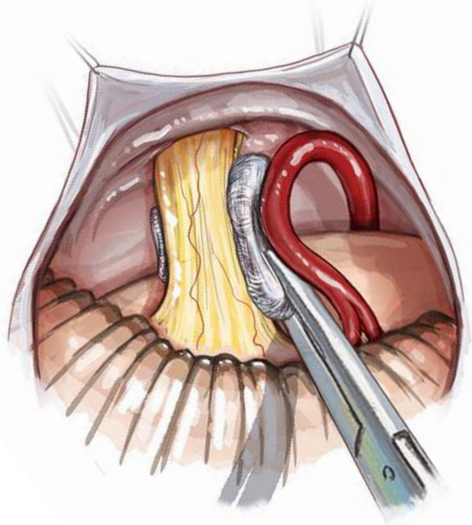


FOR TRIGEMINAL NEURALGIA

MICROVASCULAR DECOMPRESSION

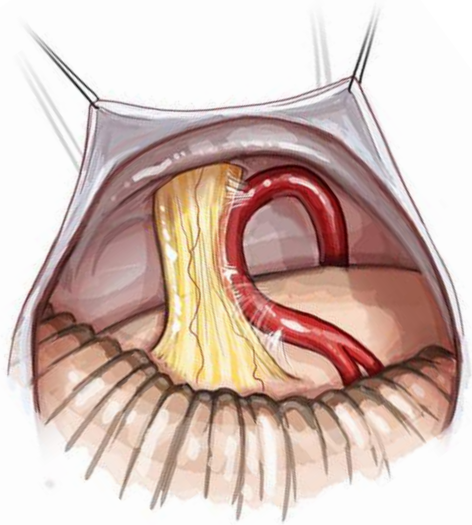
ADVANTAGE OF MICROVASCULAR DECOMPRESSION FOR TRIGEMINAL NEURALGIA

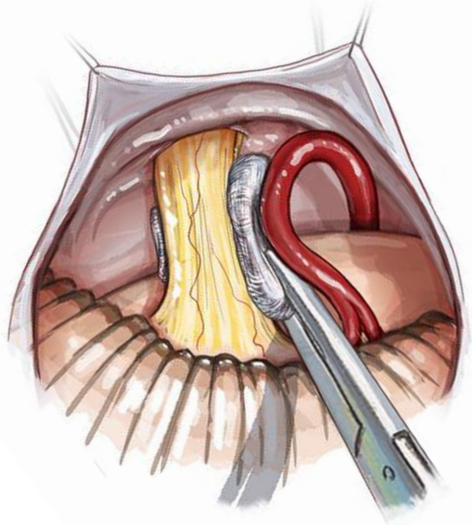




- Treat primary cause
- Trigeminal nerve is preserved
- Postoperative pain relief does not require production of sensory deficit
- Long term outcome is highest

ADVANTAGE OF MICROVASCULAR DECOMPRESSION FOR TRIGEMINAL NEURALGIA





- SCA 75,5%
- Venous contact 68,2%
- Only venous compression12,5%

MICROVASCULAR DECOMPRESSION

SUCCESS RATE

- Jannetta total success rate 88% at 1y, 74% at 10y
- reoperated 11%, 96% of reoperated patients had > 75% pain relief (89% at 10y)
- Annual recurrence 2% at 5y, <1% at 10y
- Factors for long-term recurrence: gender, preop.symptoms more than 8 years, venous compression, failure of immediate pain relief
- Sindou (2006): 100% recurrence rate within 4y if intraoperative neurovascular compression missing

GAMMA-KNIFE FOR TRIGEMINAL NEURALGIA

First irradiation by Leksell in 1951 (ganglion) since than more than 20 000 patients were treated

Since 1993, target: more proximal part of nerve V., near the brainstem

75% pain free with/without medication within 1-8 weeks of the initial treatment

10% recurrance within the 1st year, 60% pain free long-term

Complication: facial sensory loss 0-10%

No anaesthesia dolorosa, no SCF leak

GASSERIAN GANGLION STIMULATION

- Shelden 1967, Meyerson 1980: subtemporal, epidural, percutan cervical, trans foramen magnum electrode implantation
- Hartel technique – foramen ovale
- Not for tic douloureux
- Indication: trigeminal neuropathic pain
- Test period of 7-20 days mandatory
- Steude 200 test,100 implantation(1998)
  - 86% good results for maxillary or orthodontic surgery
  - 92% good result in posttarumaticfacial pain
  - 100% good result in chronic pain after ablative trigeminal procedures

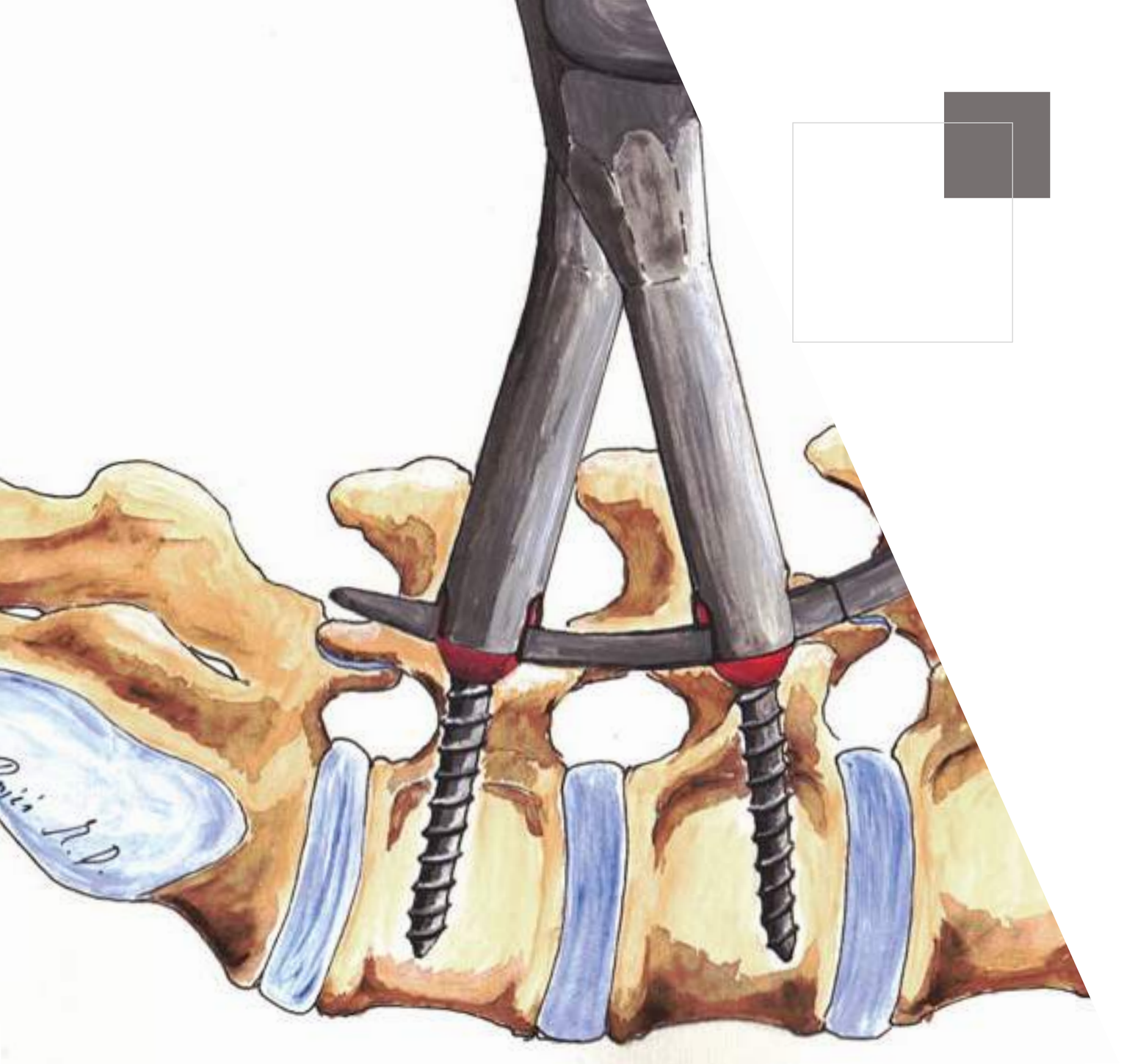
STIMULATION OF THE NUCLEUS CAUDALIS OF THE DESCENDING TRACT OF THE TRIGEMINAL NUCLEUS

FOR ATYPICAL FACIAL PAIN

SPINAL CORD STIMULATION

INDICATIONS FOR SCS

- NEUROPATHIC PAIN
  - failed back surgery syndrome
  - chronic regional pain syndrome
  - radiculopathy
  - diabetic neuropathy
  - postherpetic neuralgia
- PERIPHERAL NERVE INJURY
- ISCHEMIC PAIN (REFRACTORY ANGINA)
- DEAFFERENTATION PAIN
  - phantom limb
  - spinal cord injury



SUCCESS RATES IN
SPINAL SURGERY

98% success rate for fusion

Pain relief

- one level fusion 40-80%
- three level fusion 15%

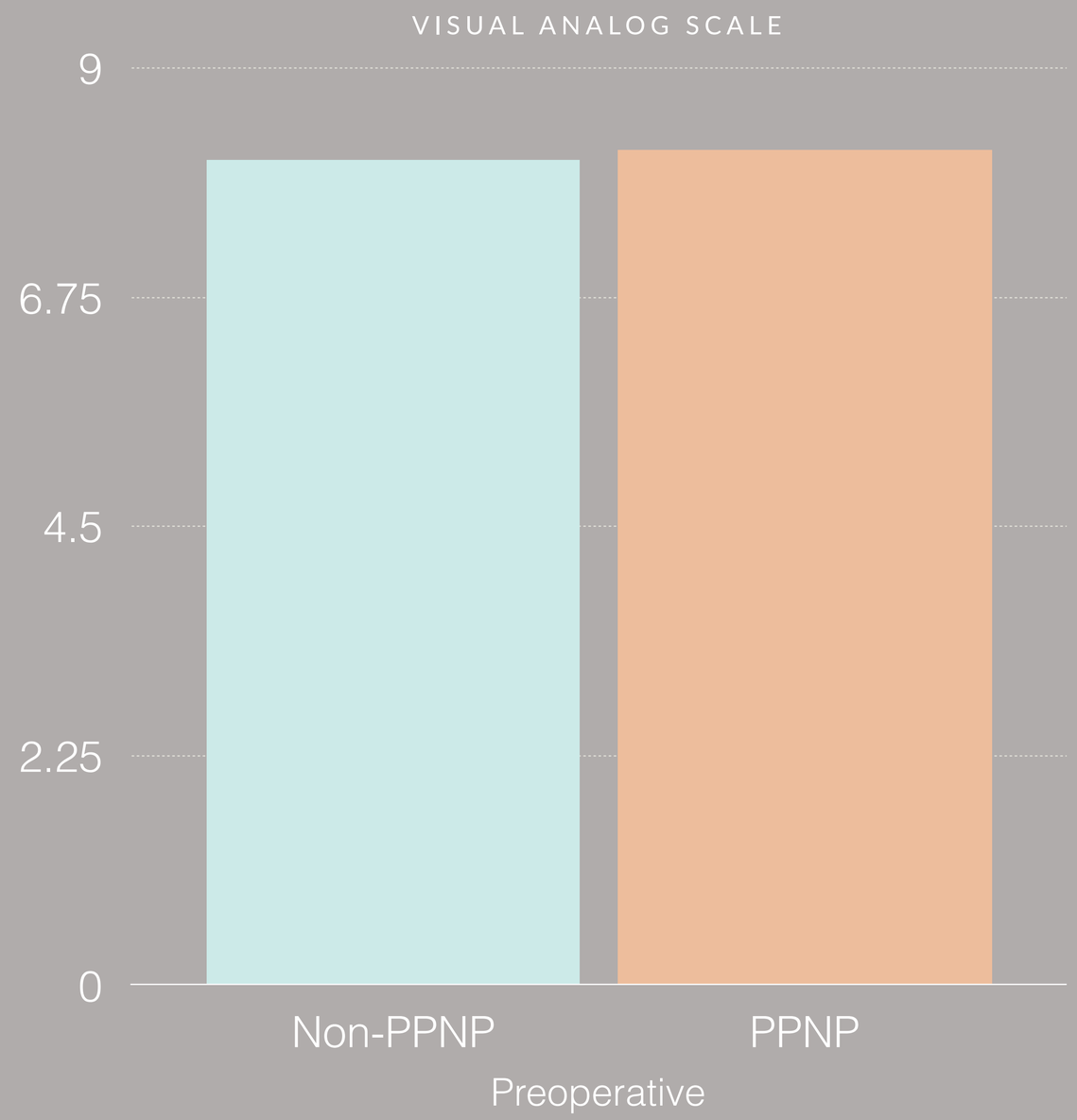
95-98% success rate for microdiscectomy
return to work without medication is 74%

SURG. NEUROL., 1998 MARCH; 49(3):263-8

NEUROPATHIC PAIN

NEUROPATHIC PAIN RETURNED AFTER 6 MONTHS IN THOSE CASES IF IT WAS ALREADY PRESENT BEFORE SURGERY

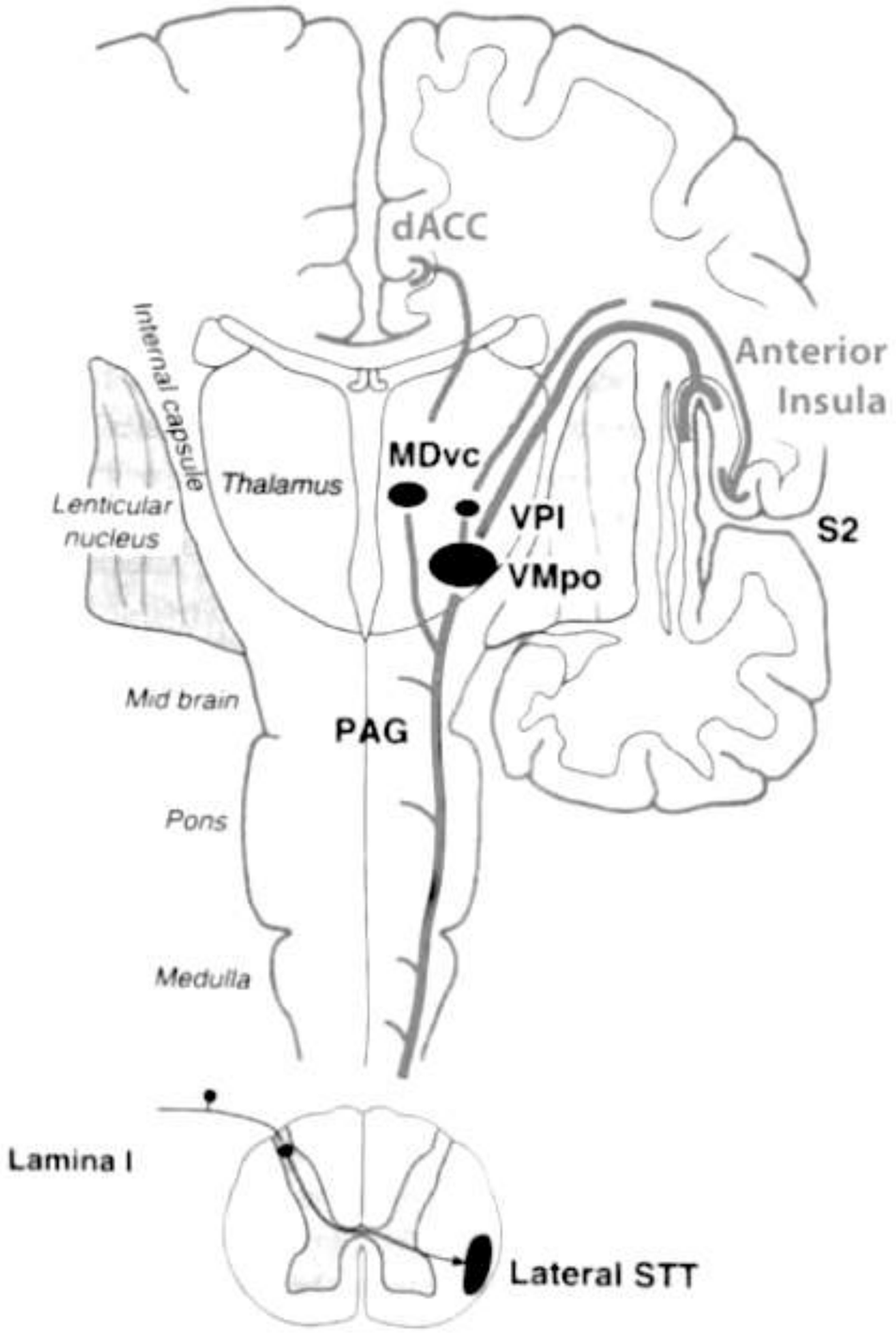
PPNP - PERSISTING POSTOPERATIVE NEUROPATHIC PAIN



Shamji et al - Use of neuropathic pain questionnaires in predicting persistent postoperative neuropathic pain following lumbar discectomy for radiculopathyJ Neurosurg Spine 24:256–262, 2016

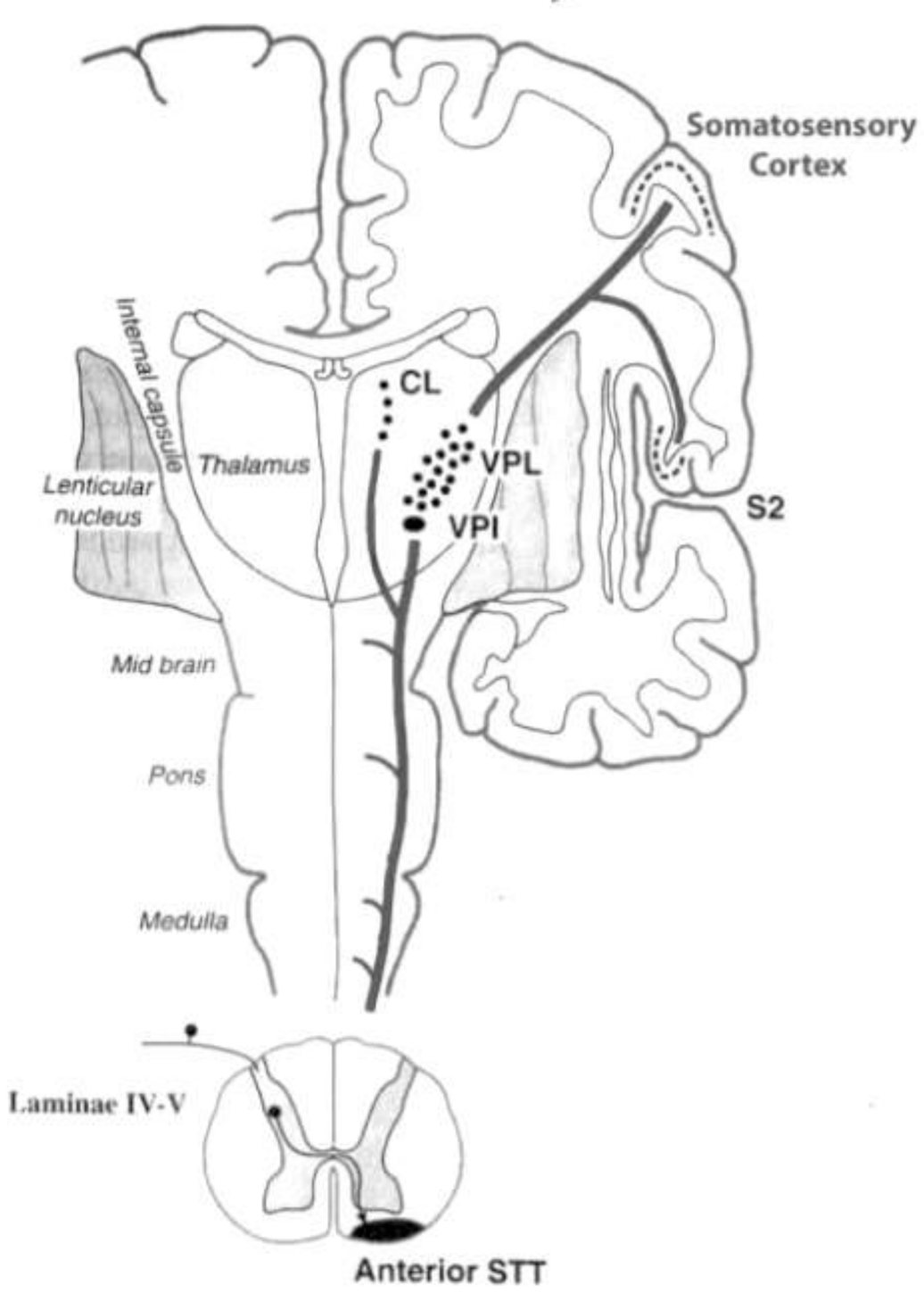
Lateral system

- Activated by C-, Aδ, Aβ fibers
- Thalamus VPL
- Somatosensory cortex
- **Sensory component of the pain**



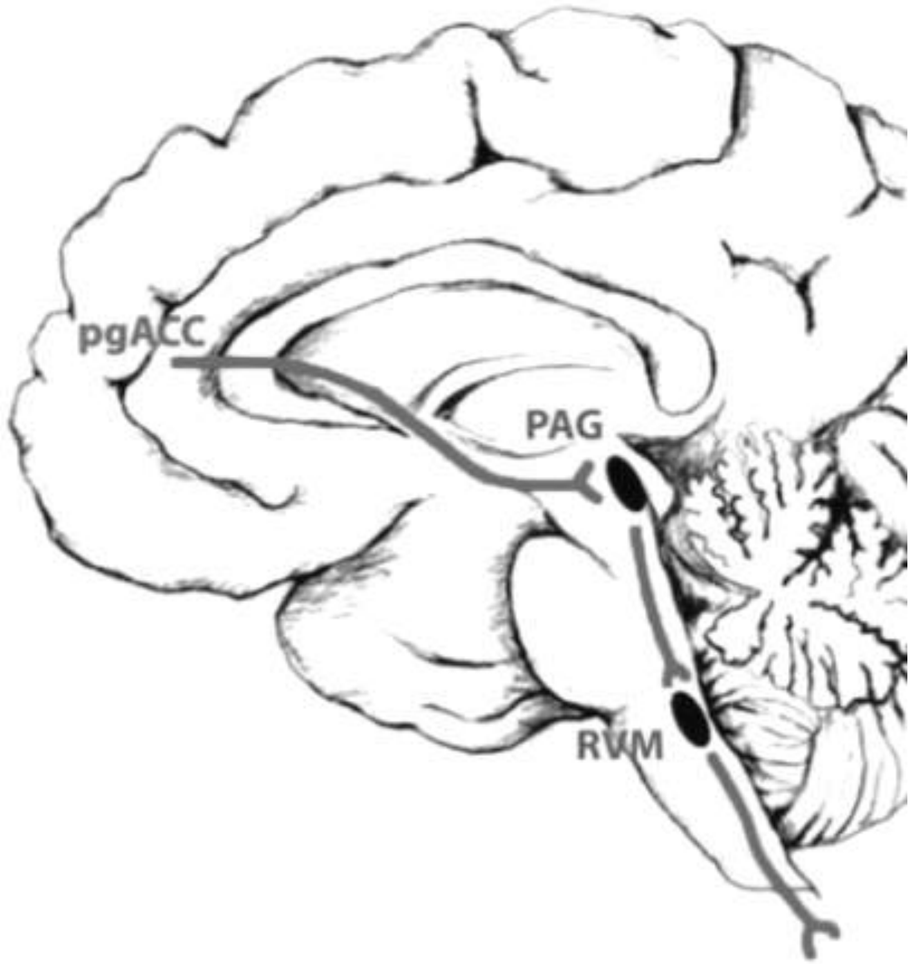
Medial system

- Activated by C-fibers
- Thalamus MD, VPL
- Anterior cingulate cortex and anterior insular cortex
- **emotional component of the pain**



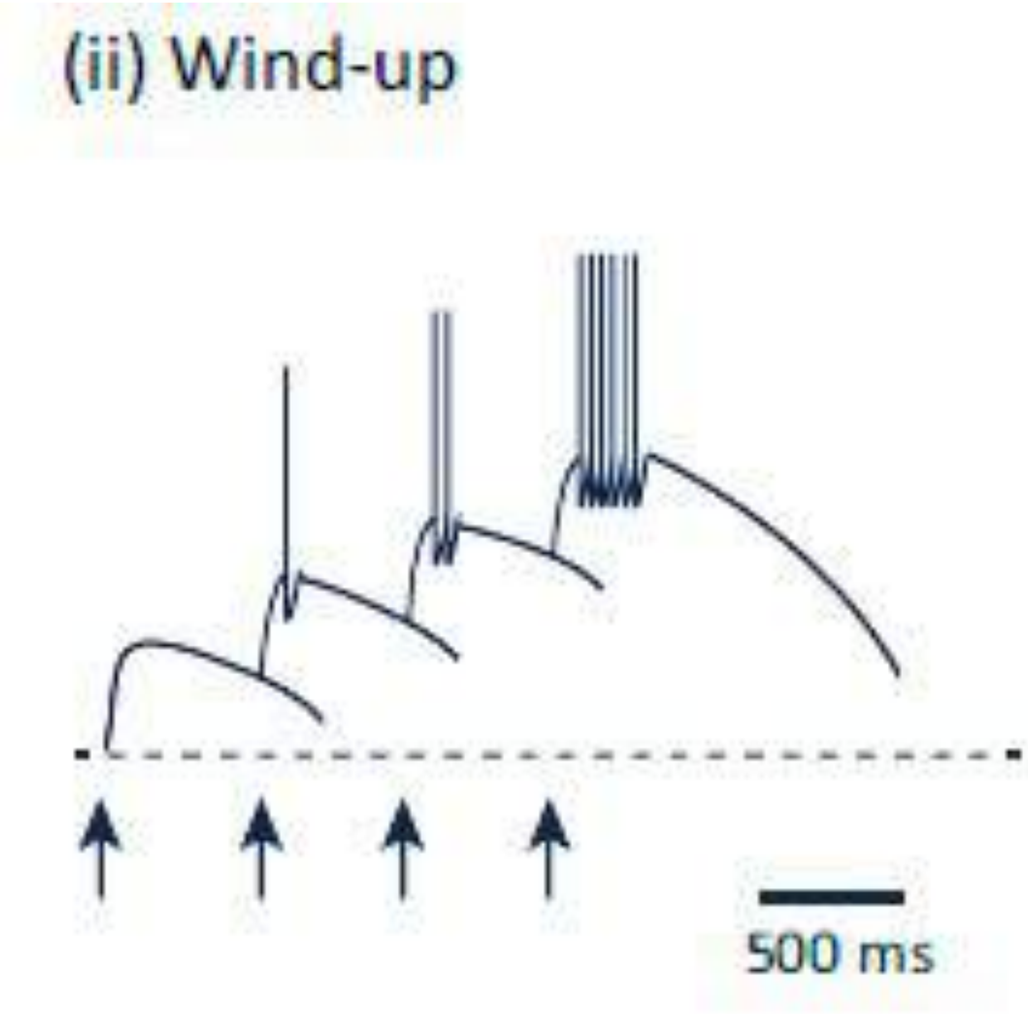
Descending pathway

- From the anterior cingulate cortex
- To the periaqueductal grey
- And the somatosensory peripheral network
- **Modulates the ascending pain signals**



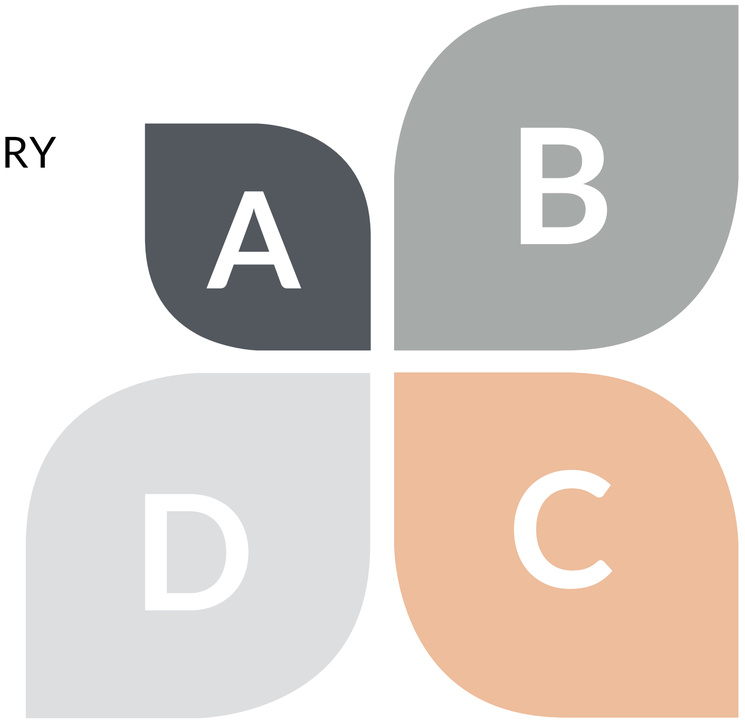
NEUROPATHIC PAIN

- **SPONTANEOUS BURST ACTIVATION OF C-FIBERS**
  - Wind up, gets more unpleasant



WHEN TO GO FOR SCS

ANATOMICALLY
CORRECT SURGERY



NO NEUROLOGICAL
DEFICIT

CHRONIC BACK
AND LEG PAIN

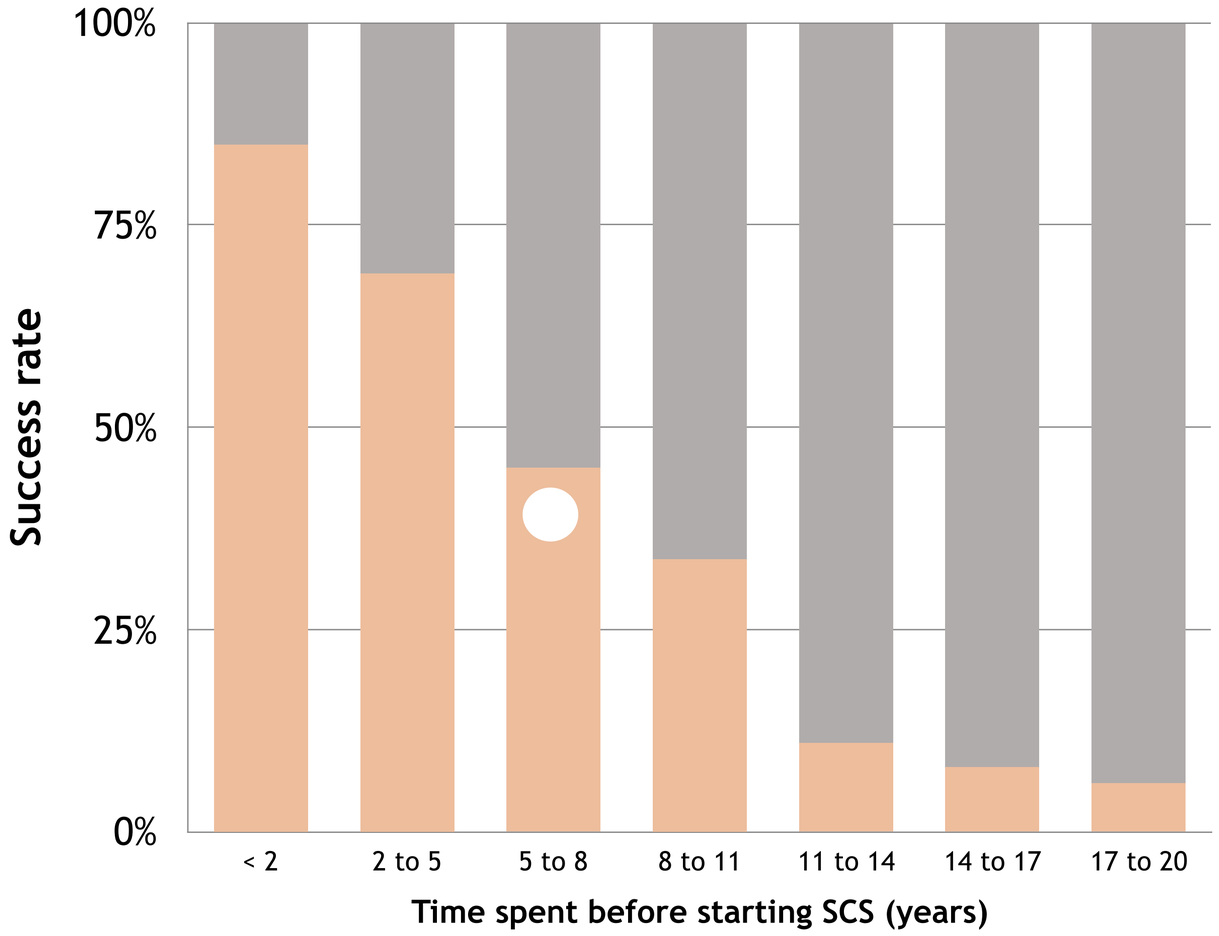
NO CMM AND
INTERVENTIONAL
PAIN THERAPY
HELPED

WHEN SHOULD I CHOOSE SCS THERAPY FOR MY PATIENT?

AN AVAREGE OF 5,4 YEARS IS SPENT BEFORE ADVISING SCS THERAPY

SUCCESS RATE IS 45% IN THESE CASES

IN CASE OF 2 YEARS
THE SUCCESS RATE IS 85%



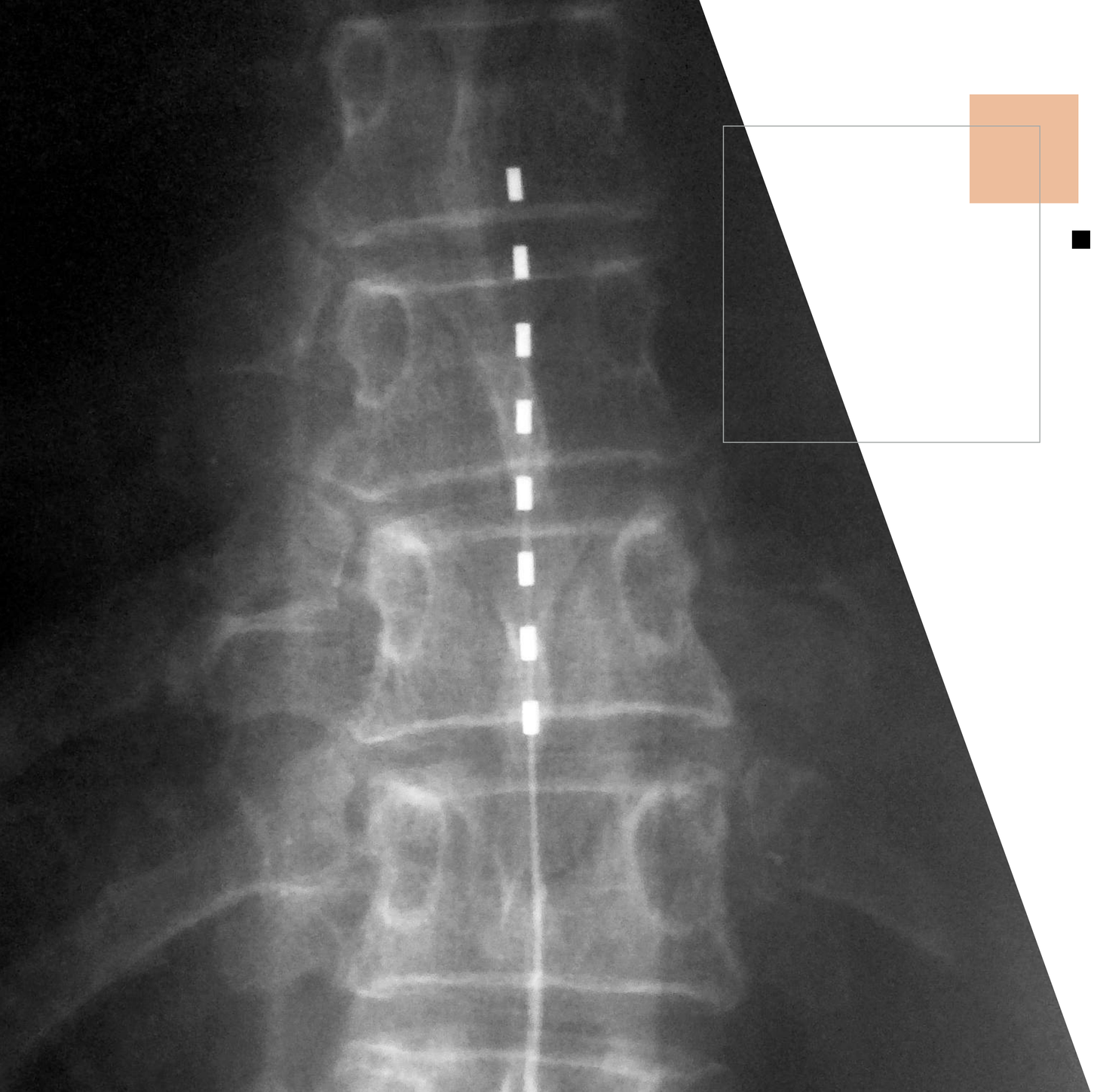
Medtronic data on File (French SCS registry)
Kumar K, Wilson JR. Factors affecting spinal cord stimulation outcome in chronic benign pain with suggestions to improve success rate. Acta Neurochir Suppl. 2007;97: 91–99.

EVIDENCES OF SCS AND PNS IN PAIN CONDITIONS

2 A+	2 B+	2 C+	0
Failed Back Surgery Syndrome (SCS)	CRPS (SCS)	Postherpetic neuralgia (PNS)	Cervical radicular pain (SCS)
	Chronic refractory angina (SCS)	Diabetic polyneuropathy (SCS)	Meralgia paraesthetica (PNS)
		Chronic pancreatitis (SCS)	Phantom pain (SCS)
			Traumatic plexus injury (SCS)
			Trigeminal neuralgia (PNS)

VAN ZUNDERT J, PATIJN J, HARTRICK CT, LATASTER A, HUYGEN FJPM, MEKHAIL G, VAN KLEEF M. EVIDENCE-BASED INTERVENTIONAL PAIN MEDICINE: ACCORDING TO CLINICAL DIAGNOSES, 2012, DOI: 10.1002/9781119968375

TECHNIQUE



PERCUTANEOUS ELECTRODE

Focused stimulation, but not directed
Cylindric lead design
Mostly in non-complicated leg pain
Can be used in isolated low back pain
Position dependent stimulation

Awake surgery, with the aid of the patient

INTRAOPERATIVE POSITIONING

ENTRY

PARAMEDIAN

45 degrees

ALWAYS USE
FLUOROSCOPY

The insertion of the needle and the lead in AP view

Check the position of the lead in Lateral view.

Navigation is the imaging technique of the future(EM, real time navigation)

NOVEL OPTIONS

THE PROBLEM

Large number of case reports,
but only few systematic RCTs available

HIGH FREQUENCY

Mean VAS decreased 67% using HF vs. 44% with TONIC
171 patients (90 HF), followed for 12 months

Kapural, Anaesthesiolgy, 2015

BURST

Back pain was suppressed 29% better
Limb pain 31% better when compared with tonic

De Ridder, Clin J Pain, 2015

HIGH DENSITY

4 of 15 patients responded to HD stimulation for 1 week
VAS for HD 2.29 ± 0.41 vs. sham stimulation 6.31 ± 1.22

Sweet, Neuromodulation, 2016

Medtronic

- High density stimulation
- 1,5T full body MR compatibility

ST. JUDE MEDICAL

- Burst stimulation
- Low energy bluetooth connection
- Software upgrade

Boston Scientific

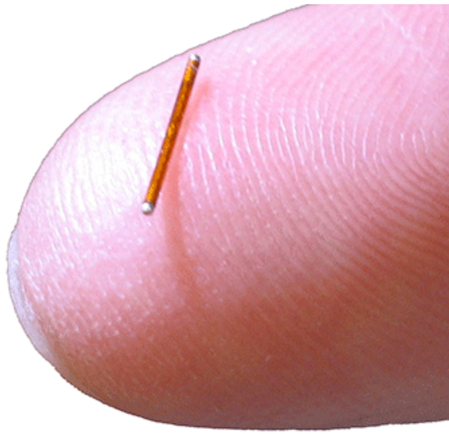
- 32 channel
- Burst, High frequency (1,2 kHz), Tonic
- Wireless programming

stim wave

freedom-8A

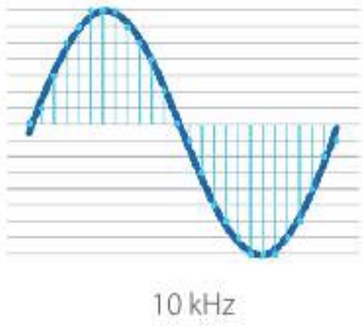
freedom-4A

- Lead receiver unit - neurostimulator in the lead itself
- telemetric energy conduction



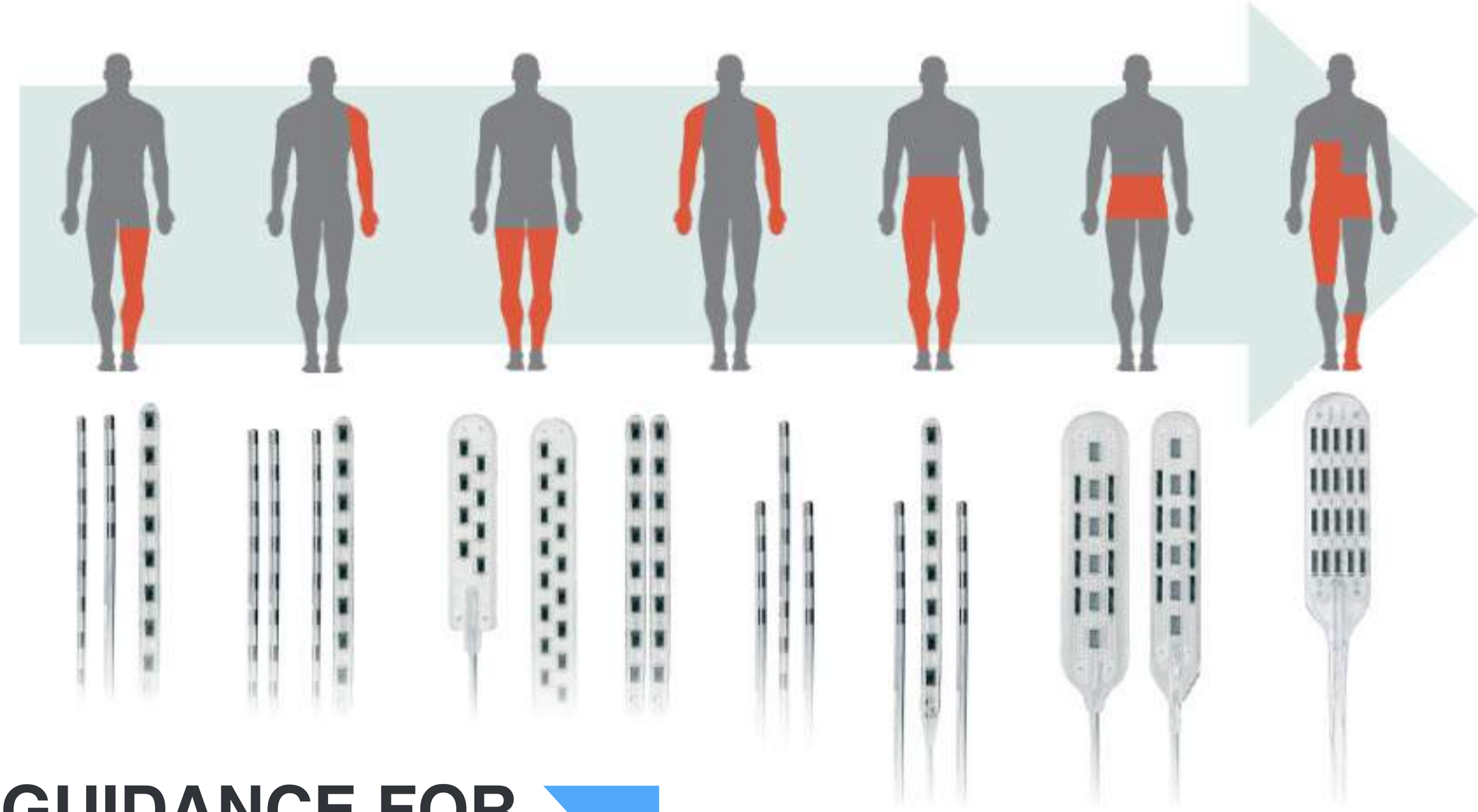
10+ year battery

10 kHz HF stimulation



Software upgrade

1,5T and 3T MR-conditional

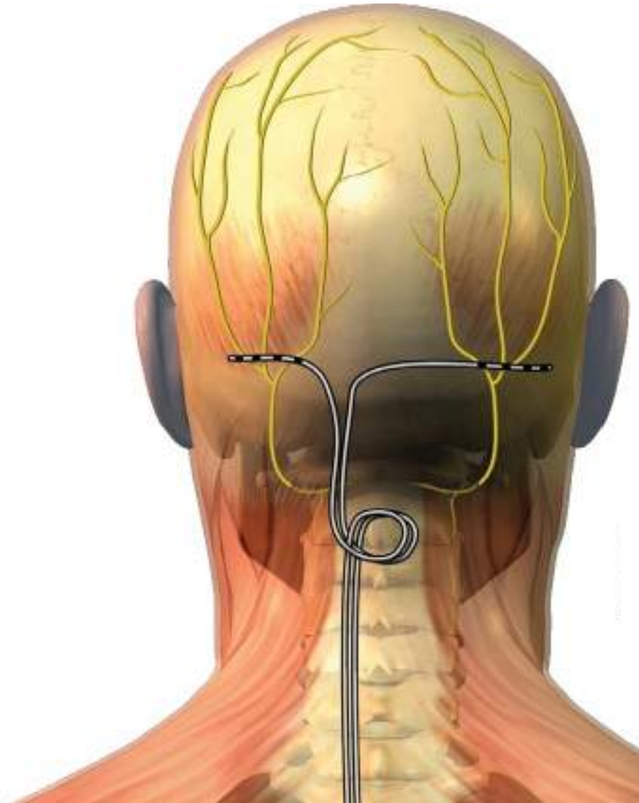


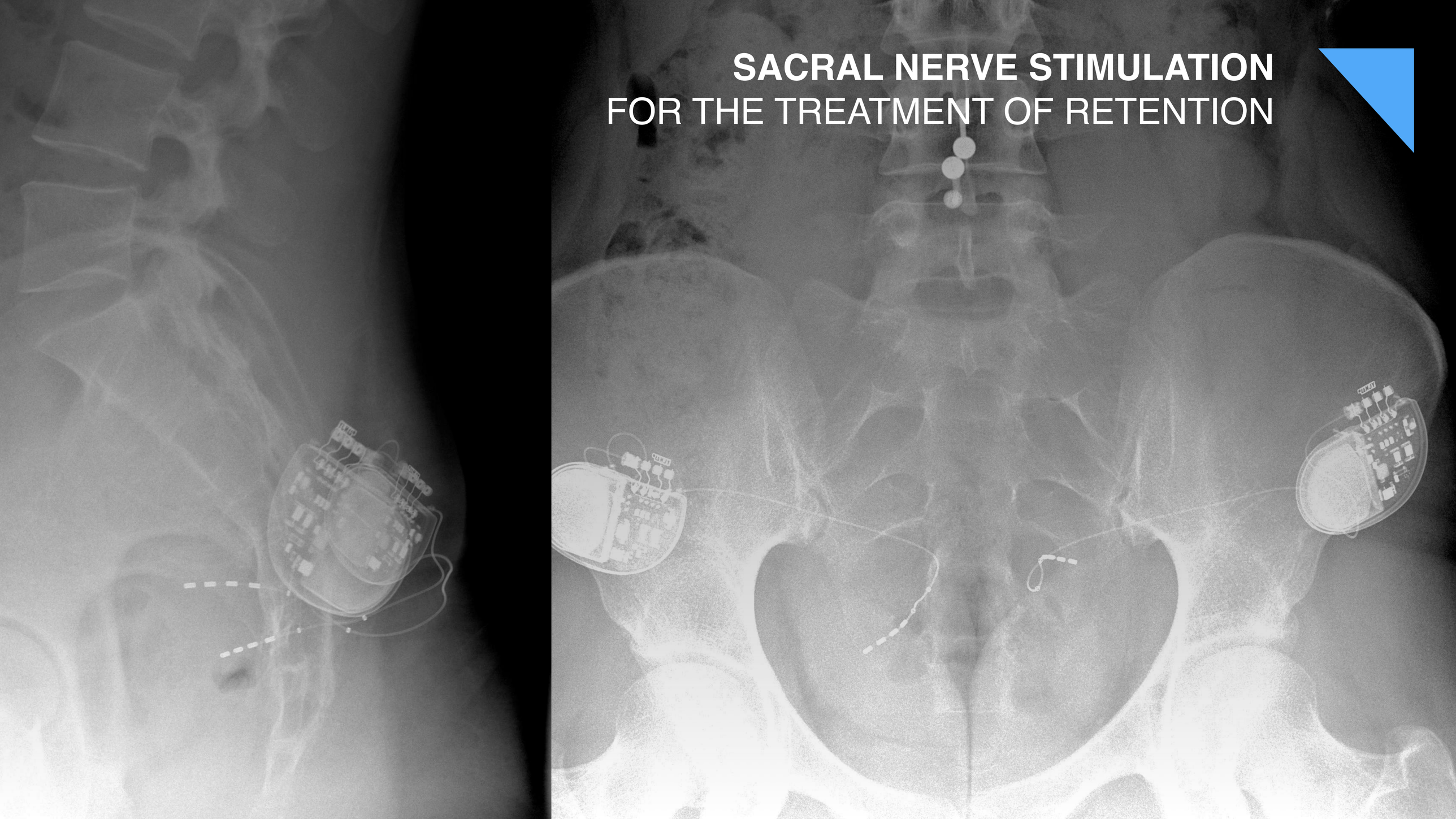
GUIDANCE FOR
COMPLEXITY

ST. JUDE MEDICAL™

OCCIPITAL stimulation

- CLUSTER HEADACHE
- CERVICOGENIC HEADACHE
- MIGRAIN

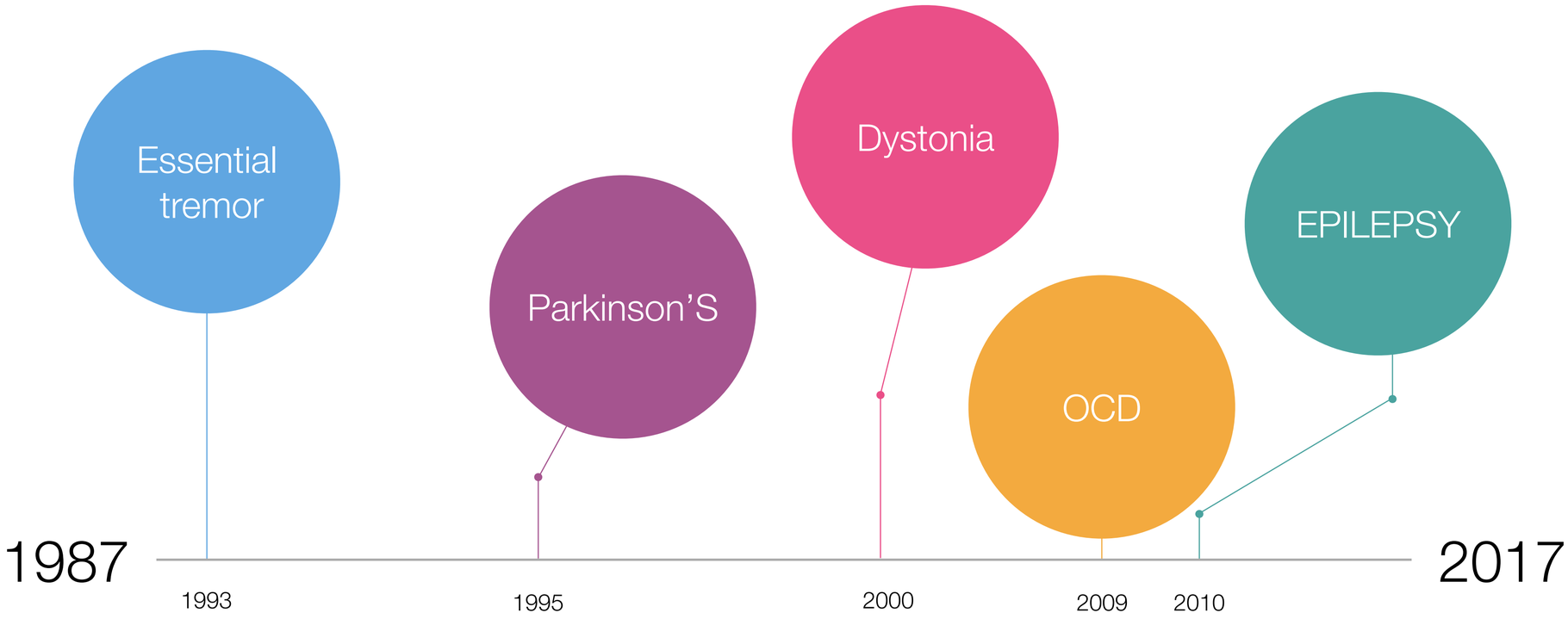




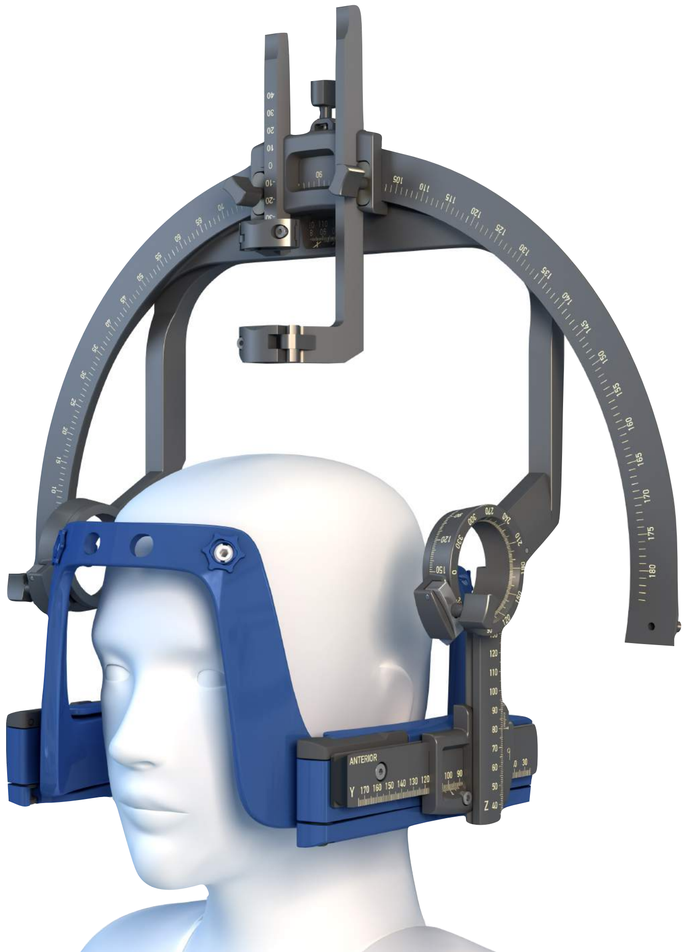
SACRAL NERVE STIMULATION
FOR THE TREATMENT OF RETENTION

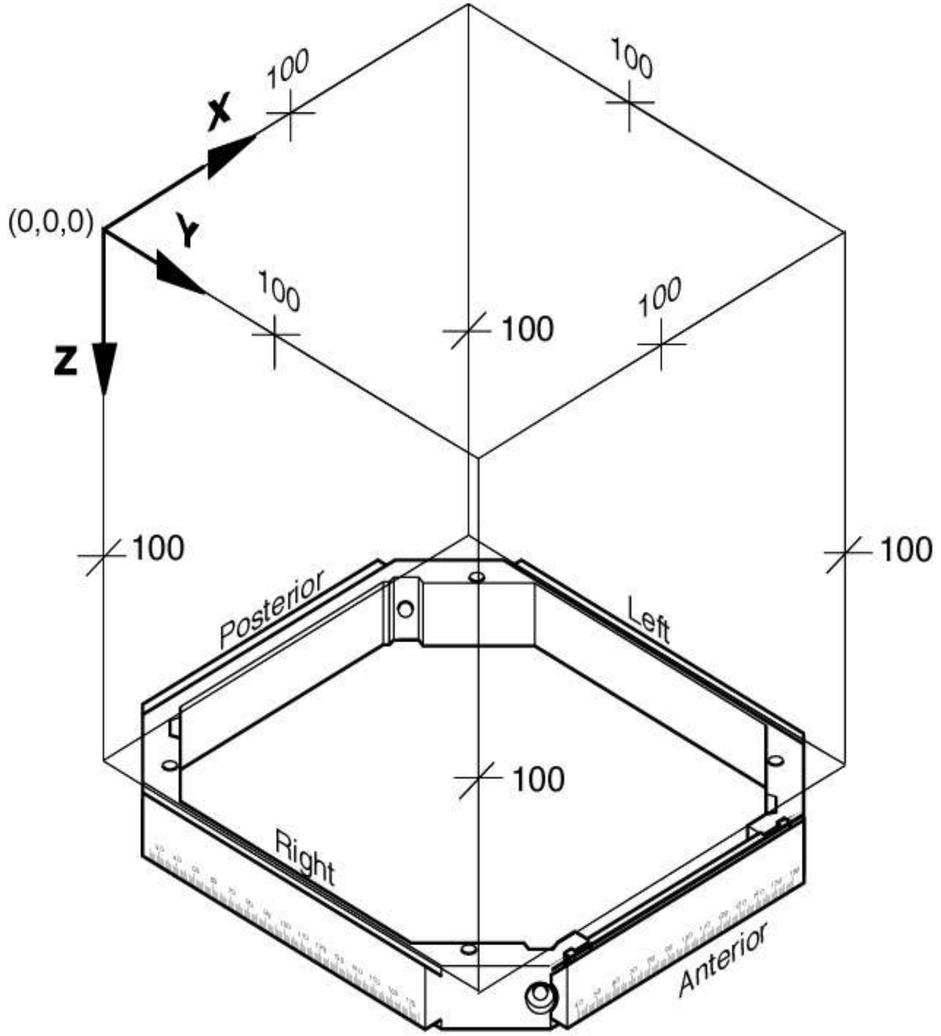

DEEP BRAIN
STIMULATION

INDICATIONS OF DEEP BRAIN STIMULATION



STEREOTACTIC PROCEDURE



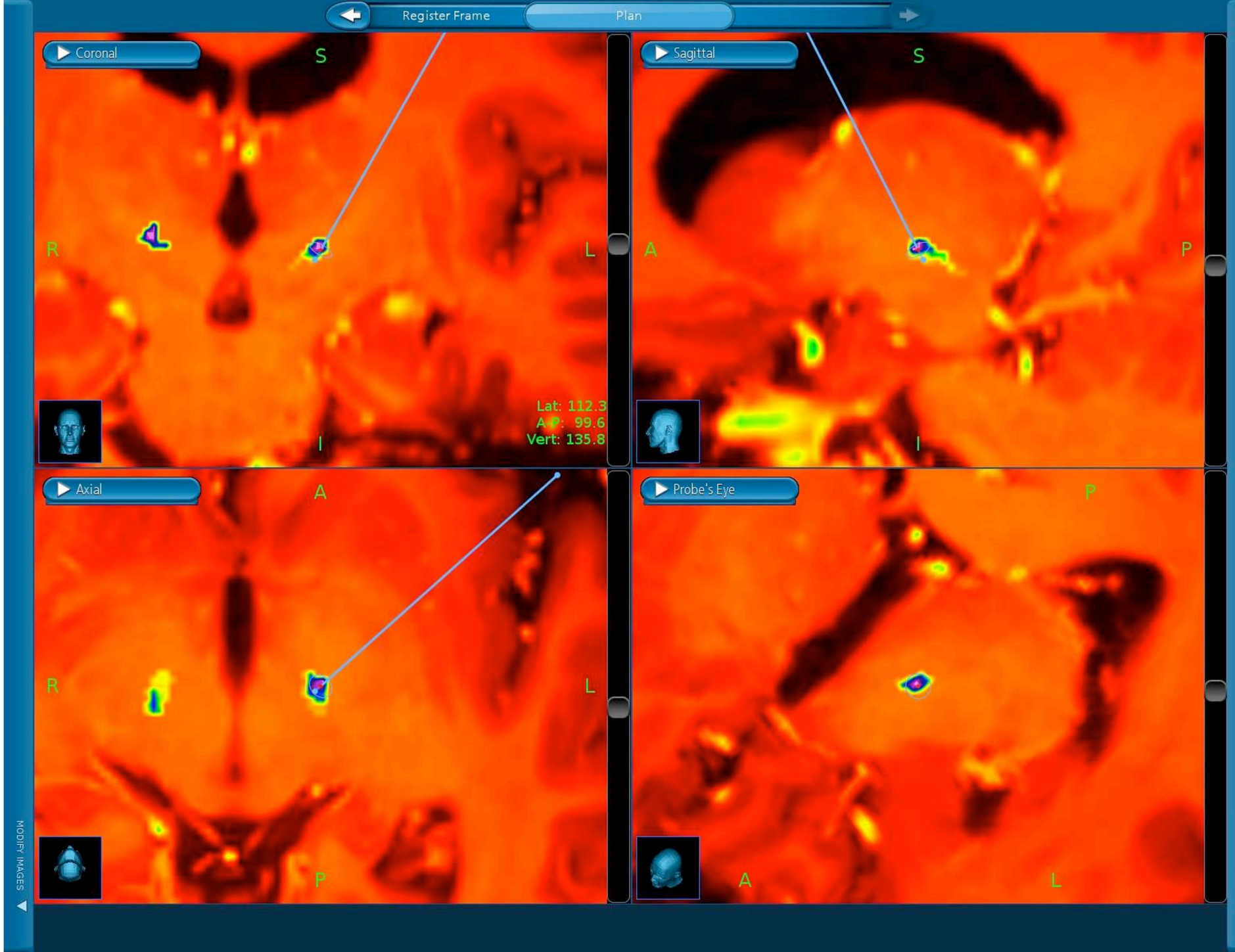


TARGETS IN MOVEMENT DISORDERS

- DBS is applied from the 1980s
- Parkinson’s disease:
- nucleus subthalamicus - STN
- internal globus pallidus - GPi
- thalamus nucleus ventralis intermedius - Vim (tremor)
- Essential tremor: thalamus ventrali intermedius
- Primary generalized and segmental dystonia - GPi

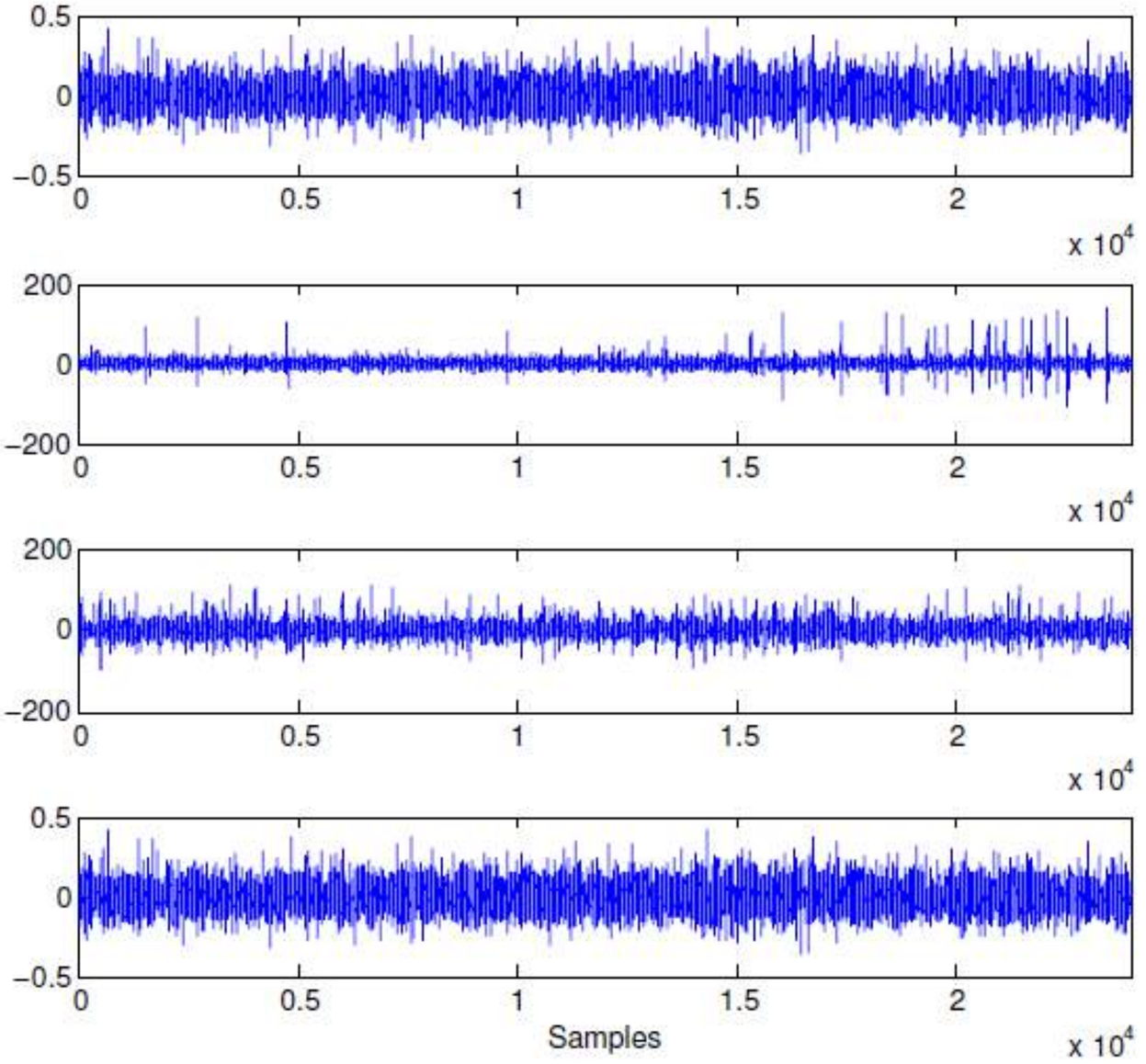
PLAN THE SURGERY

Preoperative planning



INTRAOPERATIVE MAPPING

The patient is usually awake



Thalamus

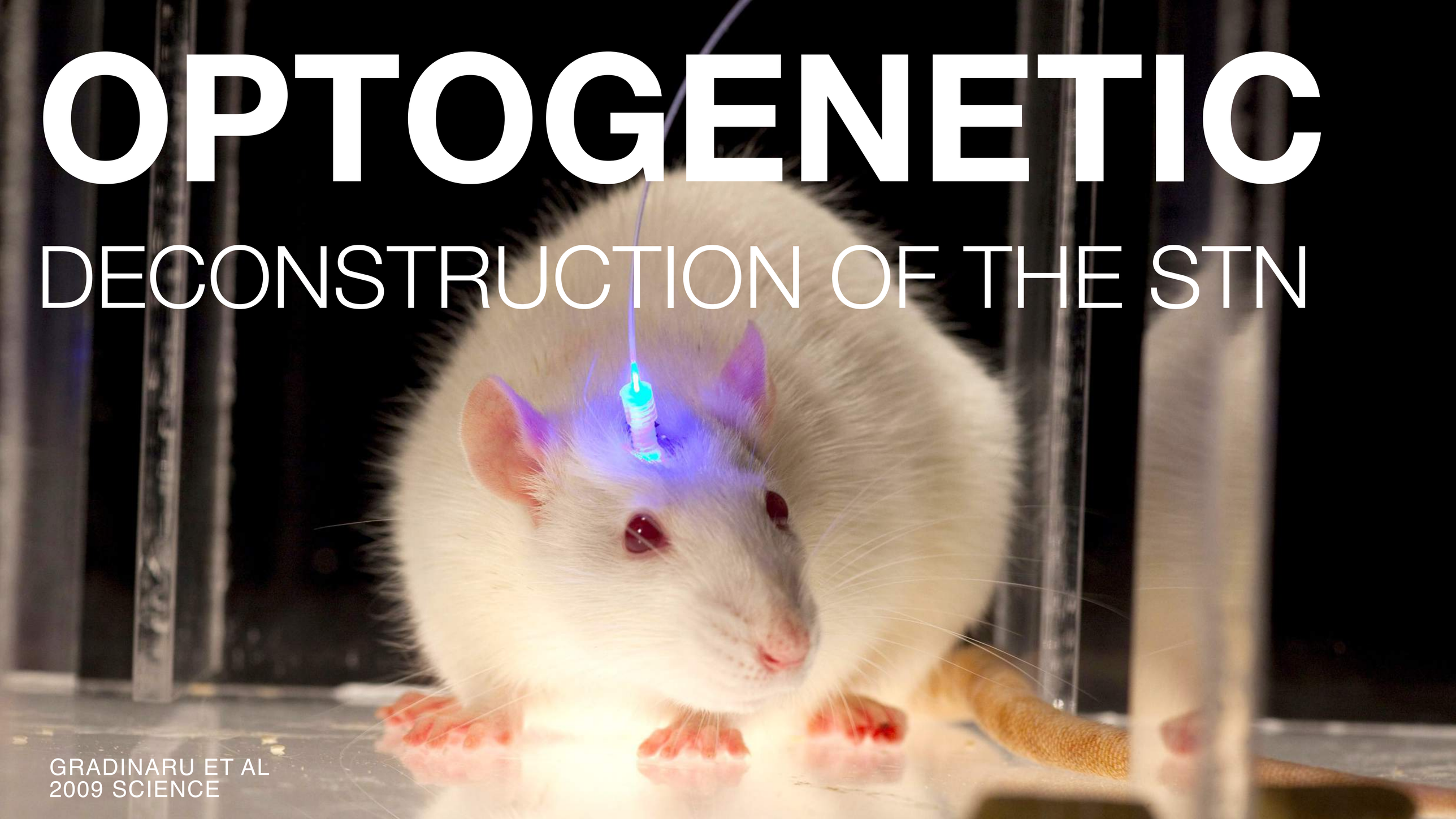
STN

SNr

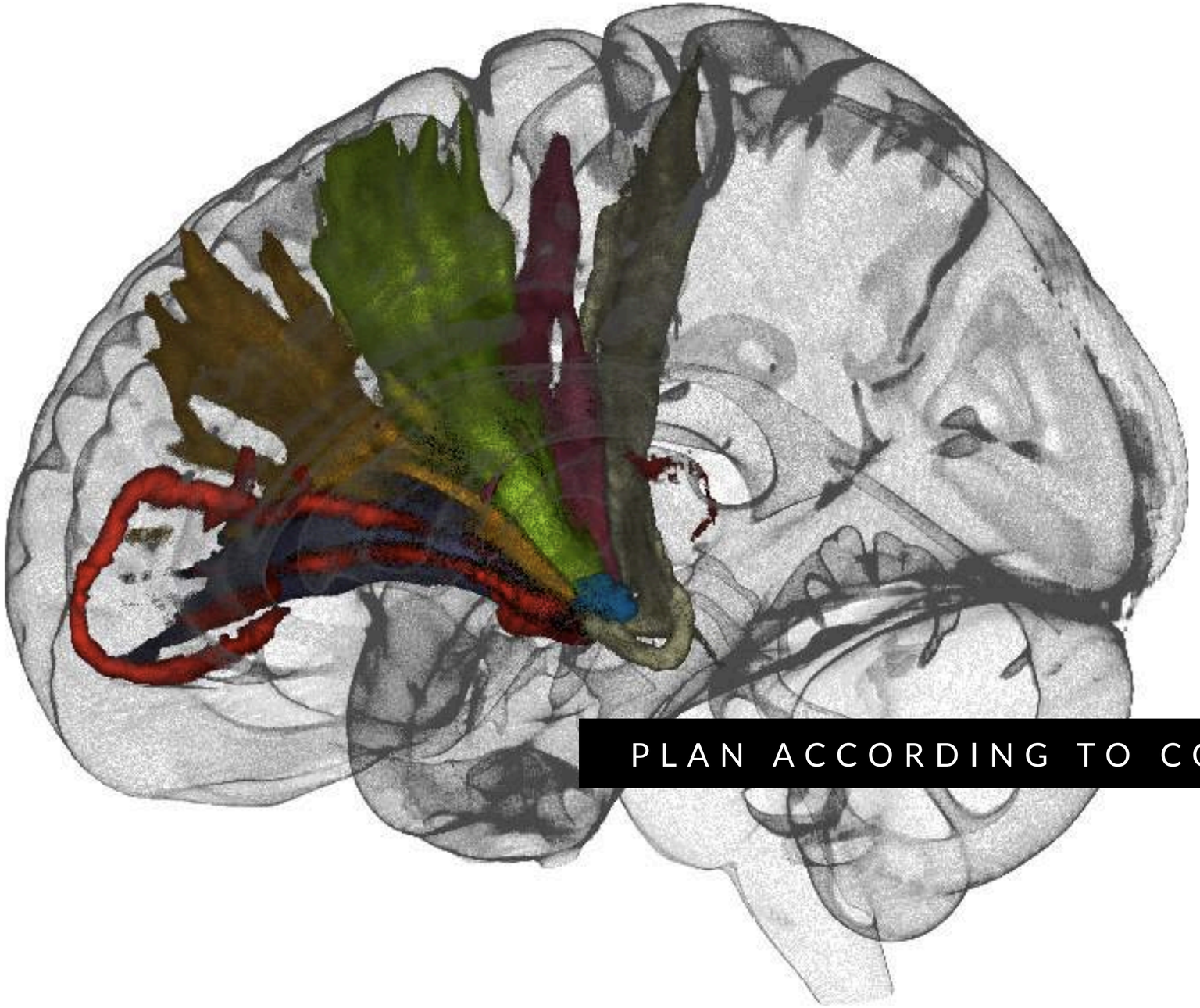
ZI

OPTOGENETIC

DECONSTRUCTION OF THE STN

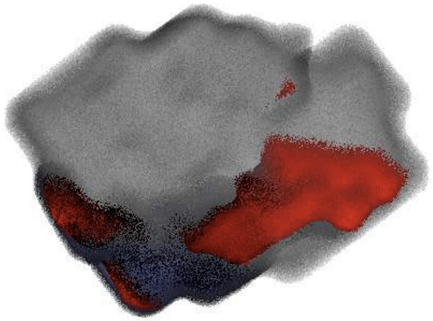


GRADINARU ET AL
2009 SCIENCE



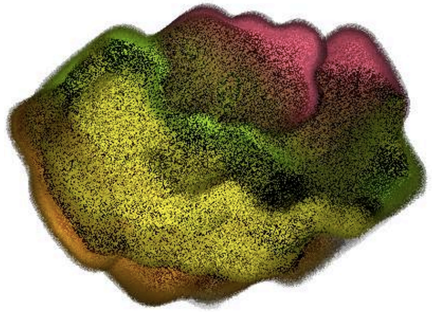
PLAN ACCORDING TO CONNECTIVITY MAPS

FUNKCIONAL CONNECTIVITIES OF THE STN



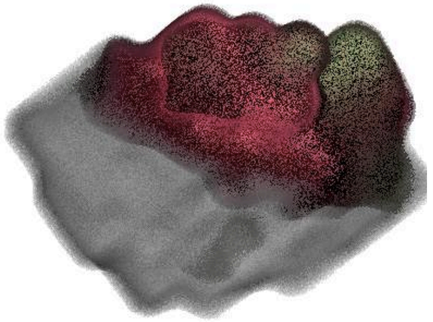
LIMBIC-ASSOCIATIVE

OFC, HIPPOCAMPUS,
AMYG, ACC, DLPFC



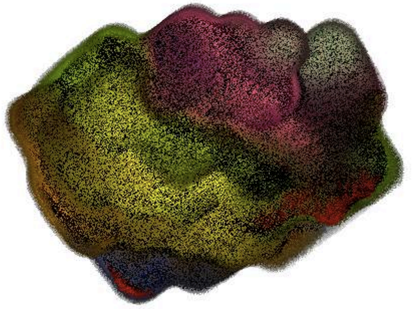
MOTOR REGIONS

PRESMA, SMA,
PREOMOTOR, M1



SENSORY-MOTOR

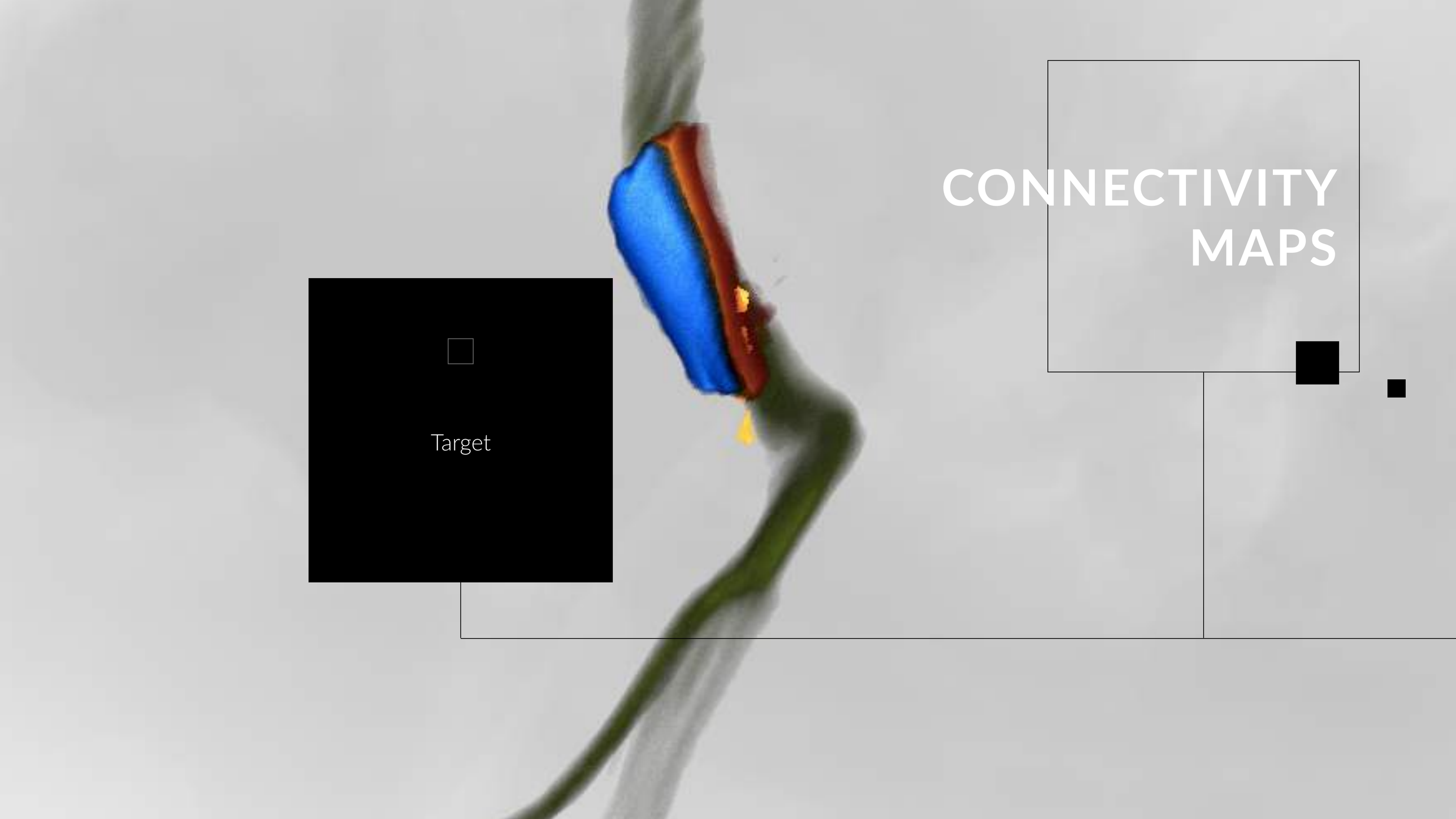
M1, S1

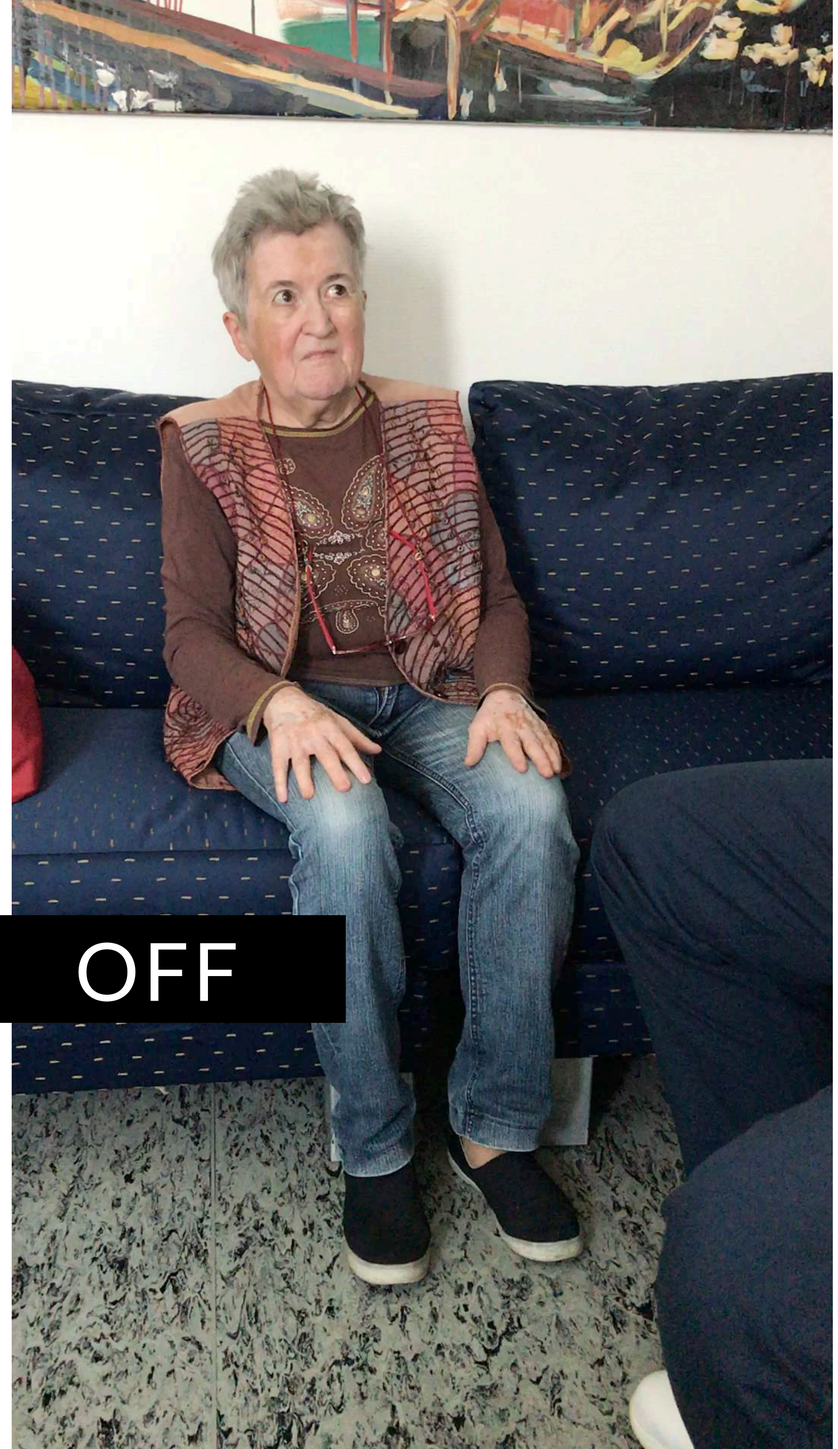


STN

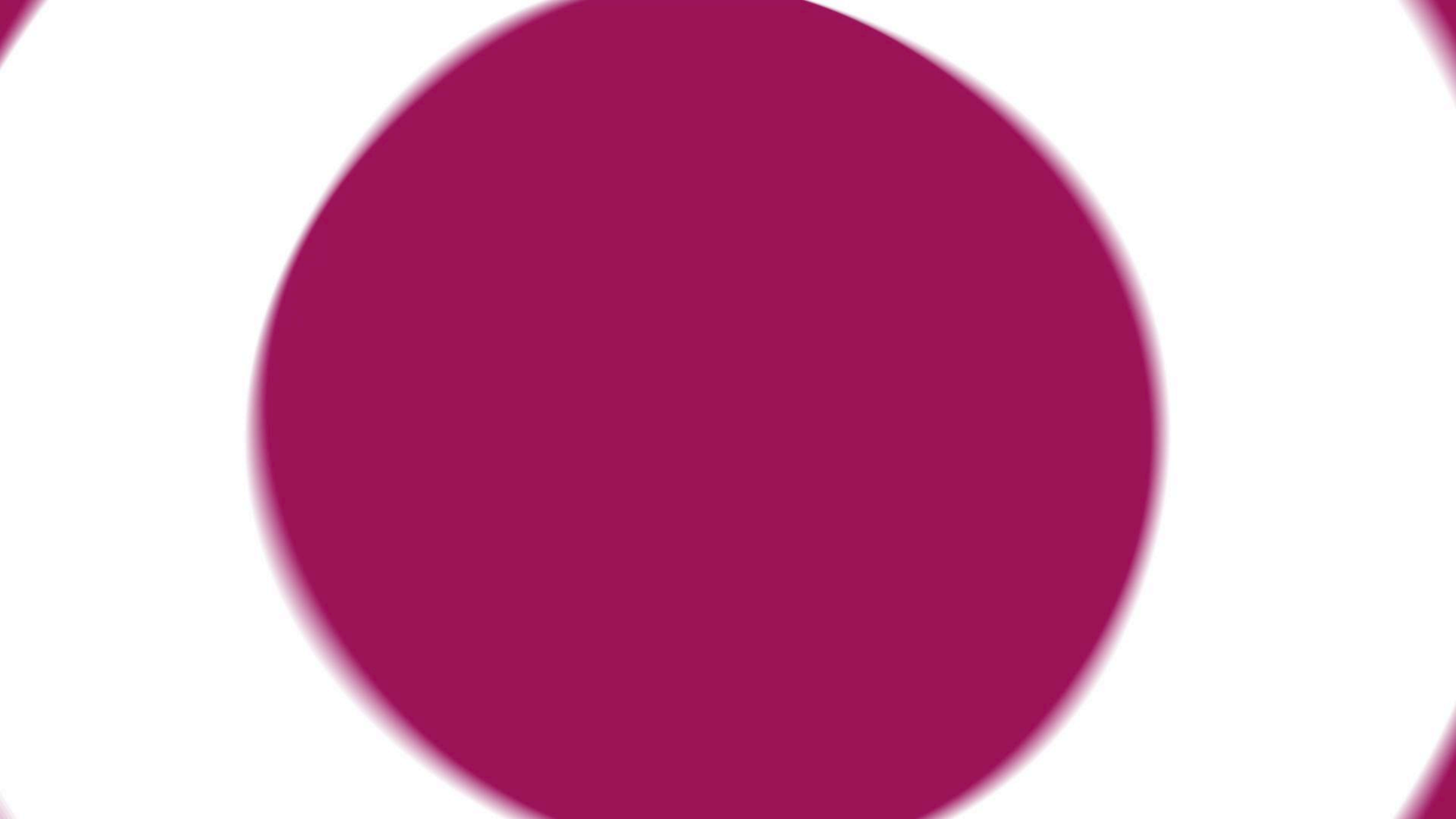
L. HALÁSZ ET AL

CONNECTIVITY MAPS




OFF


ON



INTRATHECAL DRUG DELIVERY

WHAT IS SPASTICITY?

- Spasticity is a disorder of the sensorimotor control resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles (EU-SPAZM Group, 2005)

CAUSES OF SPASTICITY

- CNS trauma
- Stroke
- Neurodegenerative diseases
- Mulptiple Sclerosis
- Clinical signs: gradual

CLINICAL SIGNS OF SPASTICITY

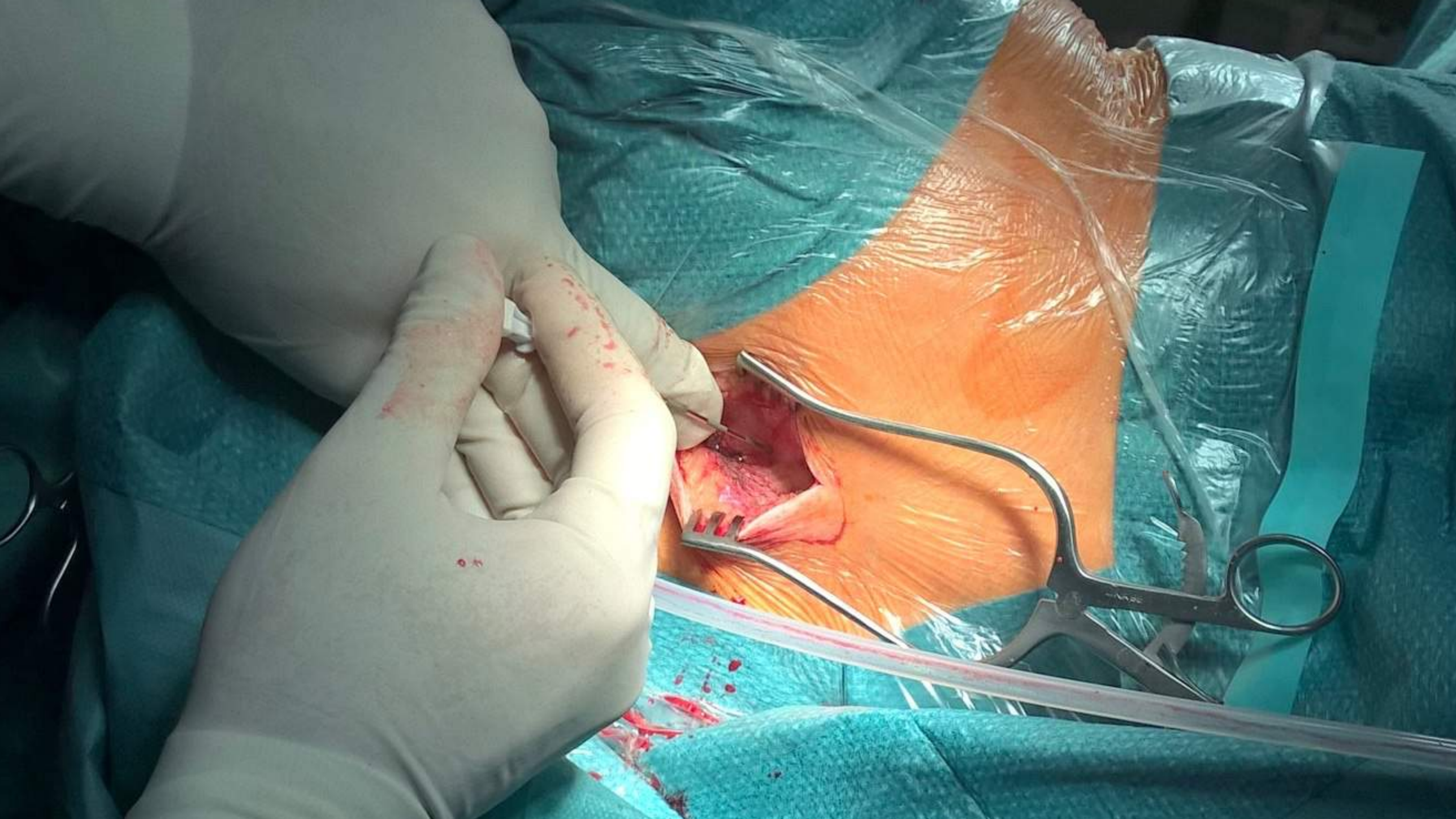
- worsening, hyperexcitability of sterch reflexes, cocontractions, abnormal postures

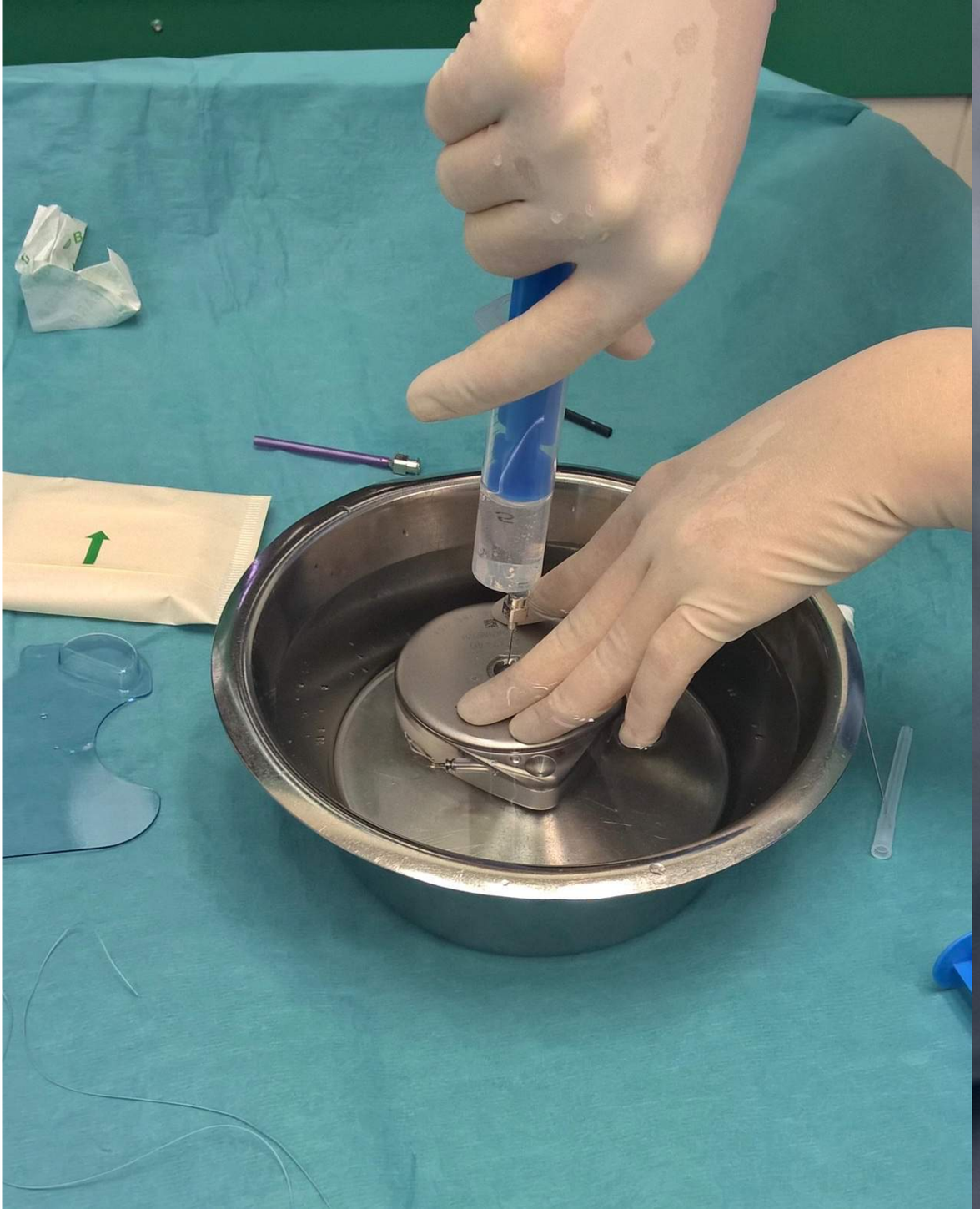
- UML: positive and negative signs (POS:spasticity, spazms, clonus, asssosiated reactions, poz. support reactions, brisk tendon reflexes, extensor plantar responses, NEG: weakness, reduced dexterity, reduced postural responses)

COMPLEX THERAPEUTIC OPTIONS

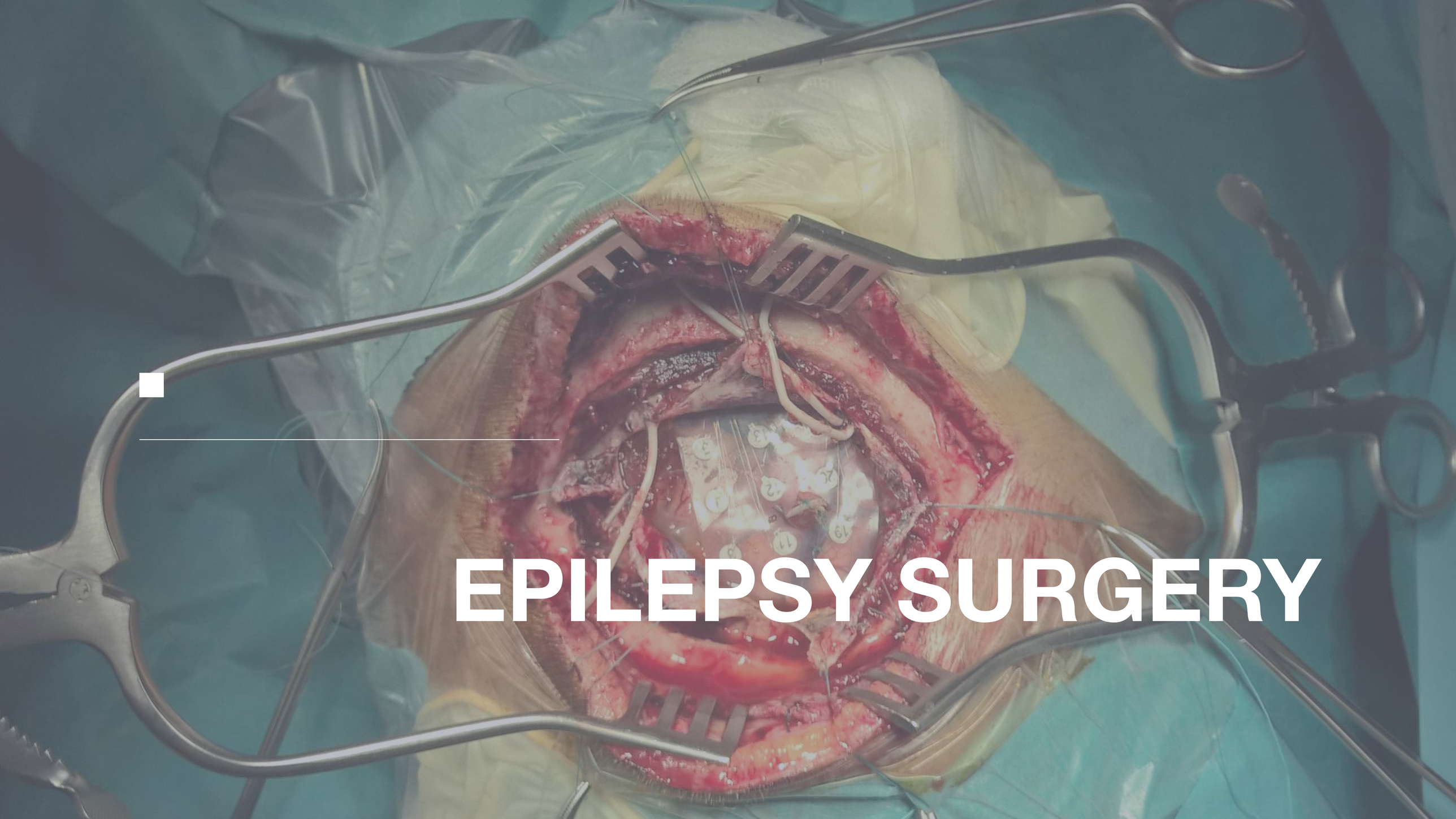
- Physiotherapy
- Oral drug therapy
- Focal botulinum toxin therapy
- Orthopedic deformity correction
- Neuroablative procedures
- Intrathecal Baclofen therapy


Medtronic
SYNCHROMED® II
Programmable Pump
8637-20






SYNCHROMED® II



EPILEPSY SURGERY

EPILEPSY & NETWORK

IDENTIFY THE SEIZURE ONSET ZONE

REMOVE THE EPILEPTOGENIC ZONE WITHOUT DOING ANY SEVERE NEUROLOGICAL DEFICIT

SURGICAL PROCEDURES

Lesionectomy

Topectomy

Standard surgeries: lobectomies, selective amygdalohipocampectomy

Extratemporal resections

Hemispherotomy

Callosocomissurotomy

MST

MULTIMODAL APPROACH

MR

PET

MAP

FMRI

HFO

CCEP

TRAC

NON-INVASIVE

HISTORY

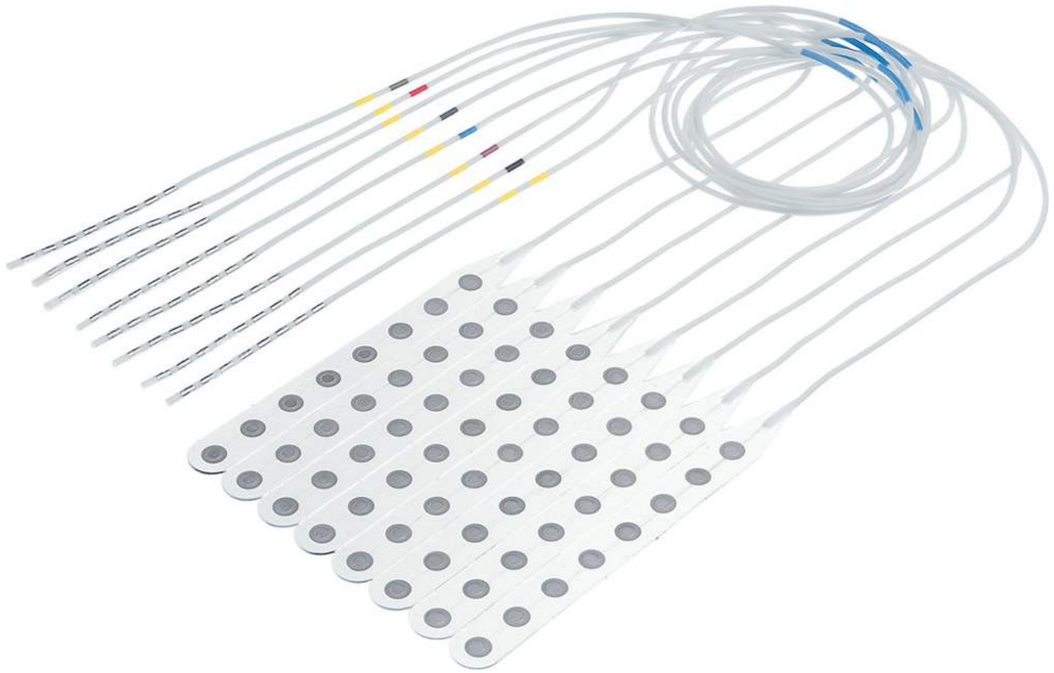
SEMIOLOGY

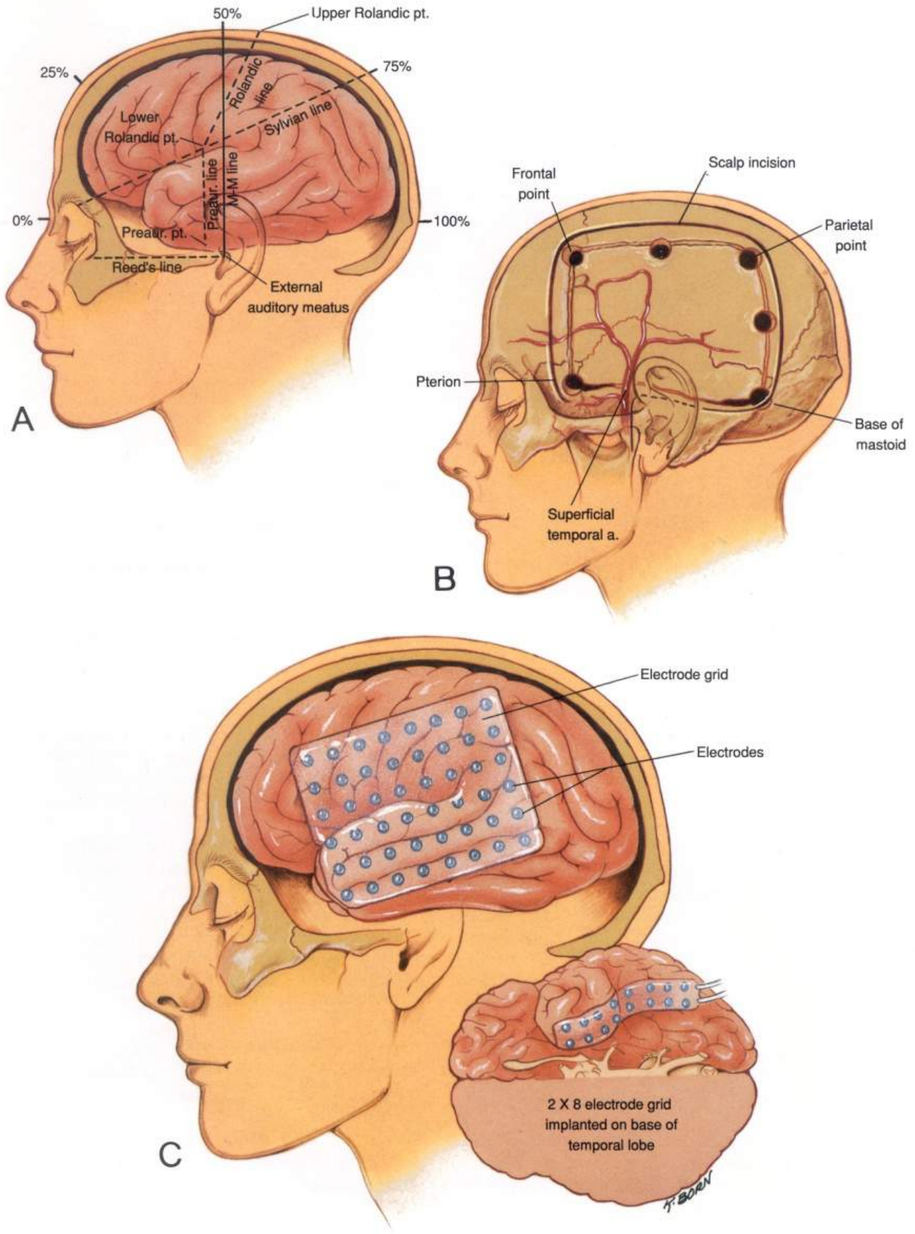
EEG

MRI

NEUROPSYCHOLOGY

FMRI, DTI, PET - CT/MR, SPECT, ASL, MAP07

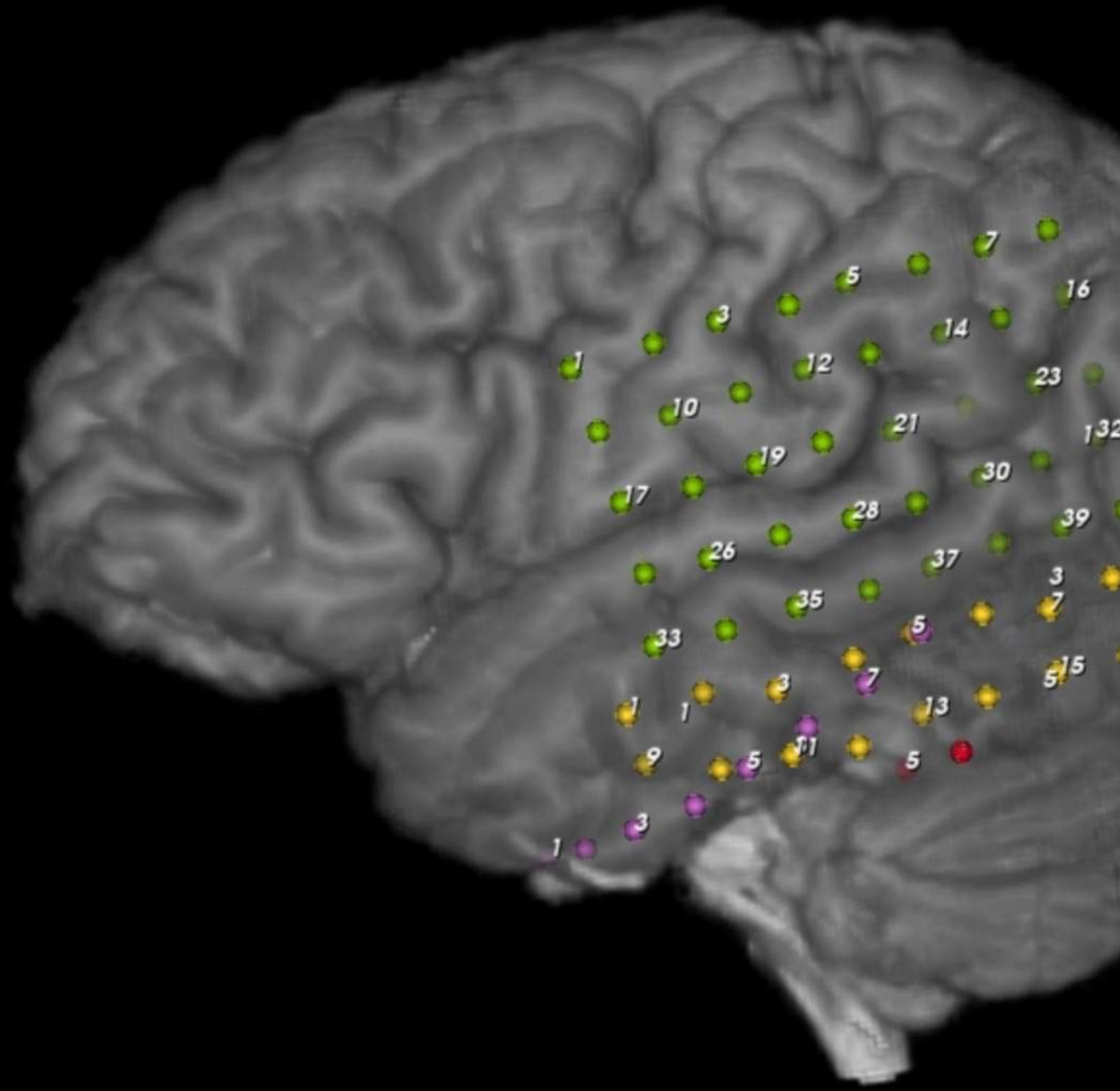


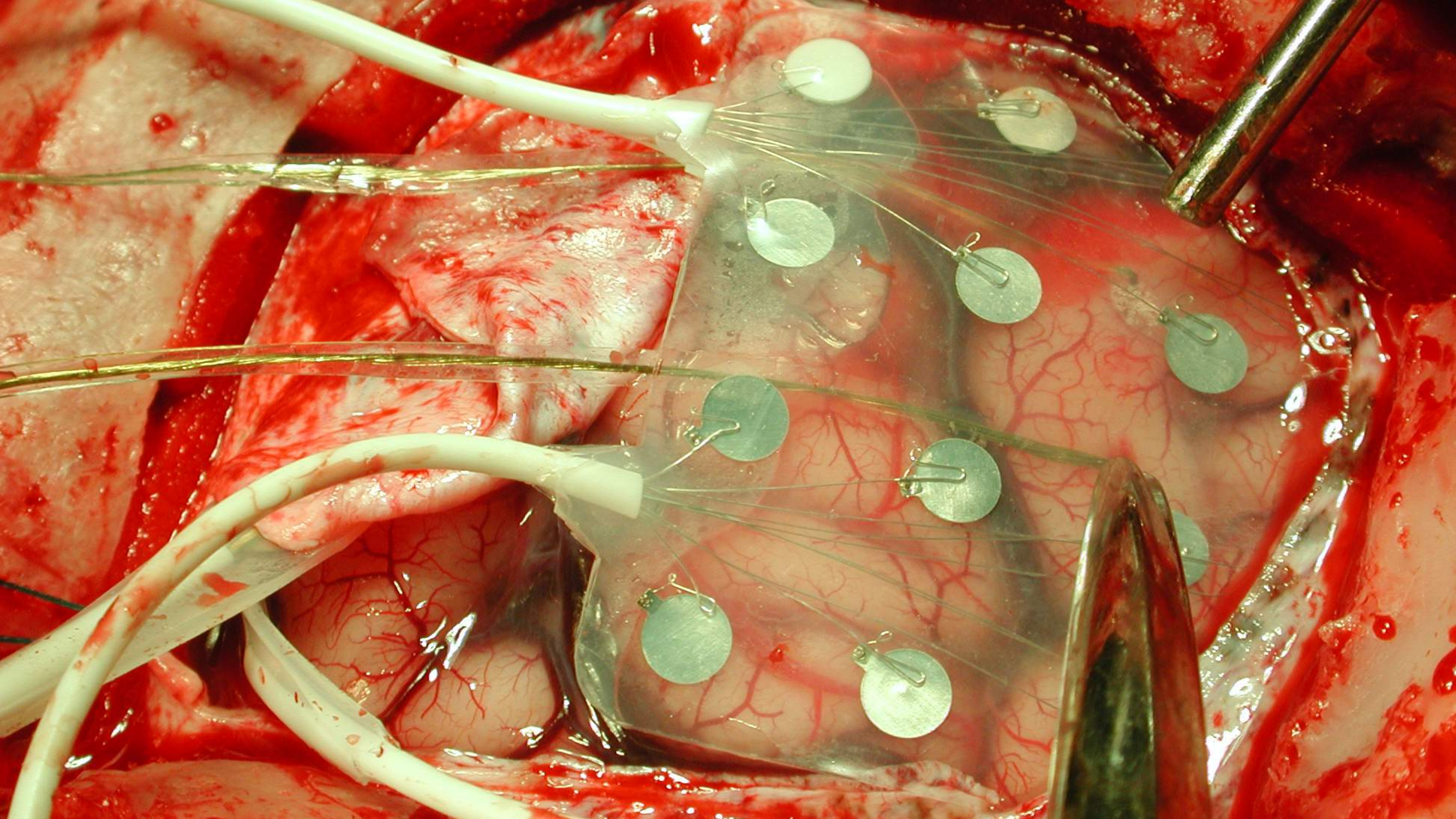

50%
Upper Rolandic pt.
25%
75%
Rolandic line
Sylvian line
Lower Rolandic pt.
Prearr. line
MFM line
0%
100%
Prearr. pt.
Reed's line
External auditory meatus
A
Frontal point
Scalp incision
Parietal point
Pterion
Base of mastoid
Superficial temporal a.
B
Electrode grid
Electrodes
2 X 8 electrode grid implanted on base of temporal lobe
C

INVASIVE MONITORING

SUBDURAL ELECTRODES

LOCALIZATION OF ELECTRODES

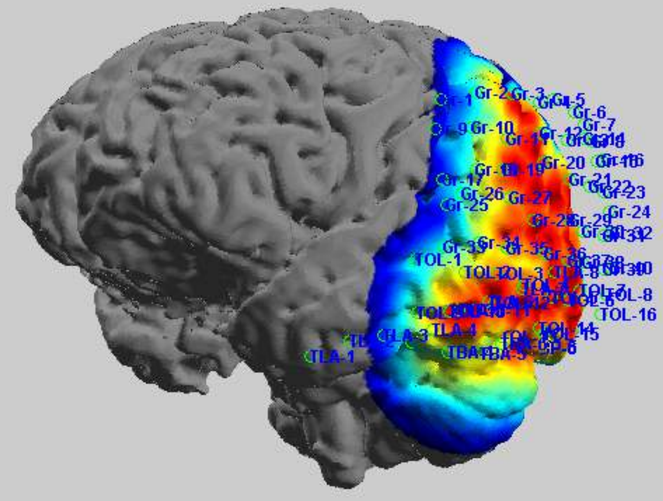


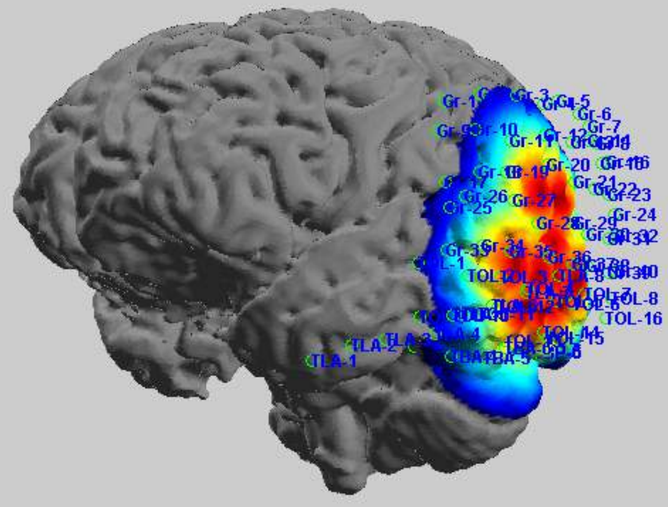


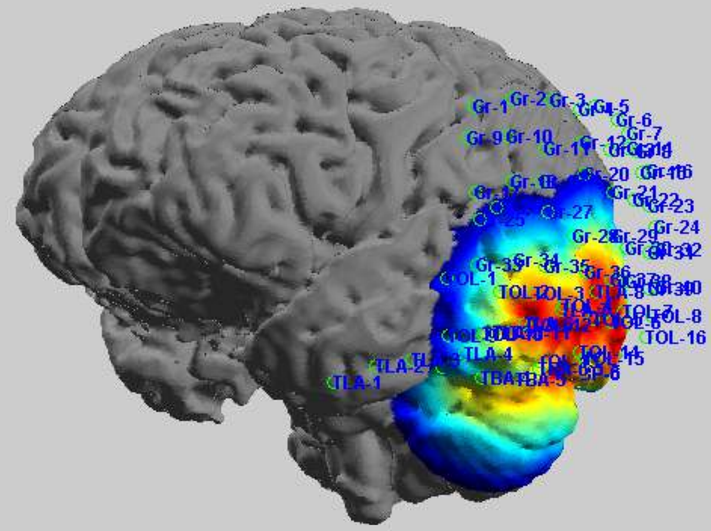
Spike map

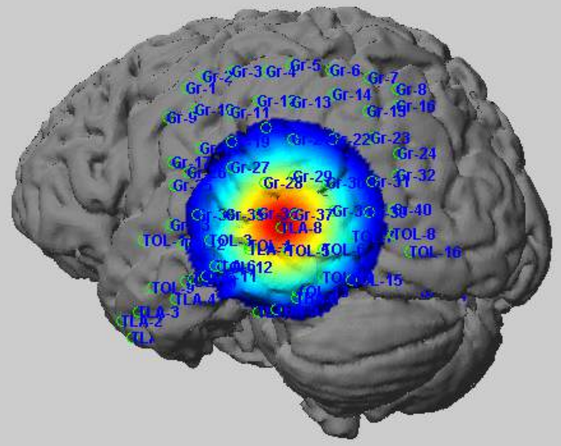
CCEP map

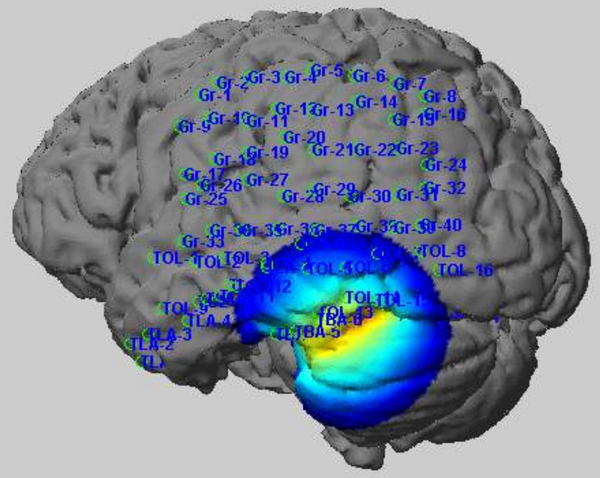
HFO map





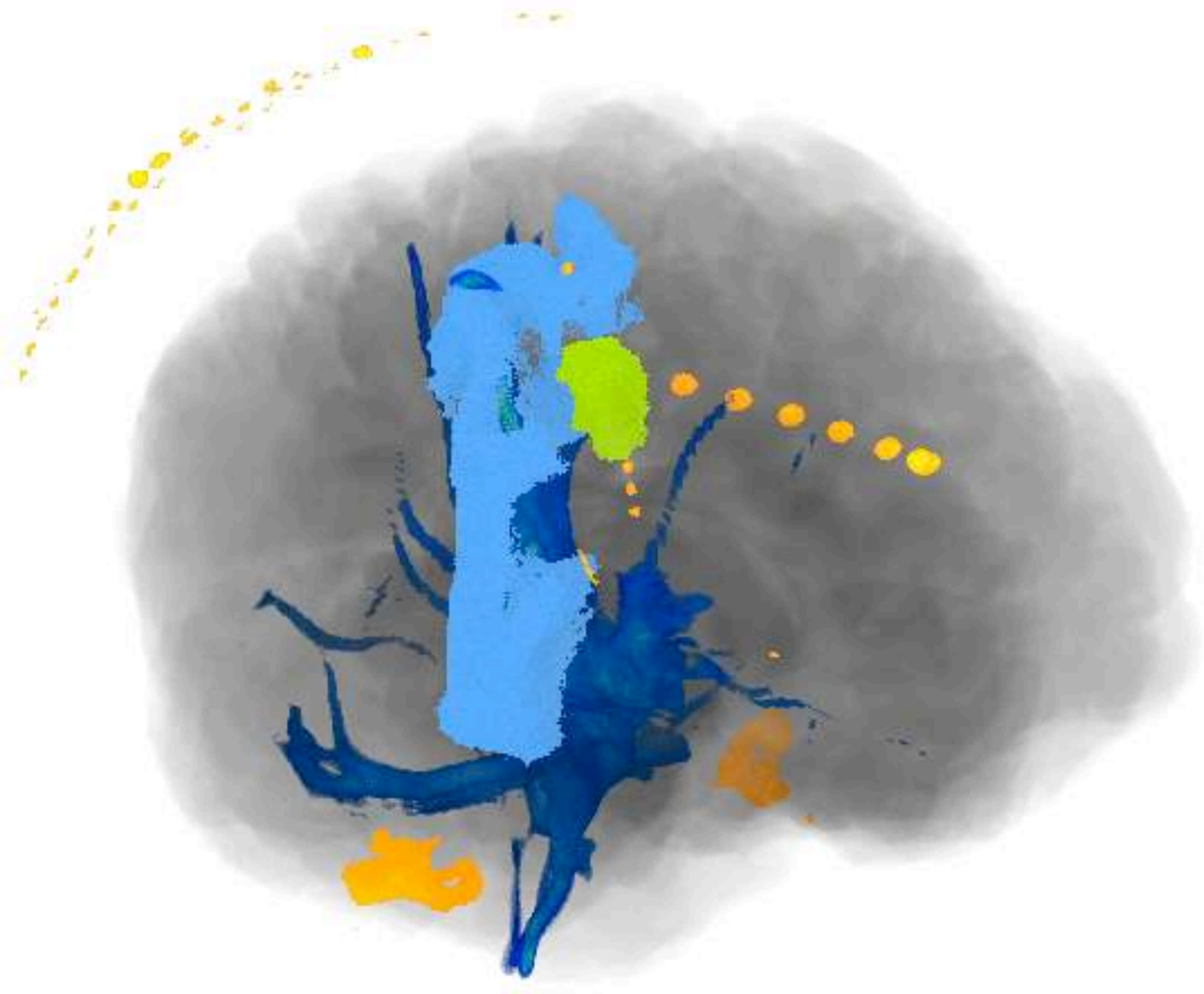




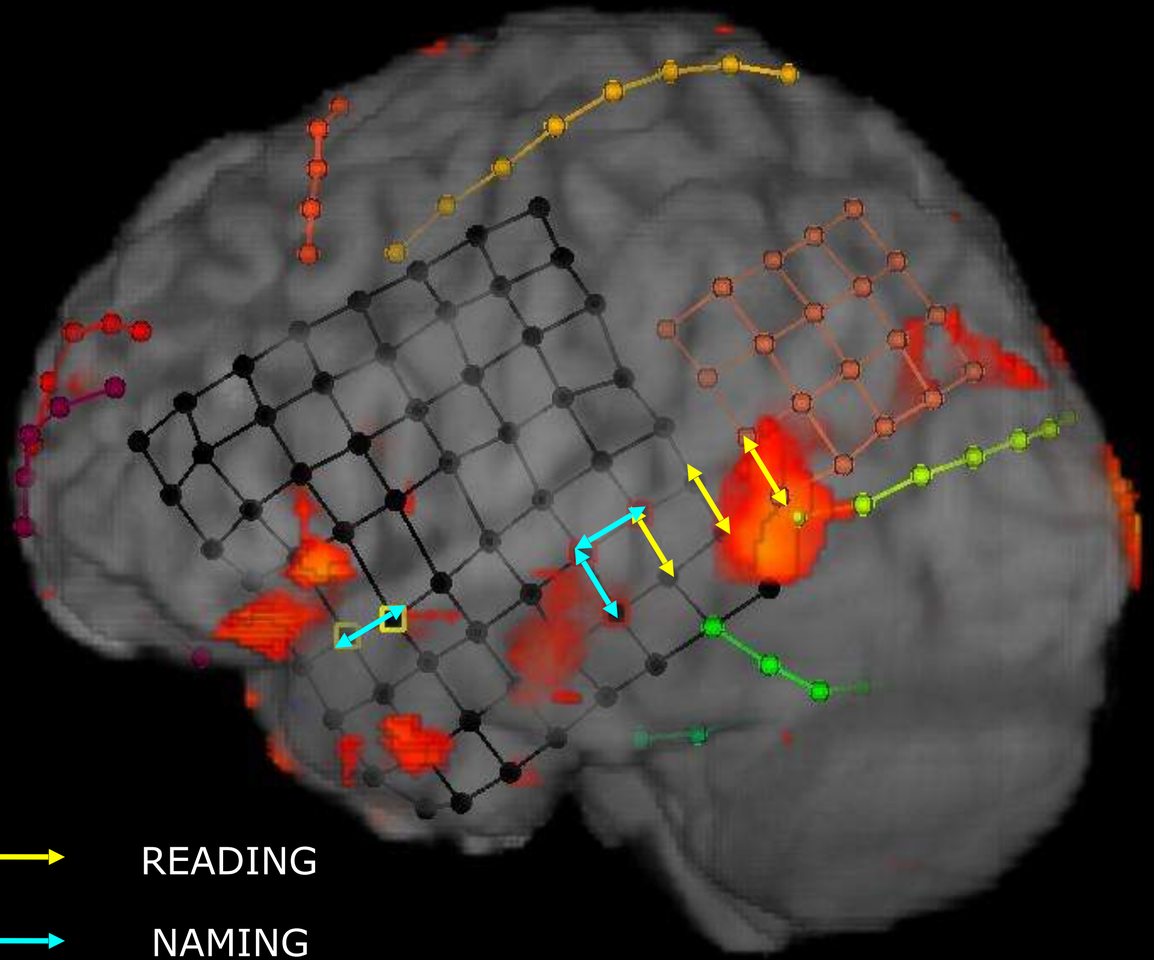


1. SEIZURE

2. SEIZURES



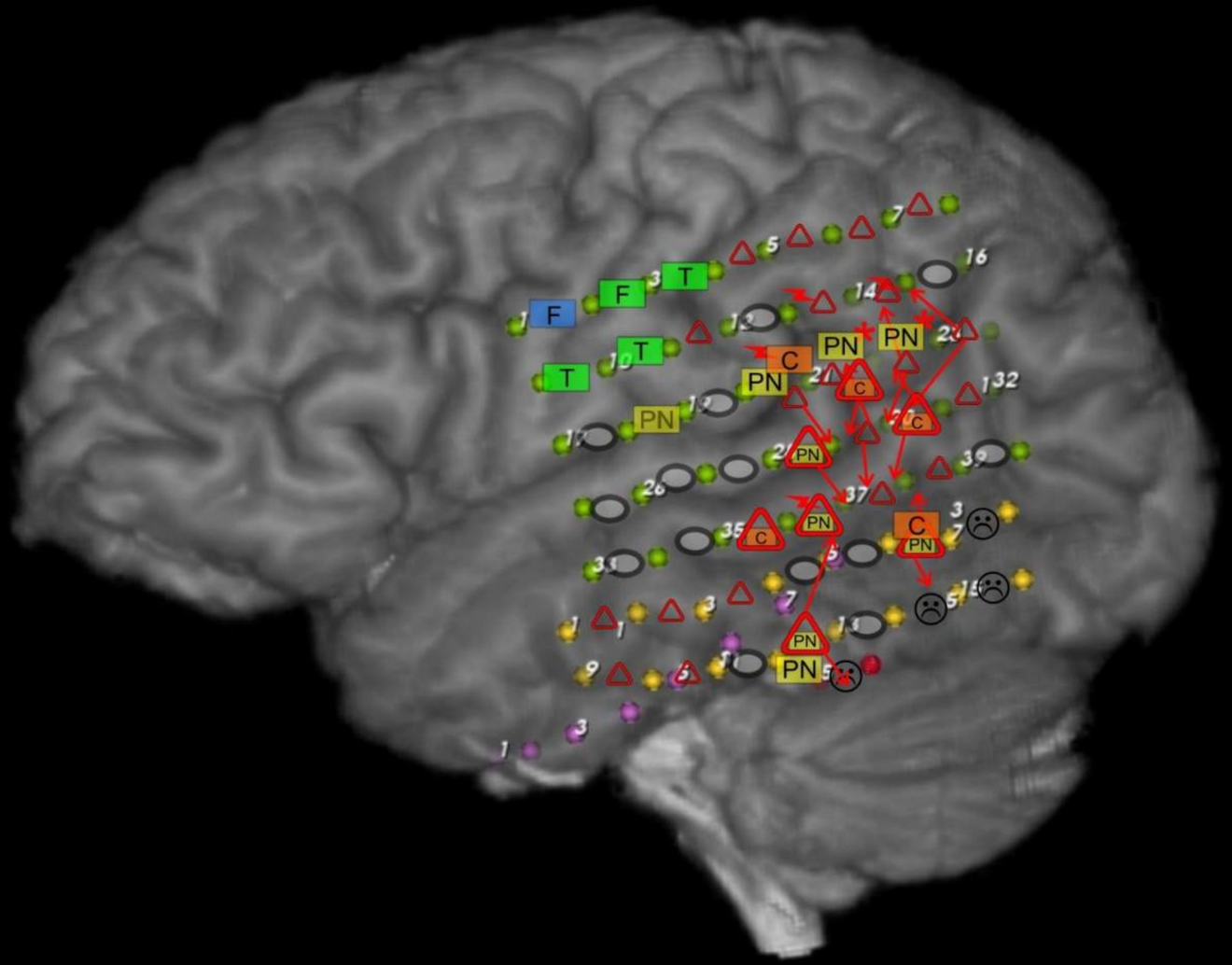
INTEGRATIVE APPROACH



READING

NAMING

INTEGRATIVE APPROACH



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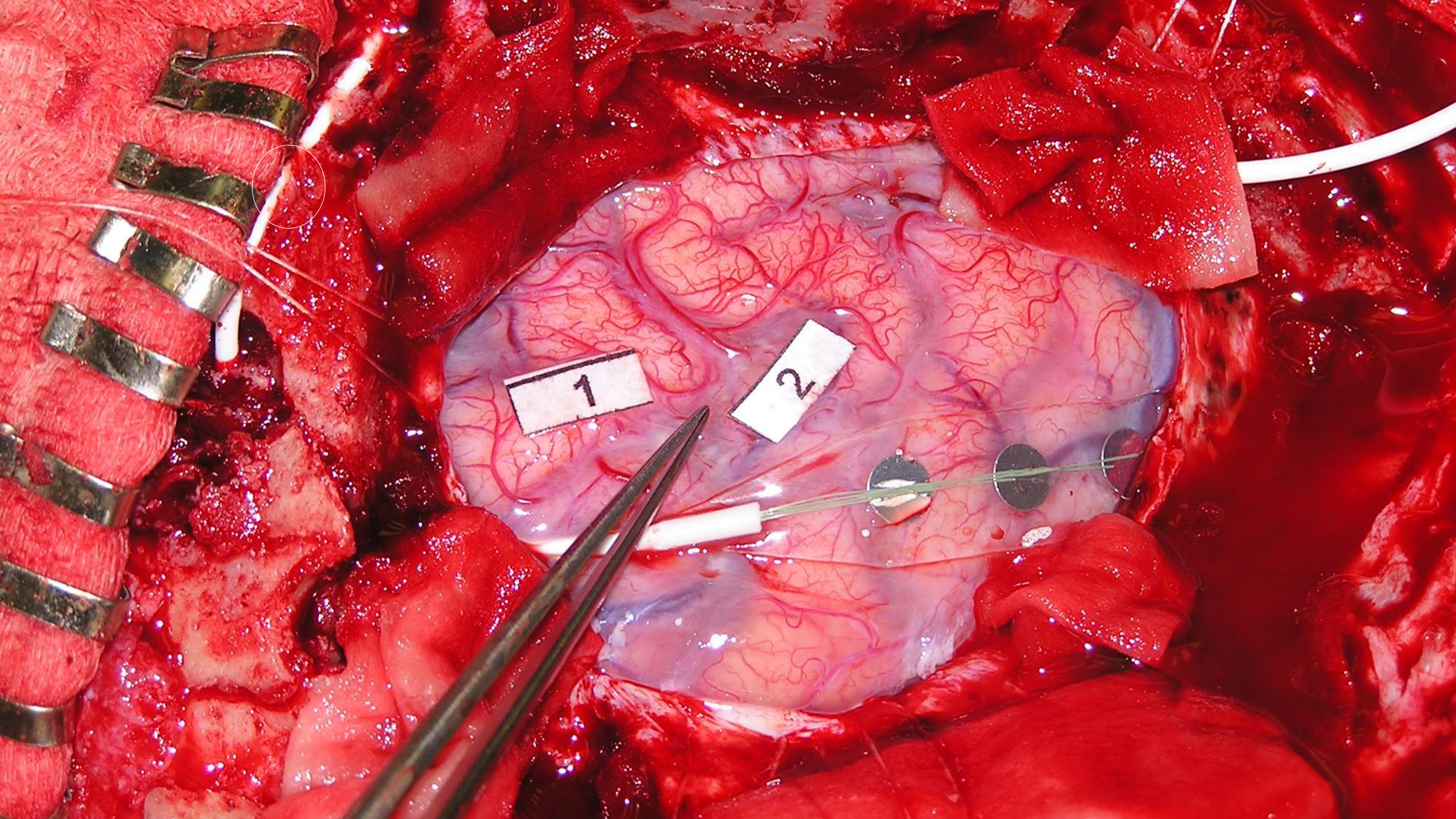
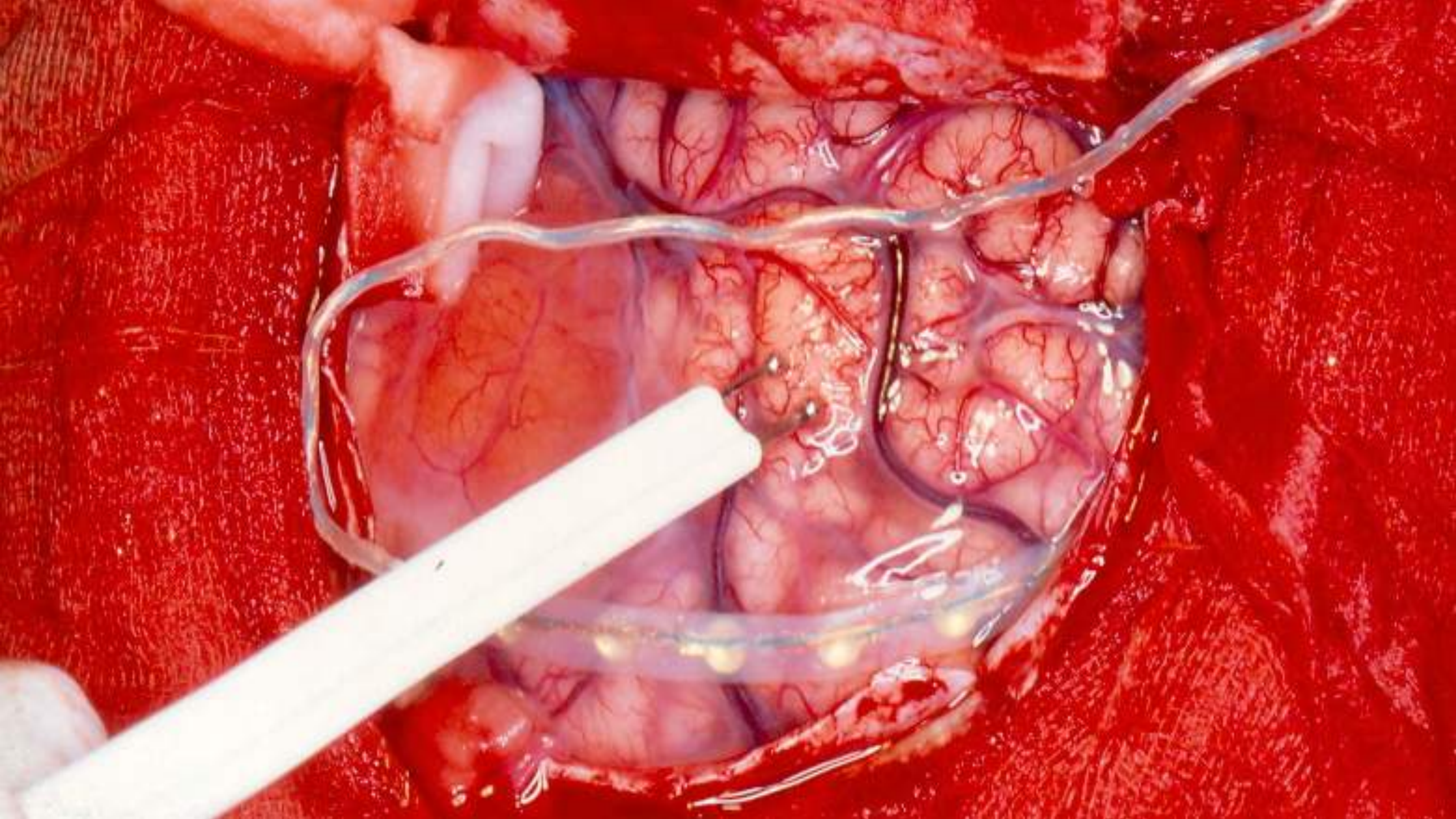

1
2



INTRAOPERATIVE STIMULATION