FUNCTIONAL NEUROSURGERY

DR. LÁSZLÓ HALÁSZ - DR. LORÁND ERŐSS NATIONAL INSTITUTE OF CLINICAL NEUROSCIENCES





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

PSYCHIATRIC DISORDERS

PAIN

EPILEPSY

MOVEMENT DISORDERS

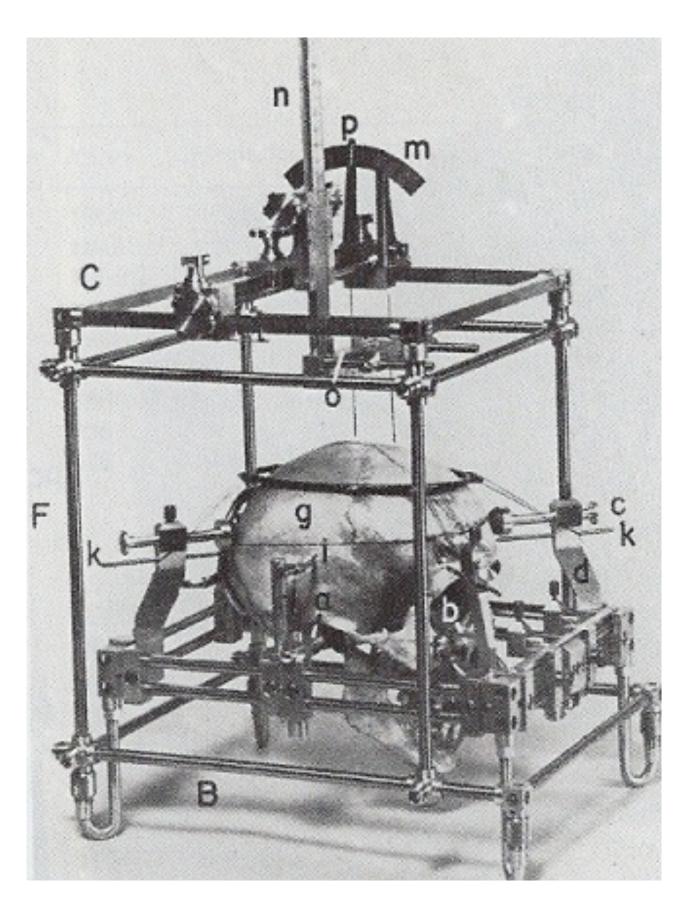
SPINAL SURGERY

SPASTICITY

STEREOTACTIC RADIOSURGERY

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 ulletneuromodulation (pumps)
- Pulse radiofrequency • procedures
- Neurovascular decompression ullet
- Introduce the advanced ulletfunctional neurosurgical practice for pain

ABLATIVE, PALLIATIVE

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



DORSAL ROOT ENTRY ZONE LESION

ULTRASONIC

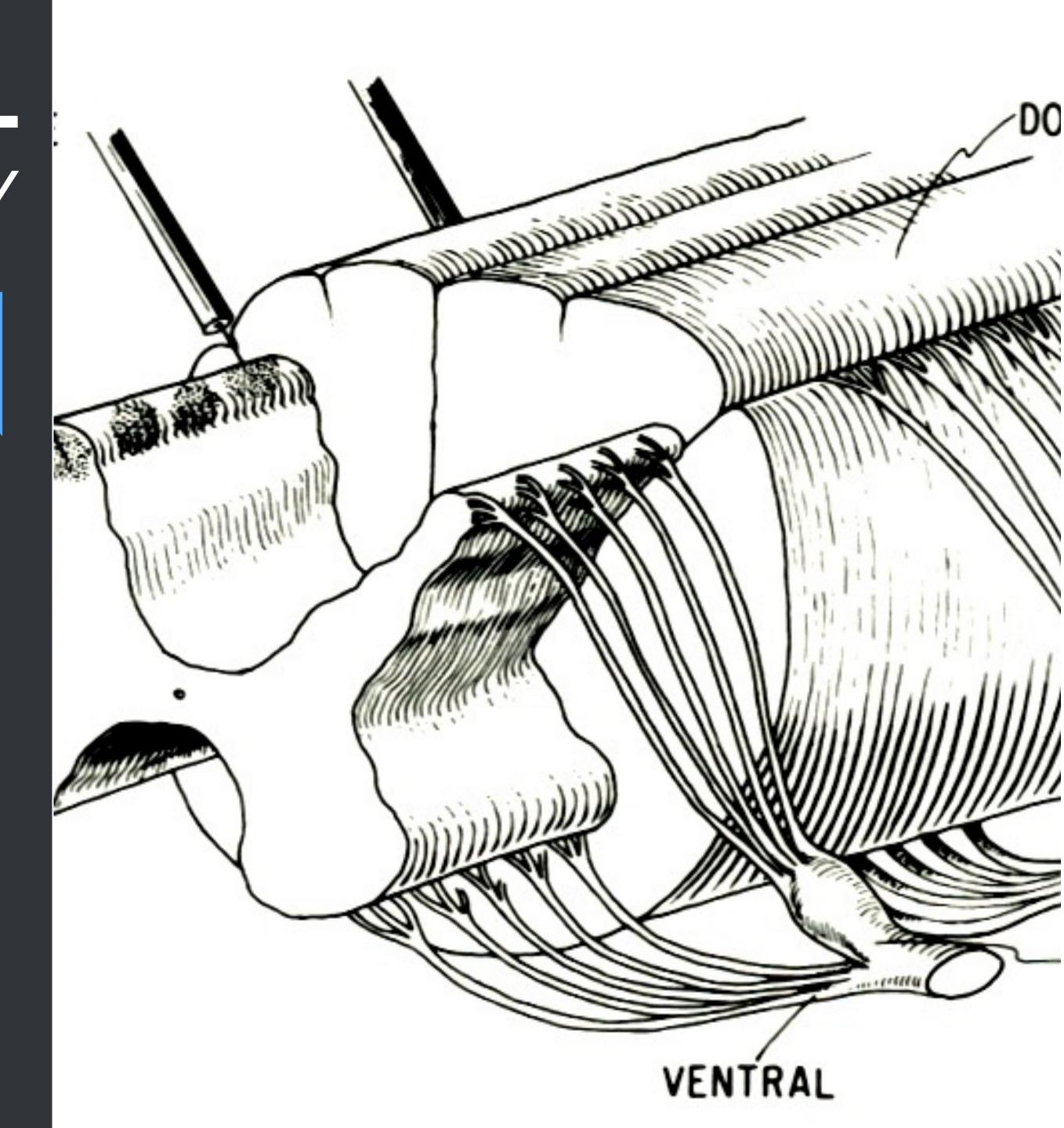
MICROSURGICAL RADIOFREQUENCY LESIONING



MICROSURGICAL DREZOTOMY

Indications:

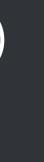
- Cancer pain limited in extent (Pancoast tumor)
- Unresectable intrinsic benign tumors of periferal nerves
- Persistent neuropathic pain due to brachial plexus avulsion
- Spinal cord lesion/trauma (segmental pain)
- Periferial nerve injuries (paroxysmal type and/or allodynia, hyperalgesia)



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!)

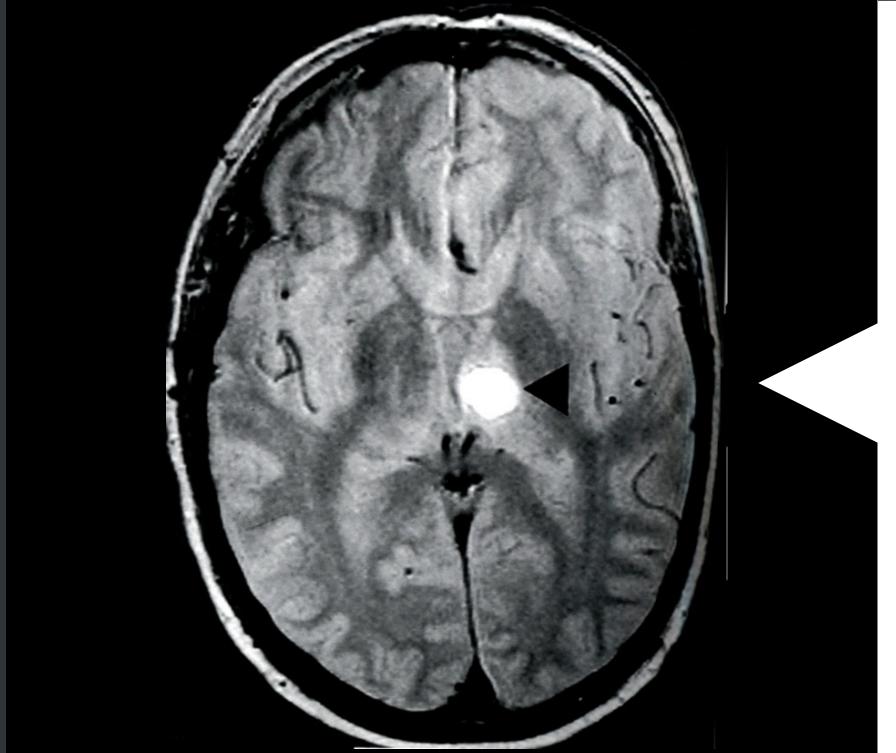
• Thoracic cordotomy:open

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



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

Induseum

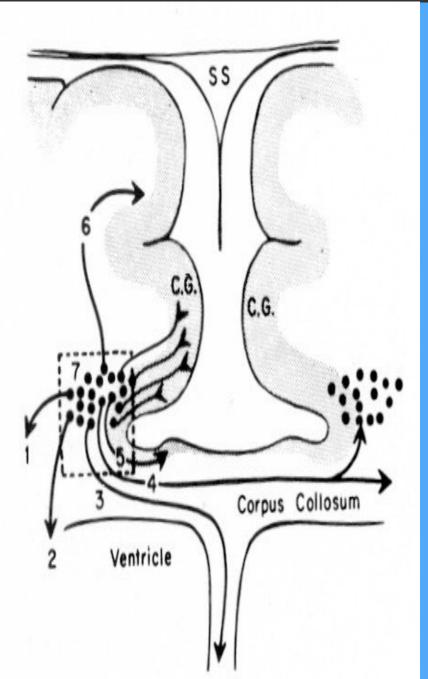
Uncinate fasciculus & Area 23 & 24 & Hippocampus

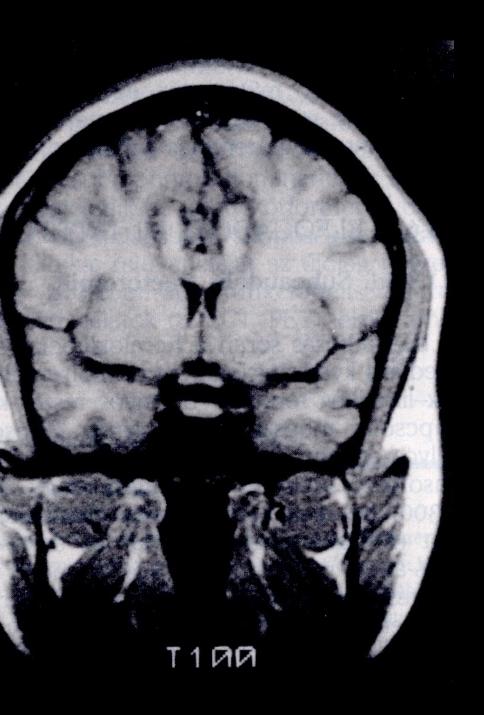
FRONTAL CINGULUM

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

> 5. "Medialmost" 6. Dorsal

> > 7. Cingulum





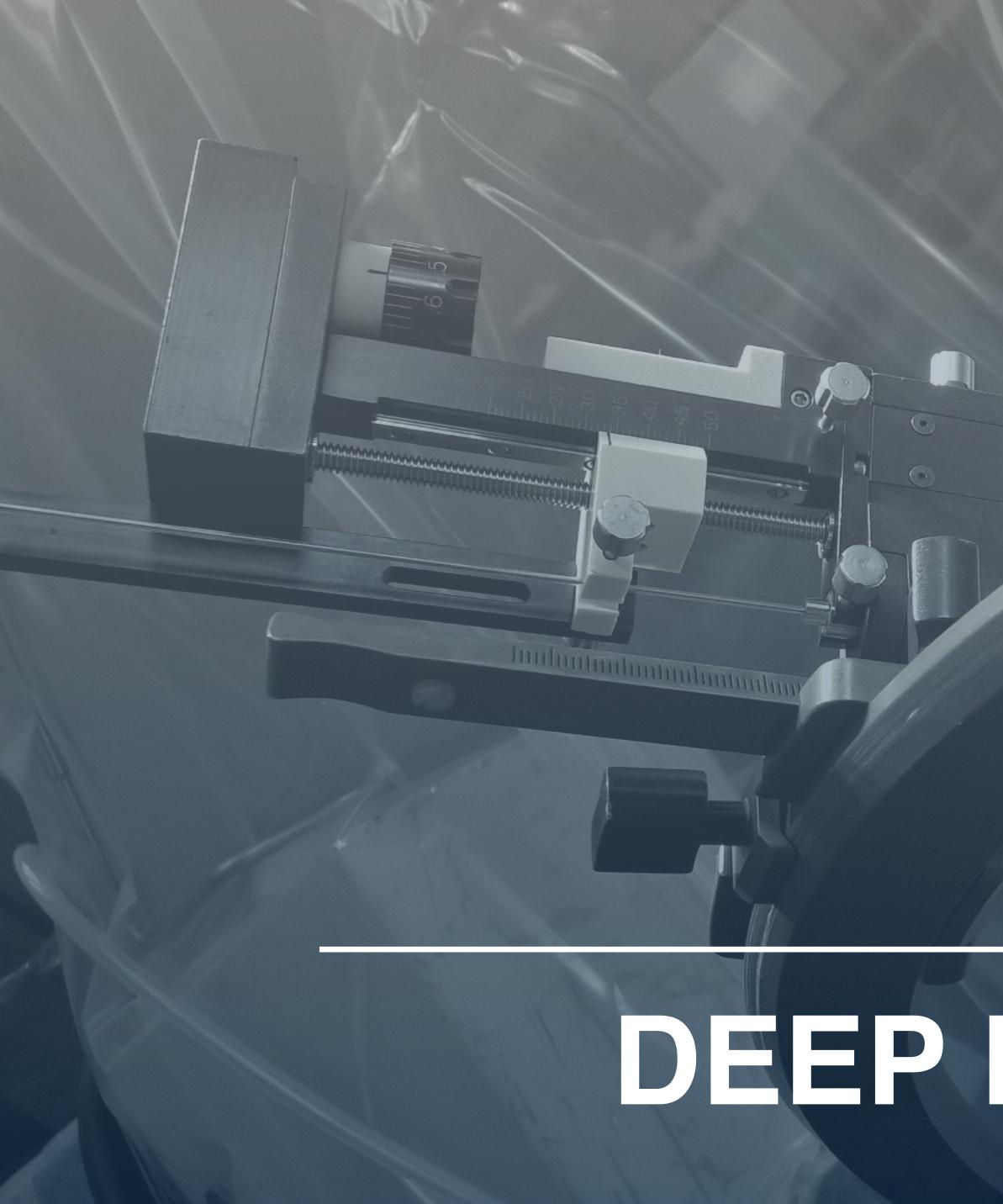
394 patient in the literature 53% useful vs.47% non useful (Burchiel 2005)

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.

FIBER RADIATIONS:

"Supralimbic" cortex



DEEP BRAIN STIMULATION

FOR CHRONIC PAIN





TARGETS FOR DBS

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

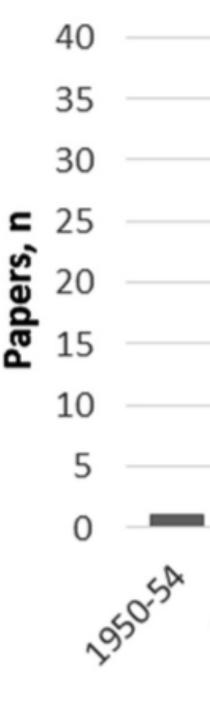


THALAMOTOMY

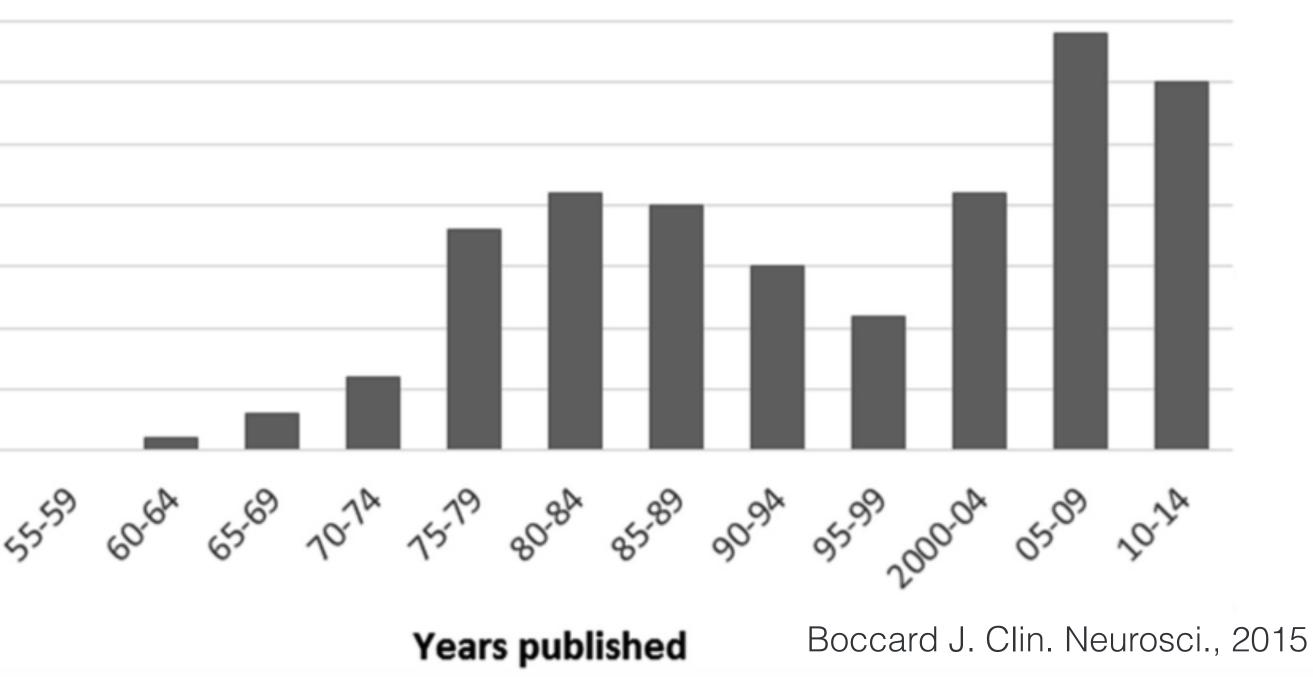
- nucleus anterior •
- nucleus dorsomedialis
- nucleus limitans
- primary somatosensory nuclei (VPL • and VPM)
- centromedian-parafascicular complex •
- nucleus centrolateralis ullet
- periventricular grey \bullet
- pulvinar



DBS FOR CHRONIC PAIN .



Published Papers on DBS for Chronic Pain



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

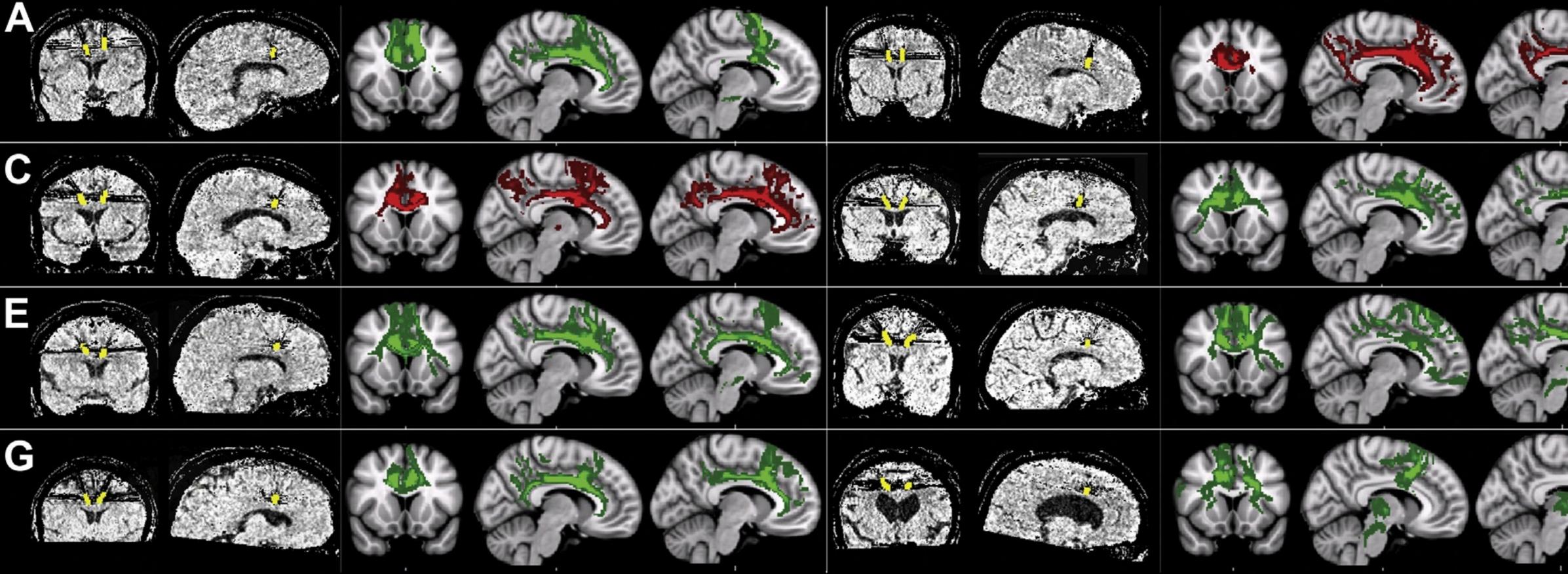
Periventricular | Periaqueductal grey matter - 79% PVG | PAG + Sensory thalamus or internal capsule - 87% Sensory thalamus alone - 58%

Bittar J. Clin. Neurosci., 2005









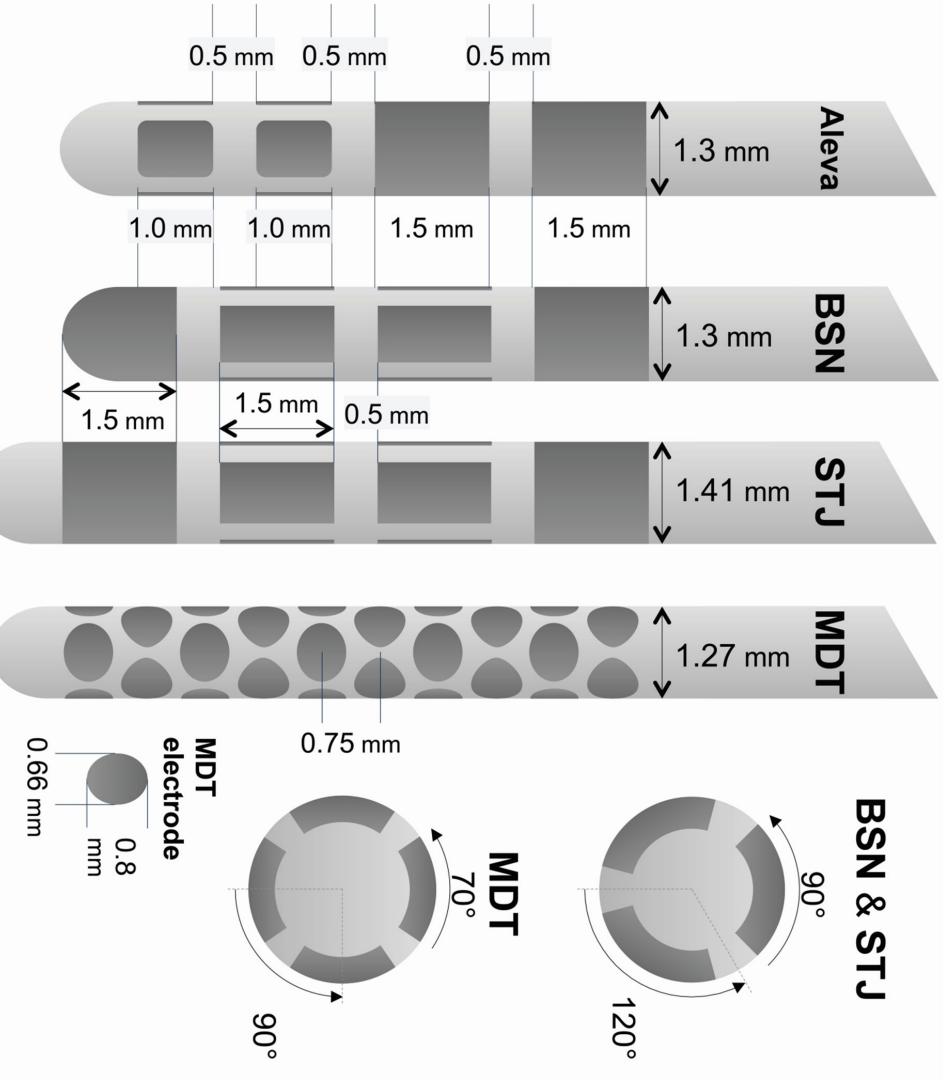
Localizing precise targets using probabilistic tractography Stimulating portion of the **ANTERIOR CINGULATE CORTEX** that has strong connectivity to the **PRECUNEUS** results in **WORSE OUTCOME (2)** Stimulating portion of the **ANTERIOR CINGULATE CORTEX** that has strong connectivity to the **BRAINSTEM**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

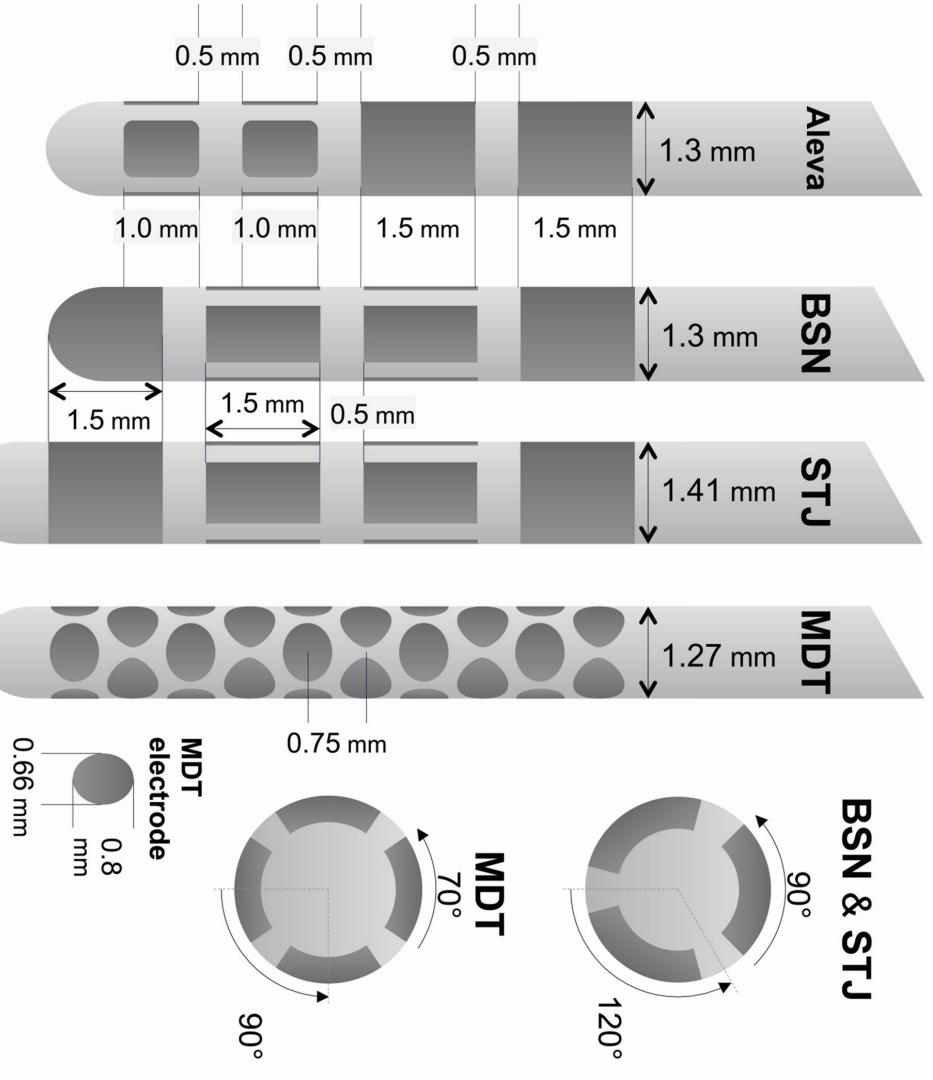
TECHNICAL ADVANCEMENTS IN DBS

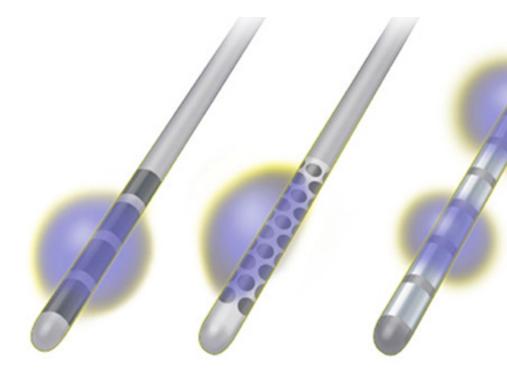
Boccard et al. World neurosurgery, 2016



TECHNICAL ADVANCMENTS IN DBS







Current steering with directional electrodes (Pollo et al Brain 2014)

٠

•

- Dual stimulation in different target structures in the brain (Sims-Williams et al. 2013) Streotact Funct Neurosurger)
- New stimulation paradigms





MOTOR CORTEX STIMULATION

FOR CHRONIC PAIN





PRIMARY MOTOR CORTEX STIMULATION "PANACEA OR PLACEBO" R.LEVY NEUROMODULATION 2014 JUNE

Tsubokawa 1991 central deaferentation pain

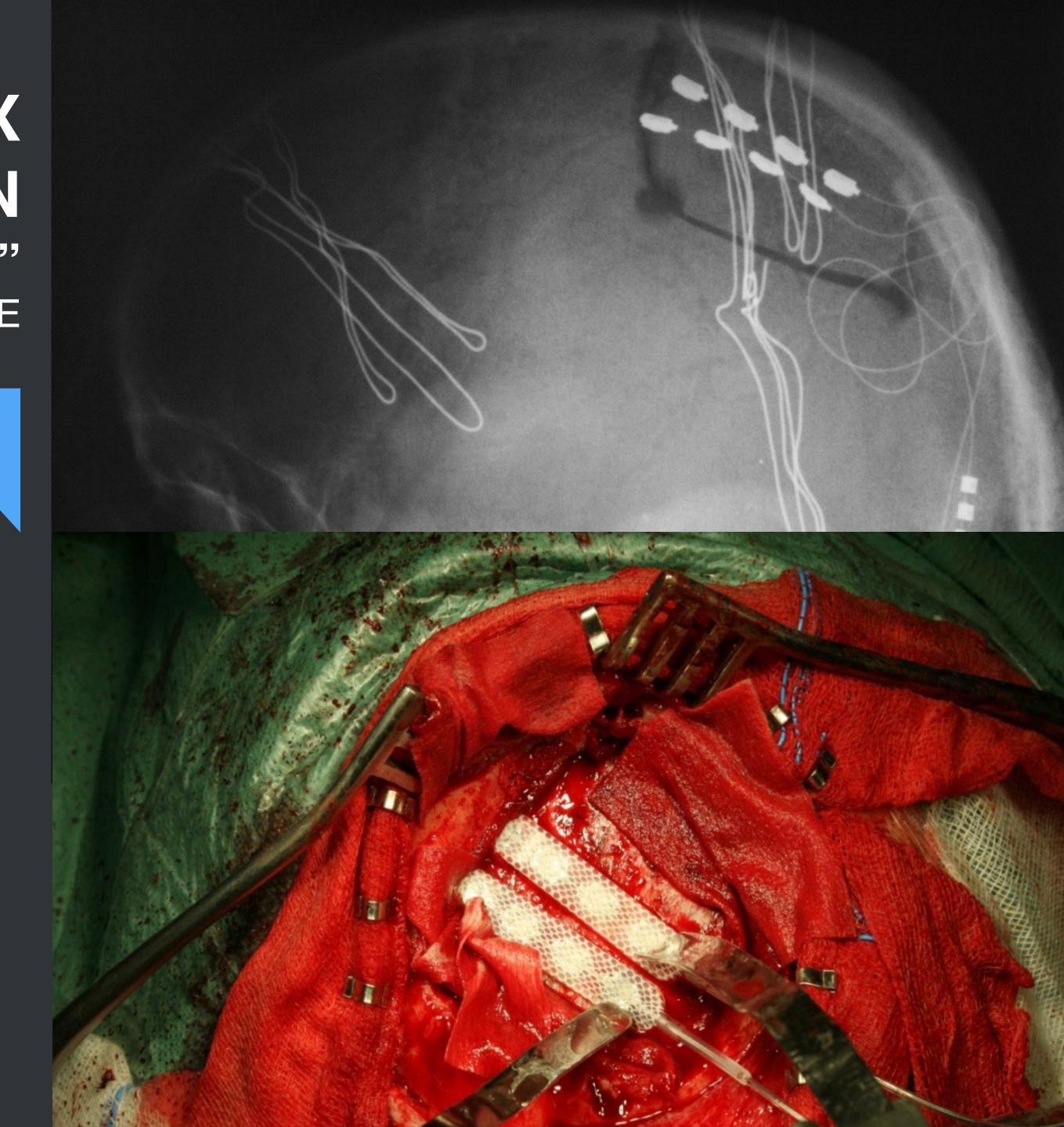
Meyerson 1993

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



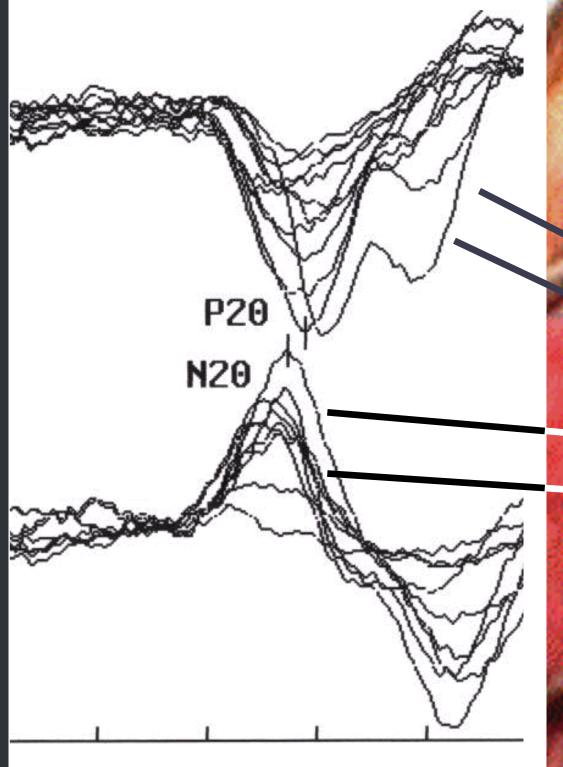
PRIMARY MOTOR CORTEX STIMULATION INDICATIONS

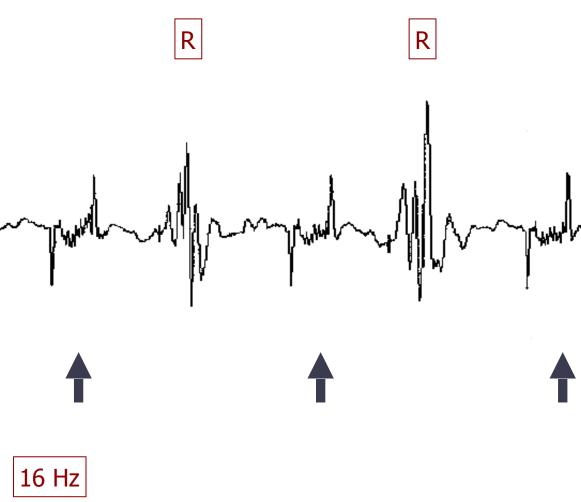
NEUROPATHIC PAIN Central : 67% of published cases Post stroke Spinal cord injury Others

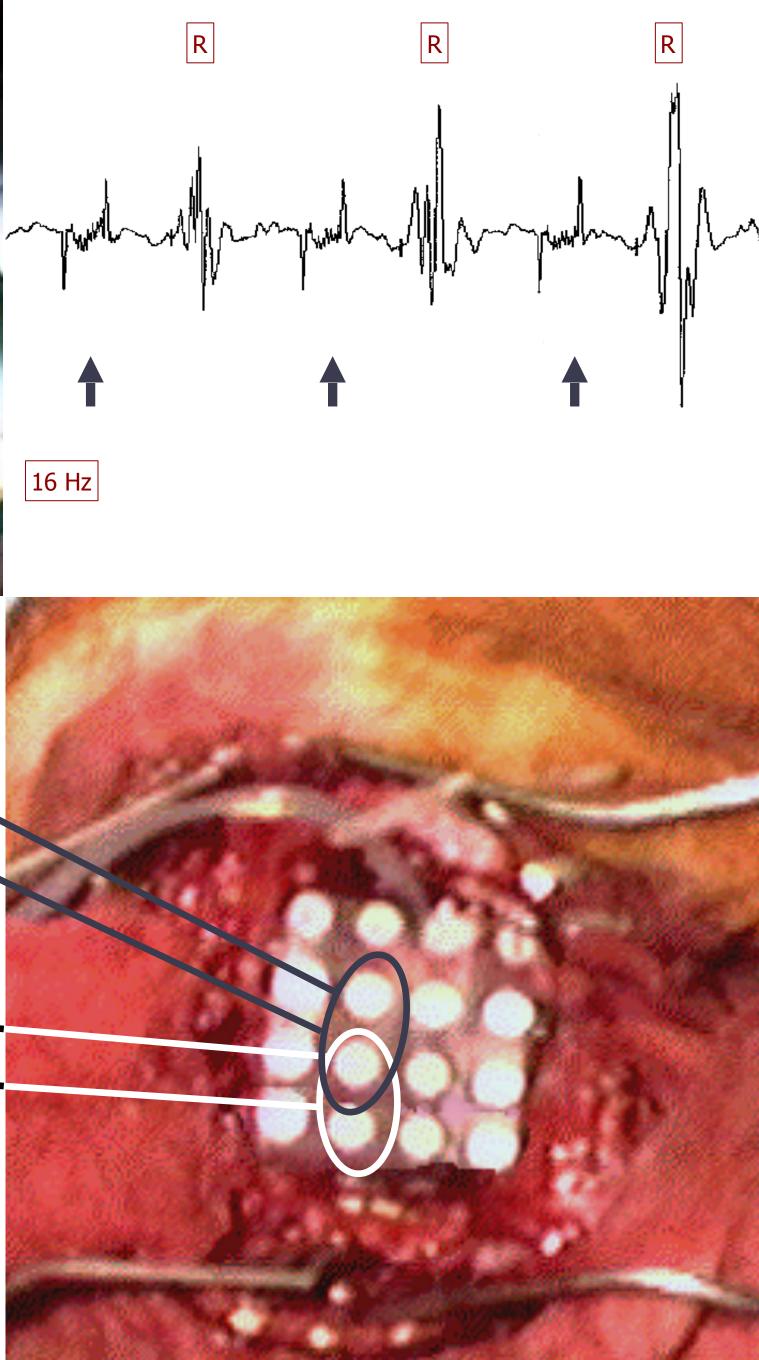
Peripheral : 31% of published cases TGN / facial pain Peripheral nerve injury Plexus avulsion Phantom pain











PRIMARY MOTOR CORTEX STIMULATION RESULTS

fMRI + navigation Navigation Anatomy (burr hole)

Results on VAS 69,2% (2005) 30,7% 12,5% (1991)

N'Guyen

	Year	Indication	EFNS le
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% ٠
- 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



TRIGEMINAL NEURALGIA

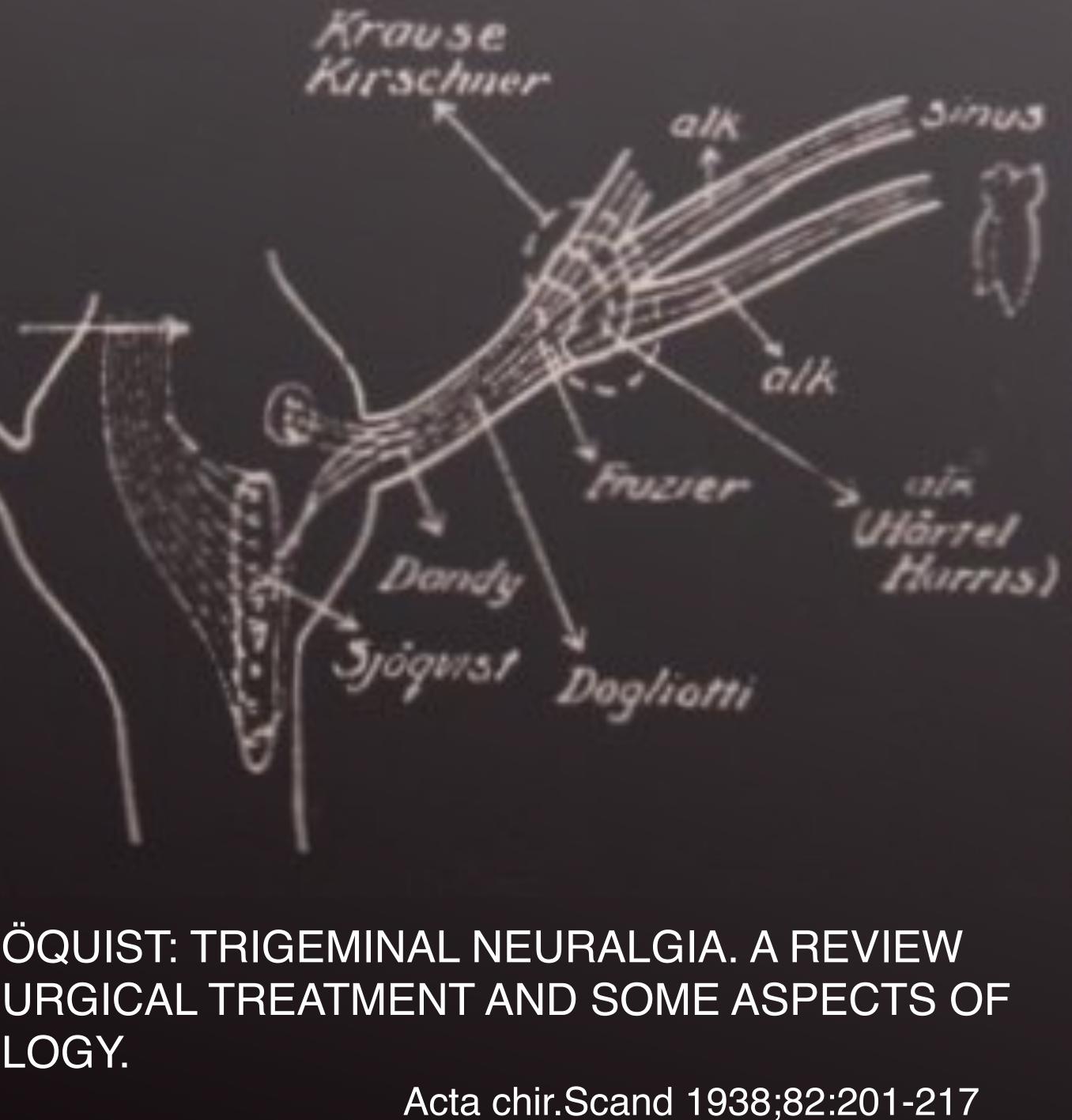
TREATMENT OPTIONS



NEUROSURGICAL TREATMENT OF TRIGEMINAL NEURALGIA

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

Serro



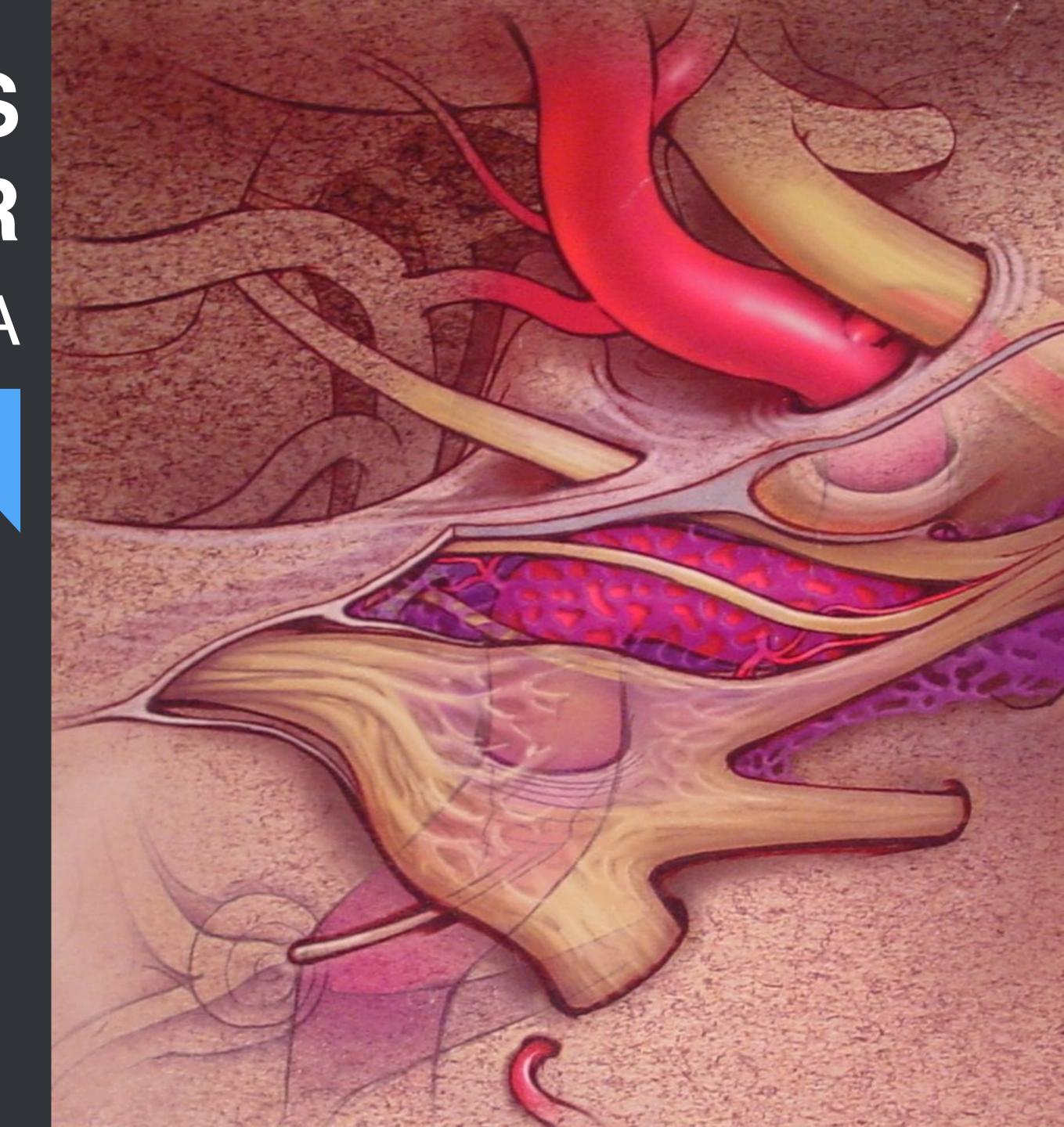
PERCUTANEOUS TECHNIQUES FOR TRIGEMINAL NEURALGIA

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

Tech
Initia
Recı
Facia
Moto
Corn
Anae

COMPARSION OF TECHNIQUES

	RF	Glycerol	Baloon
nn.success	97,4-100%	94%	93-99%
al pain relief	98%	72-96%	89,9-100
urrence	15-20%(5y-10 y)	54% (4y)	25-77,4%(
al numbness	98%-3mo 10%perm.	60%	61-72%
or deficit	24%	1,7%	19-66%
neal reflex:0	7%	3,7%	1,5%
esth.Dolor.	0,3-4%	0-2%	1,8%

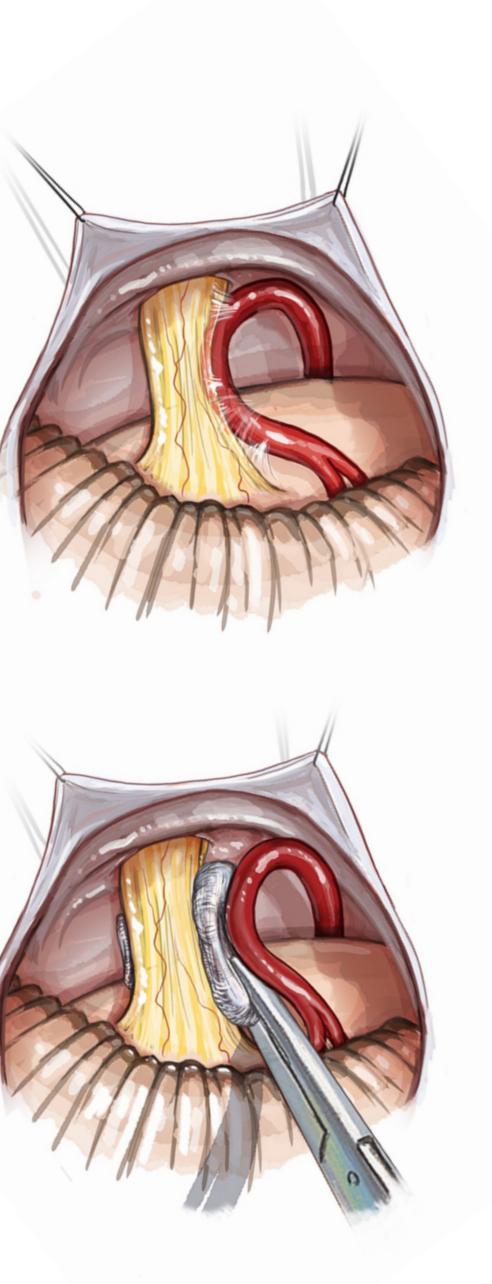


MICROVASCULAR DECOMPRESSION

FOR TRIGEMINAL NEURALGIA



ADVANTAGE **OF MICROVASCULAR** DECOMPRESSION FOR TRIGEMINAL NEURALGIA



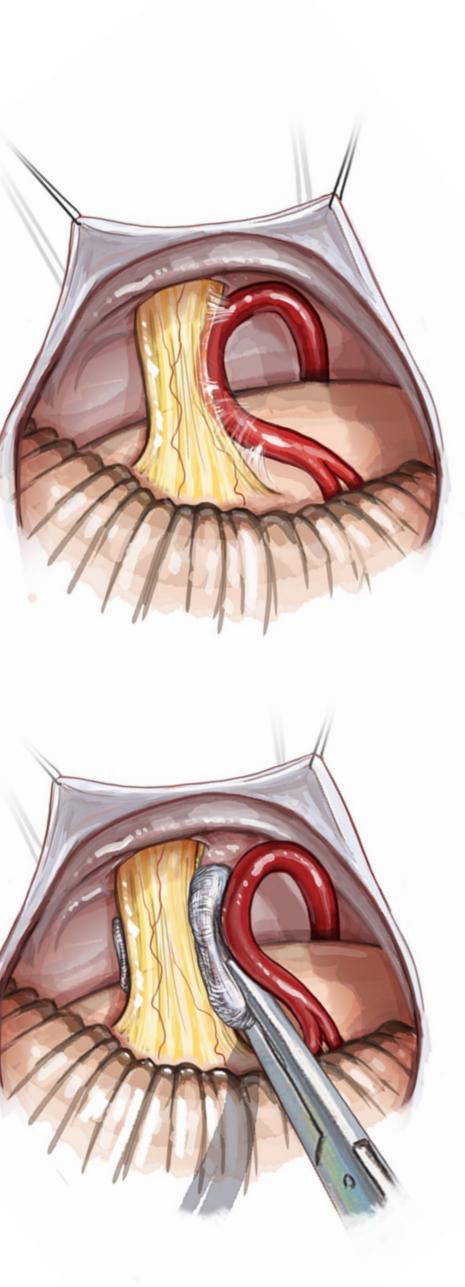
- Treat primary cause
- Trigeminal nerve is preserved
- Postoperative pain relief does not require production of sensory deficit
- Long term outcome is highest







ADVANTAGE OF MICROVASCULAR DECOMPRESSION FOR TRIGEMINAL NEURALGIA



SCA 75,5%

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



MICROVASCULAR DECOMPRESSION SUCCESS RATE

•

ullet

•

ullet

ullet

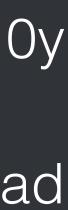
Jannetta total success rate 88% at 1y, 74% at 10y

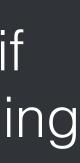
reoperated 11%, 96% of reoperated patients had > 75% pain relief (89% at 10y)

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, \bullet percutan cervical, trans foramen magnum electrode implantation
- Hartel technique foramen ovale •
- Not for tic douloureux \bullet
- Indication: trigeminal neuropathic pain \bullet
- Test period of 7-20 days mandatory
- Steude 200 test, 100 implantation (1998) \bullet
 - 86% good results for maxillary or orthodontic surgery \bullet
 - 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

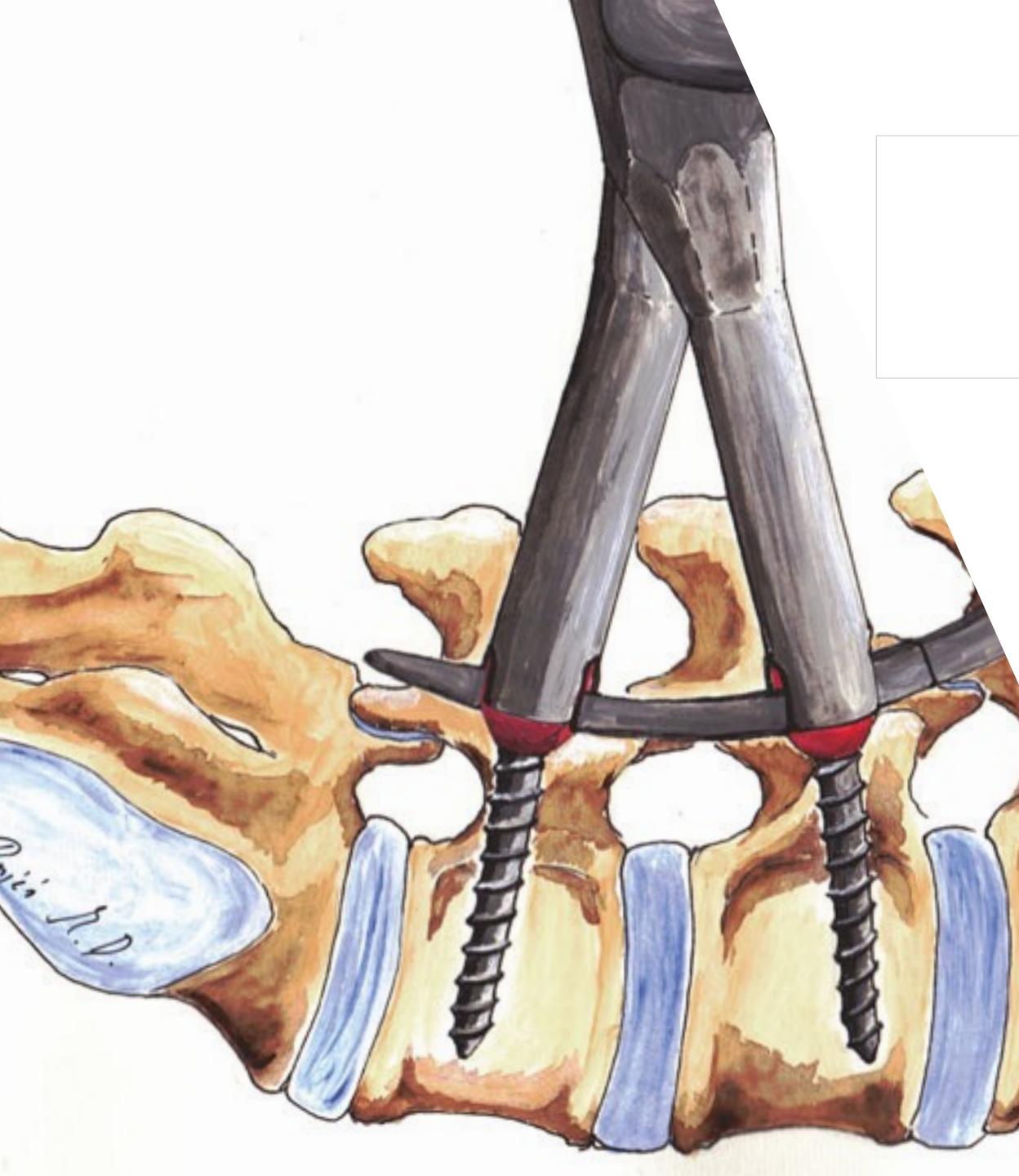


SPINAL CORD STIMULATION



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

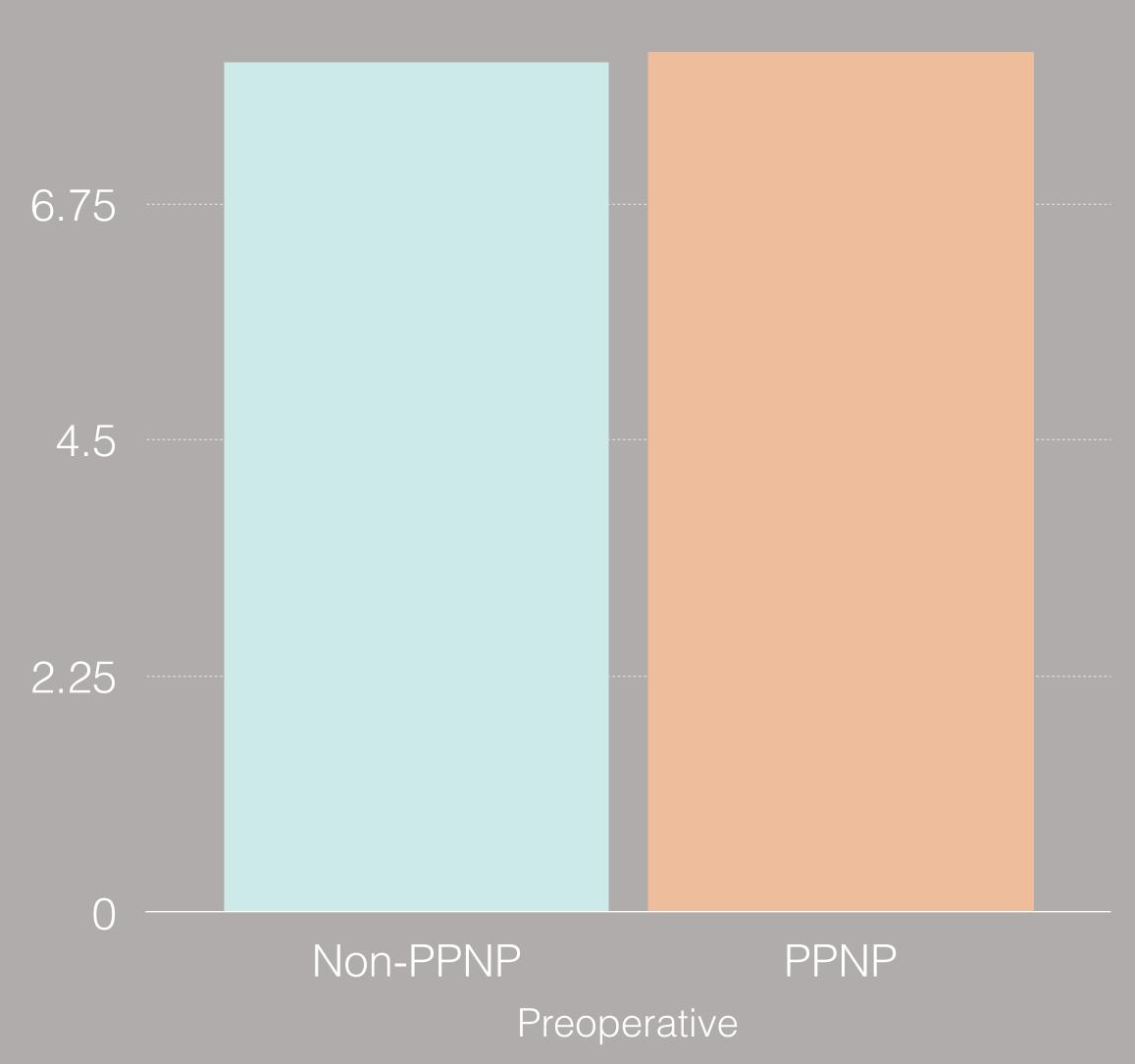
NEUROPATHIC PAIN RETURNED AFTER 6 MONTHS IN THOSE CASES IF IT WAS ALREADY PRESENT BEFORE SURGERY

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

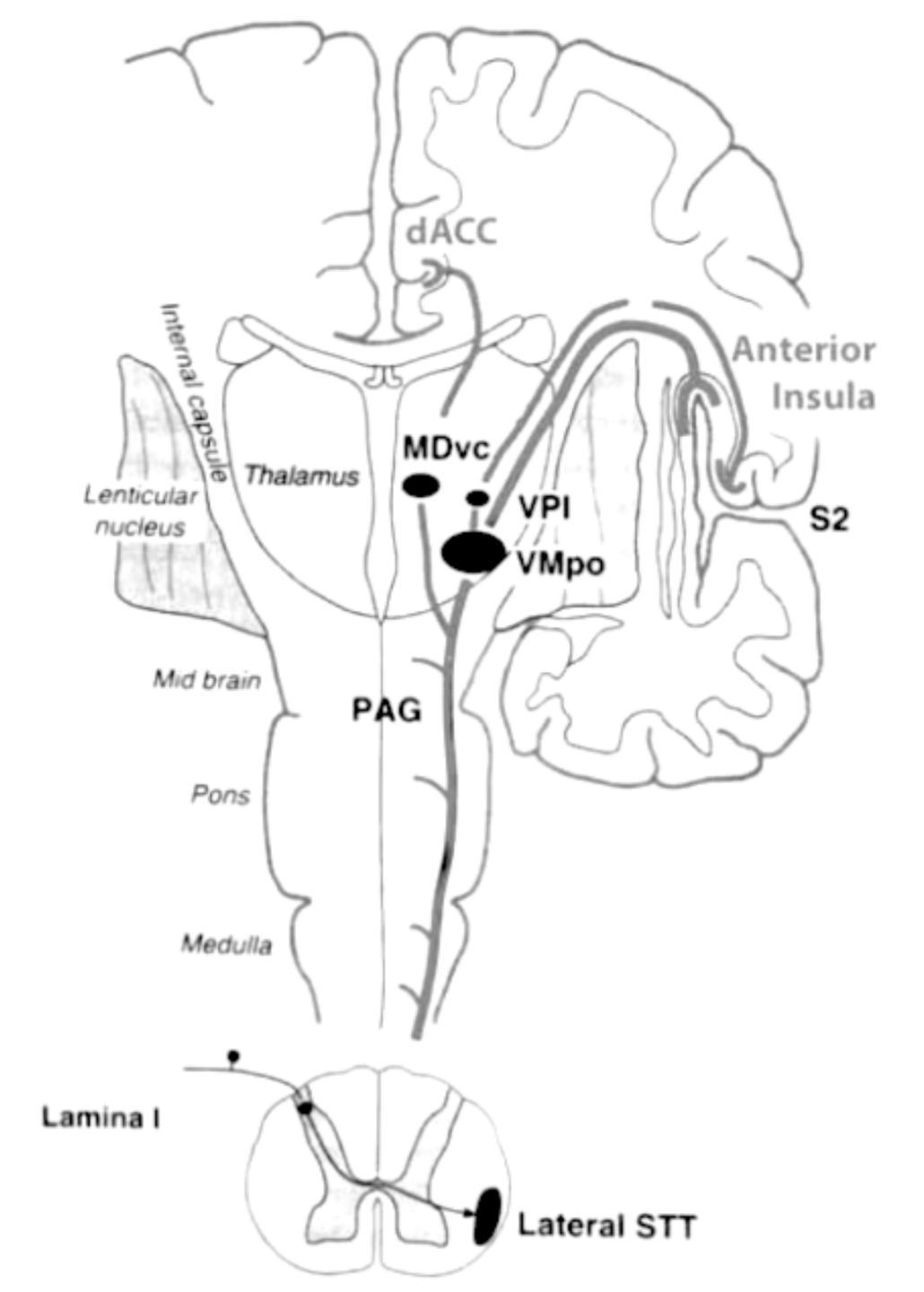
9

VISUAL ANALOG SCALE



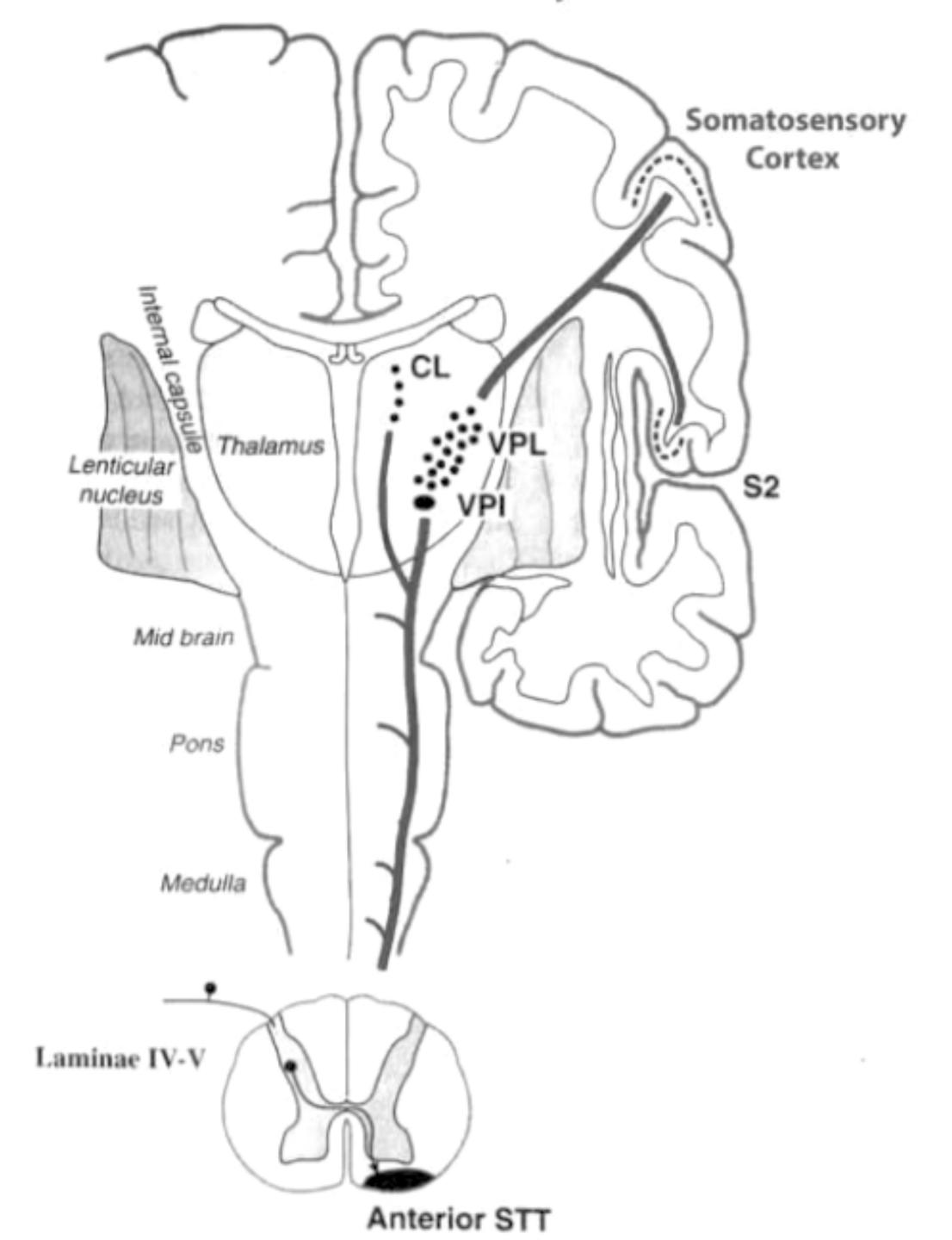
Lateral system

- Activated by C-, A δ , A β 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

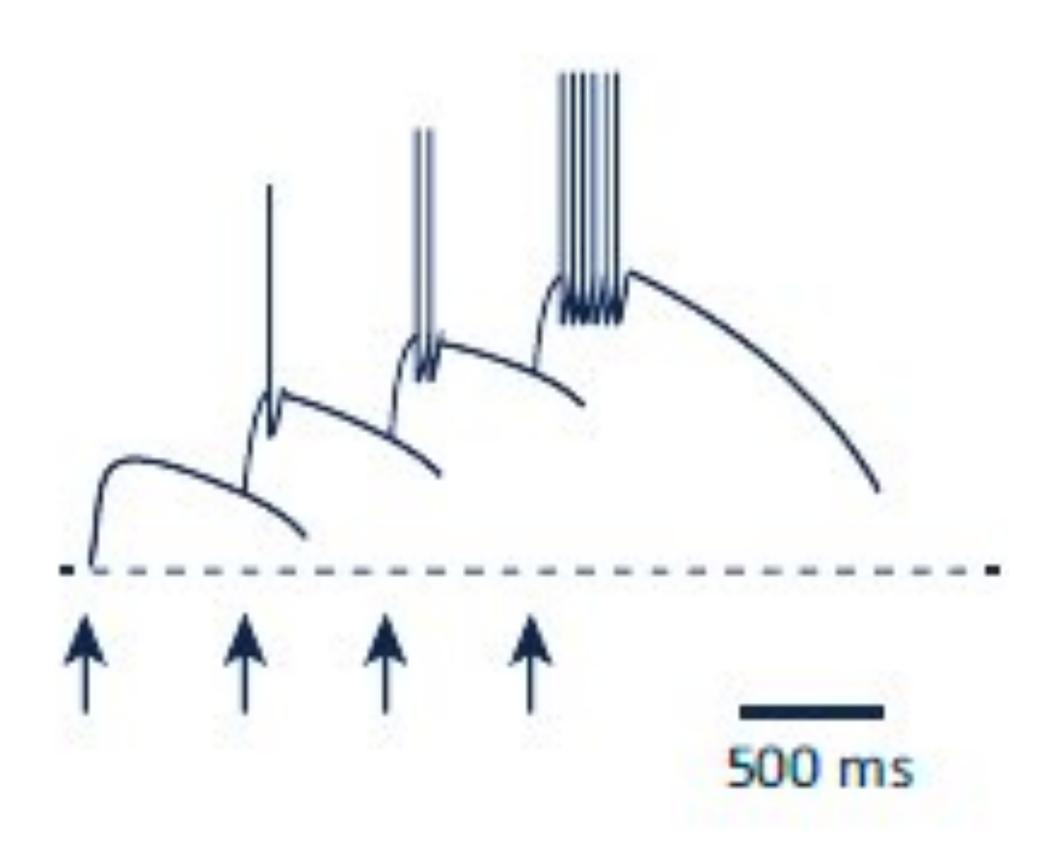


NEUROPATHIC PAIN

• SPONTANEOUS BURST ACTIVATION OF C-FIBERS

• Wind up, gets more unpleasant

(ii) Wind-up



WHEN TO GO FOR SCS

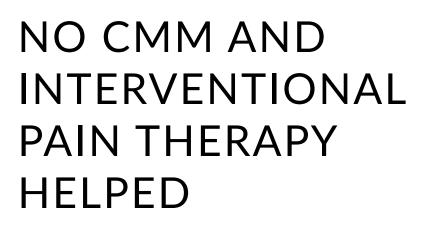
B

ANATOMICALLY CORRECT SURGERY



CHRONIC BACK AND LEG PAIN





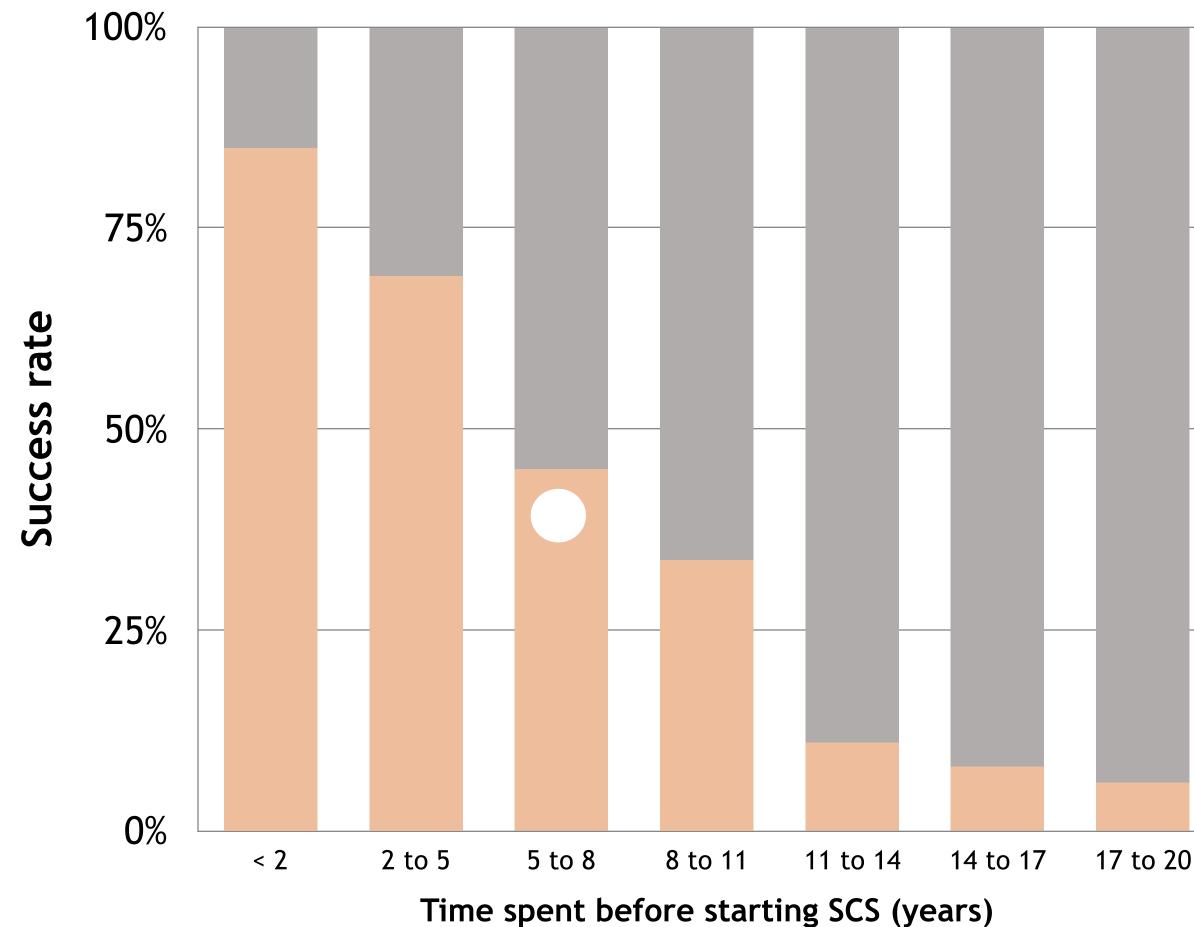
WHEN SHOULD I CHOOSE SCS THERAPY FOR MY PATIENT?

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.

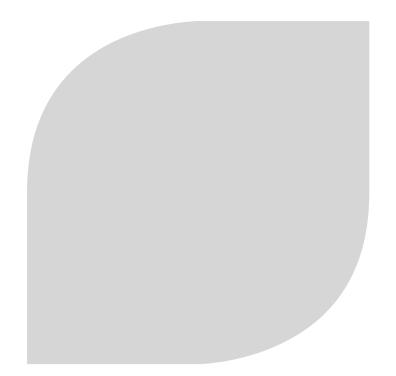


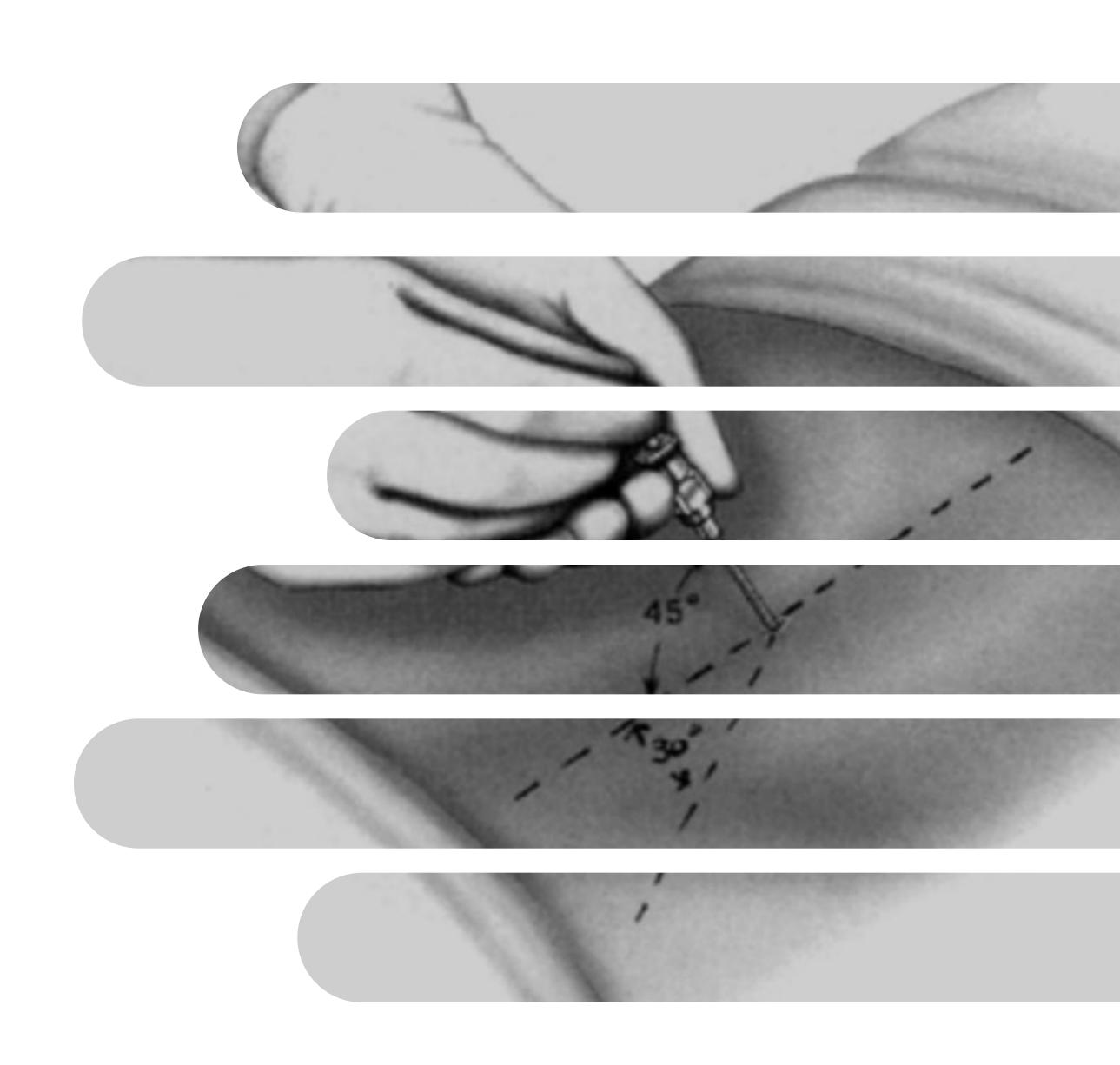
EVIDENCES OF SCS AND PNS IN PAIN CONDITIONS

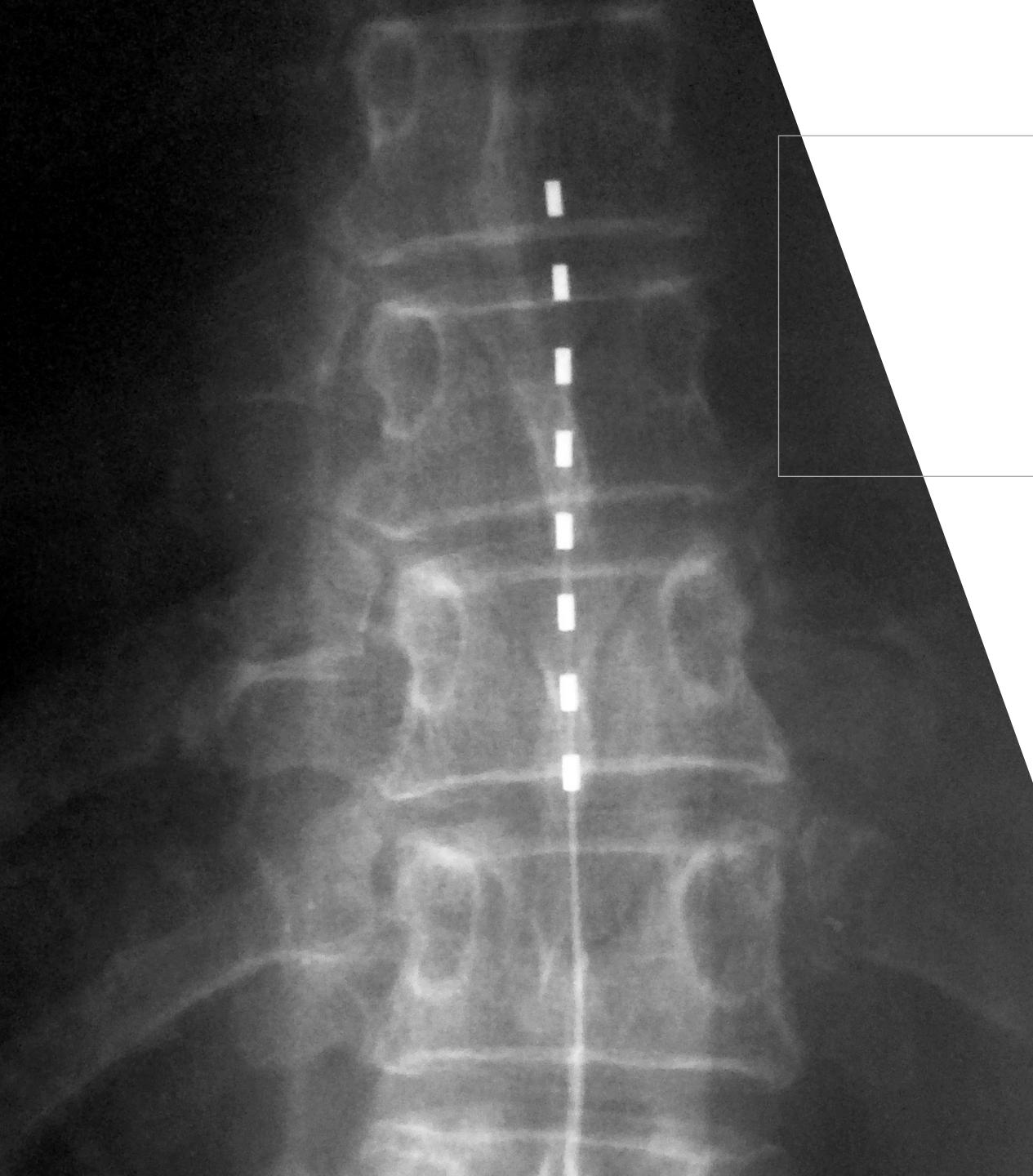
	2 A+
	Failed Back Surger Syndrome (SCS)
00	

	2 B+	2 C+	0
ery)	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)

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







INTRAOPERATIVEPOSTIONING



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

BURST

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

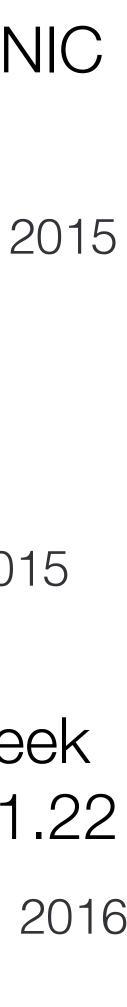
HIGH DENSITY

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

Kapural, Anaesthesiolgy, 2015

De Ridder, Clin J Pain, 2015

Sweet, Neuromodulation, 2016



Medtronic

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





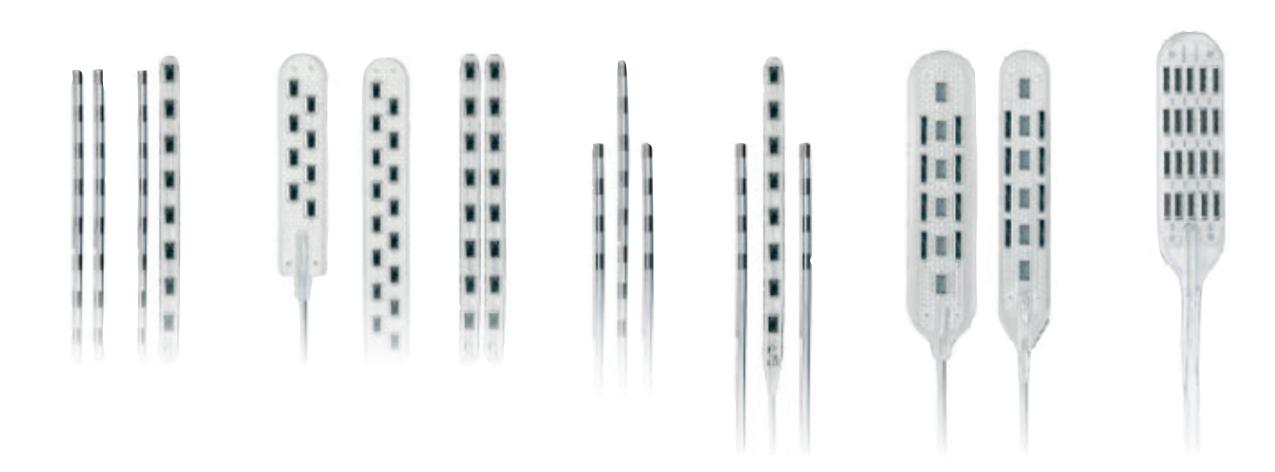






- Burst stimulation
- Low energy bluetooth connection
- Software upgrade









Boston Scientific



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





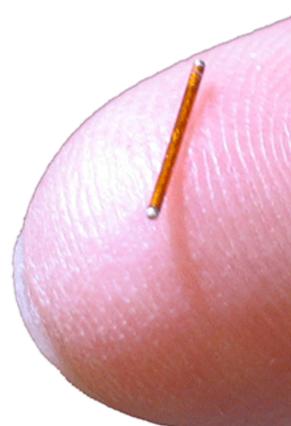
- Lead receiver unit neurostimulator in the lead itself
- telemetric energy conduction



freedom-8A

freedom-4A



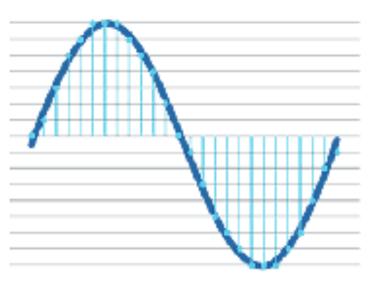






10+ year battery

10 kHz HF stimulation



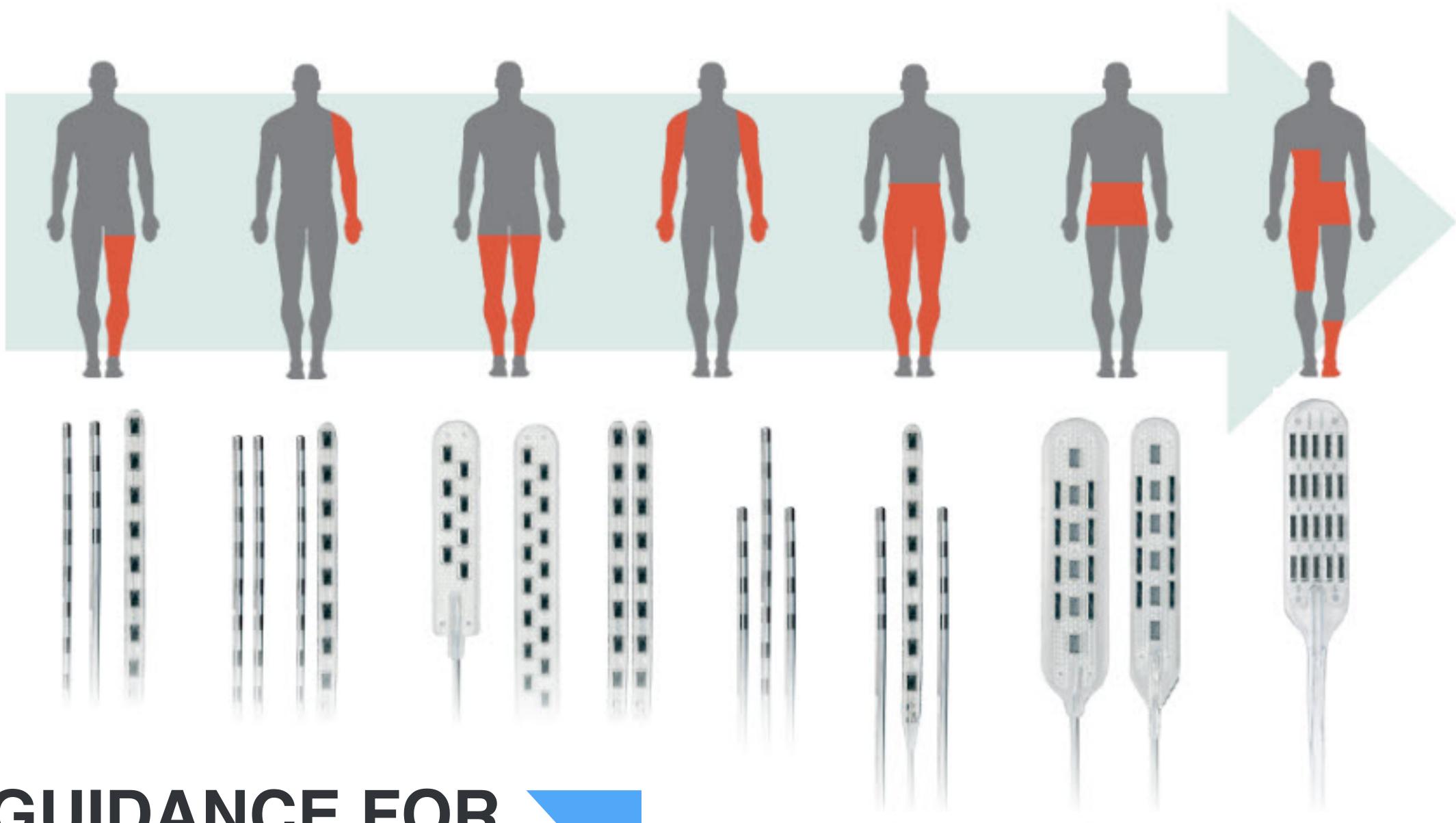
10 kHz

Software upgrade

1,5T and 3T MR-conditional

GUIDANCE FOR COMPLEXITY

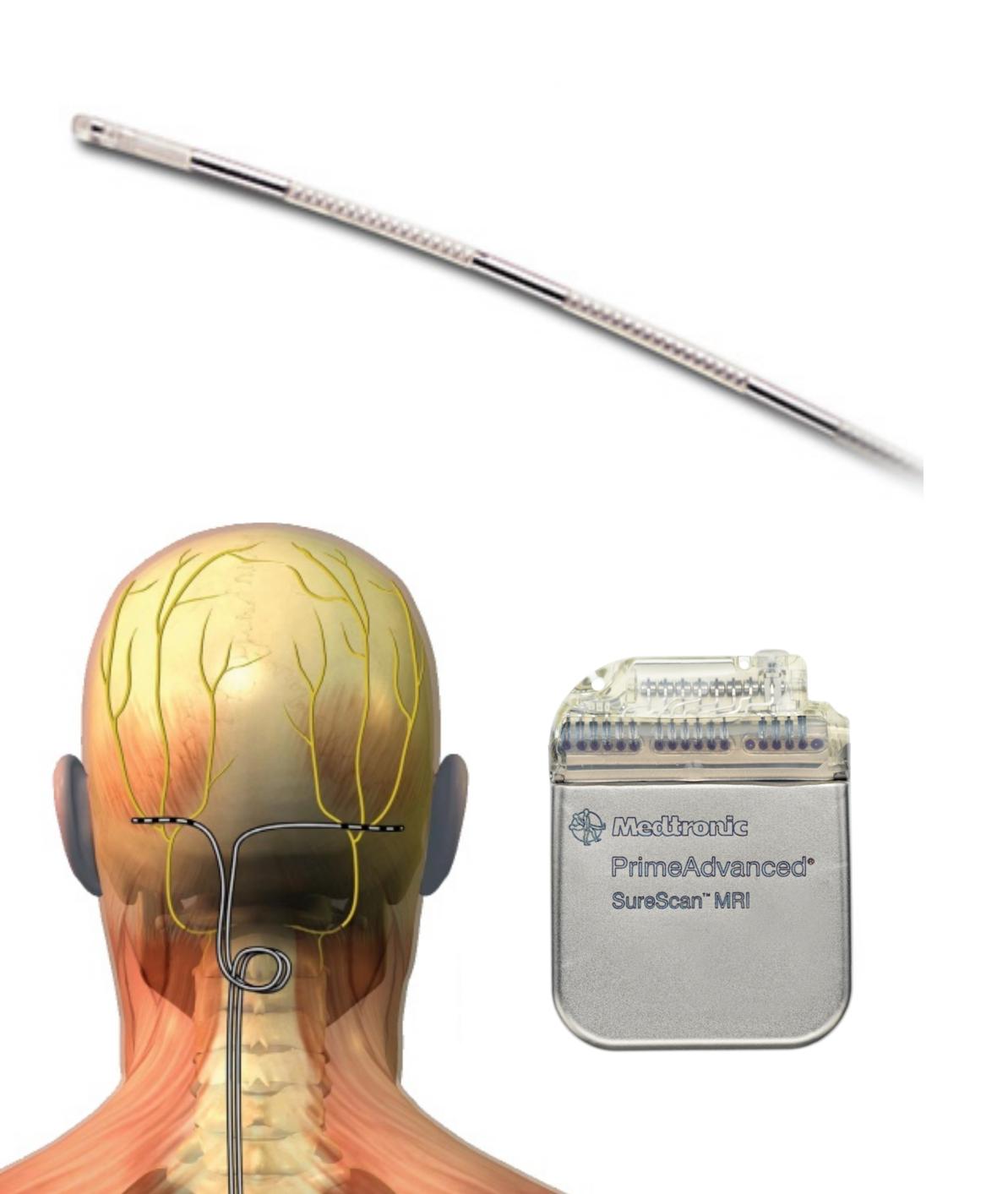


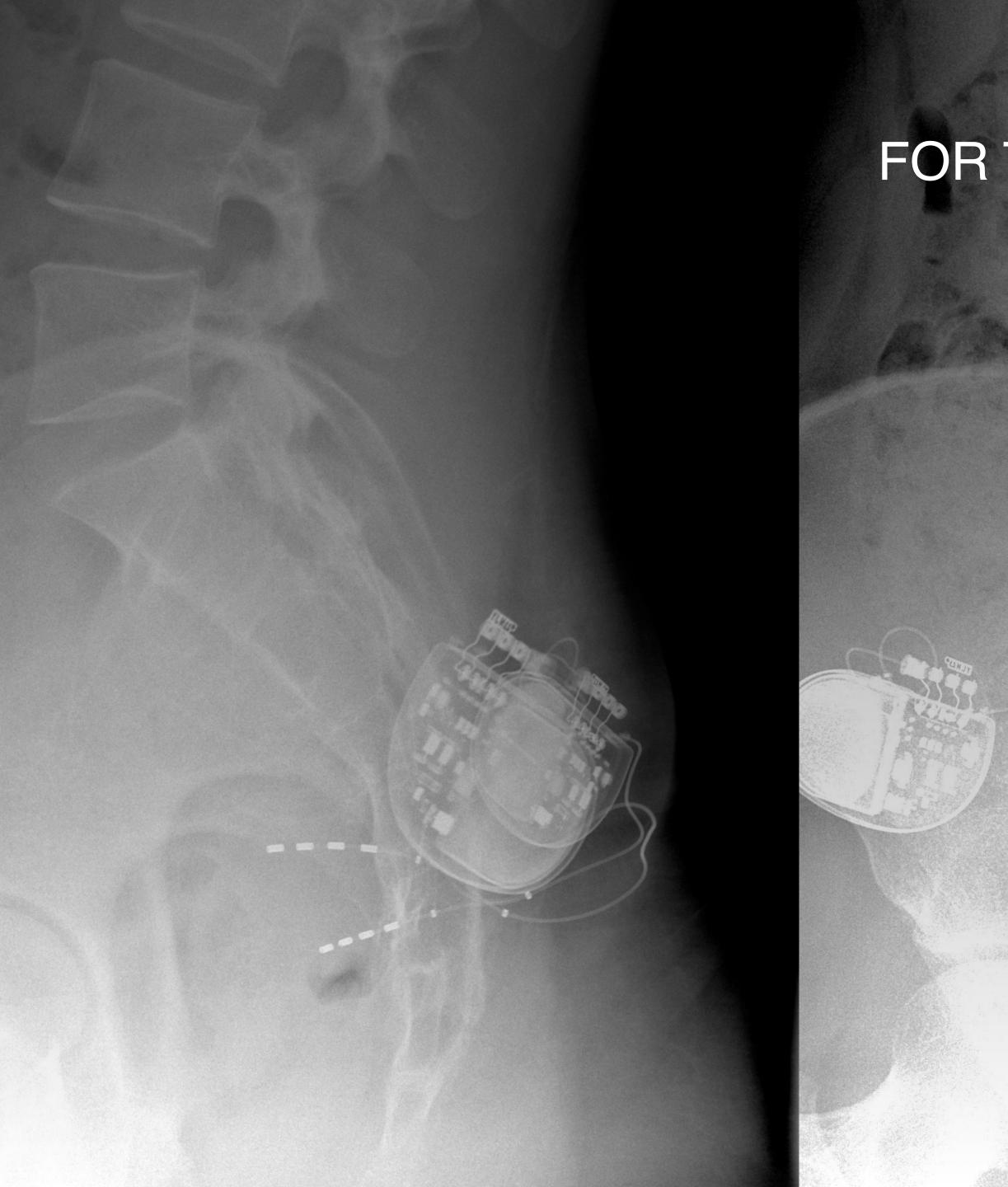




OCCIPITAL stimulation

- CLUSTER HEADACHE
- CERVICOGENIC HEADACHE
- MIGRAIN



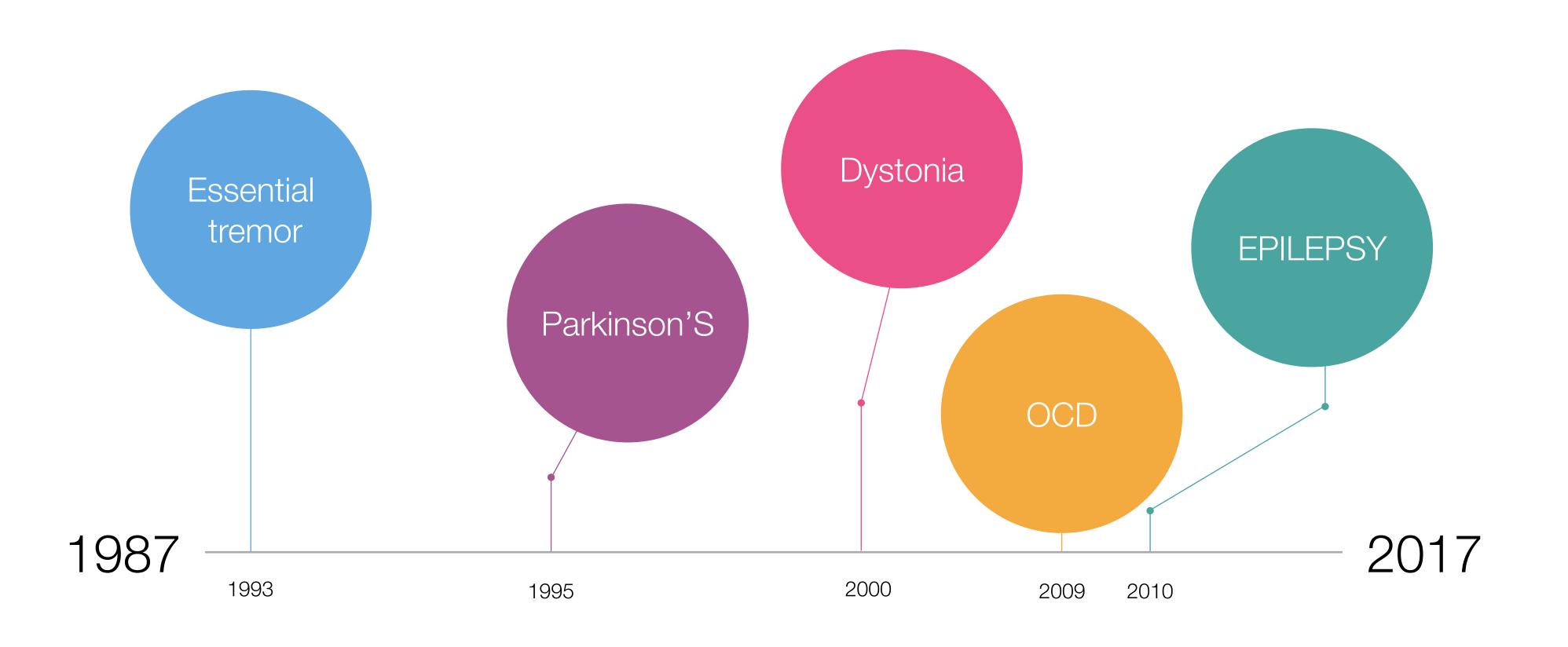


SACRAL NERVE STIMULATION FOR THE TREATMENT OF RETENTION

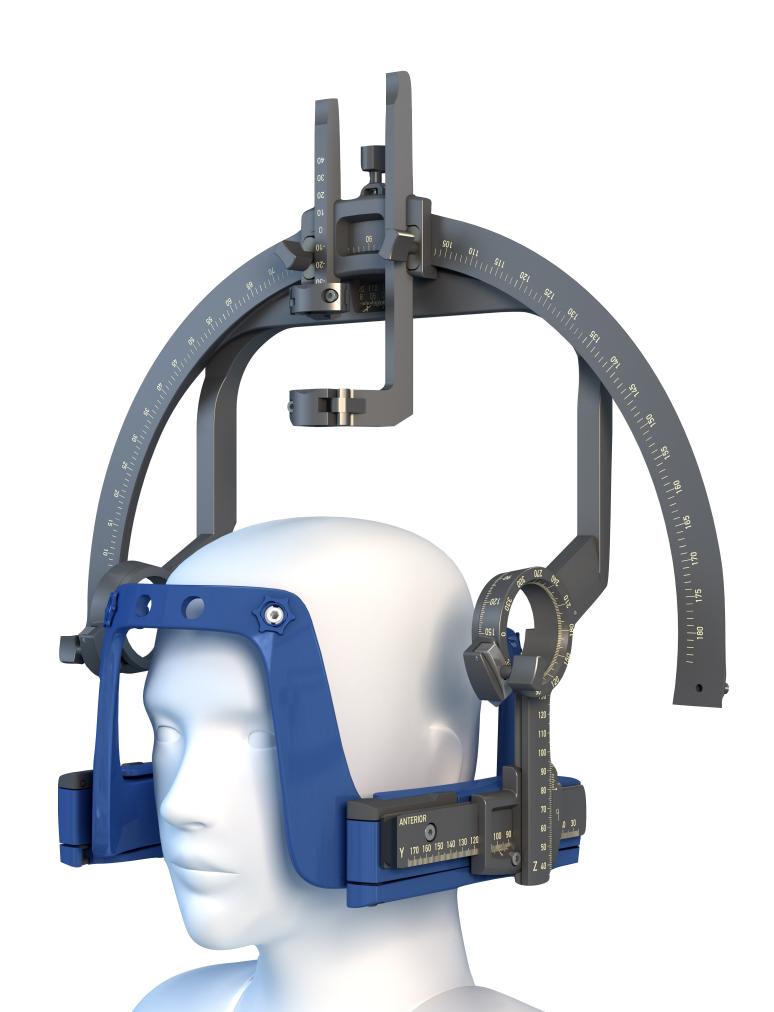


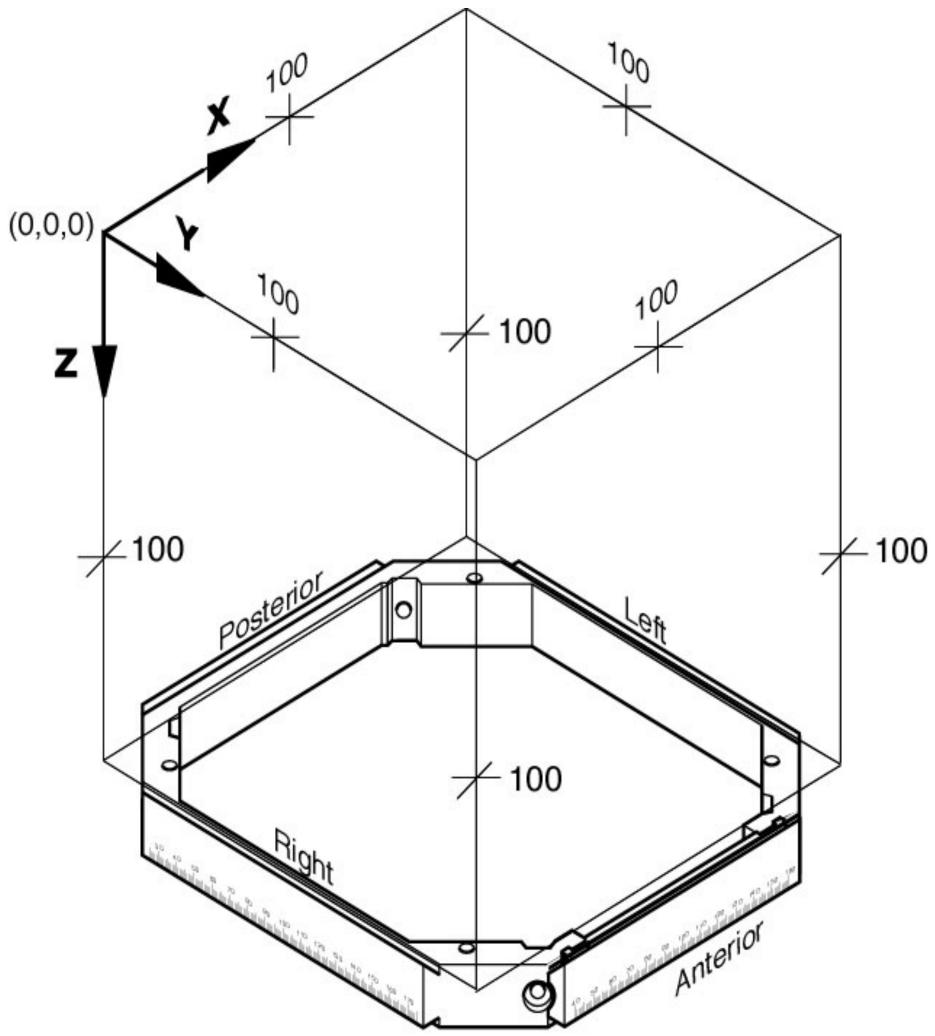


INDICATIONS OF DEEP BRAIN STIMULATION



STEREOTACTIC PROCEDURE





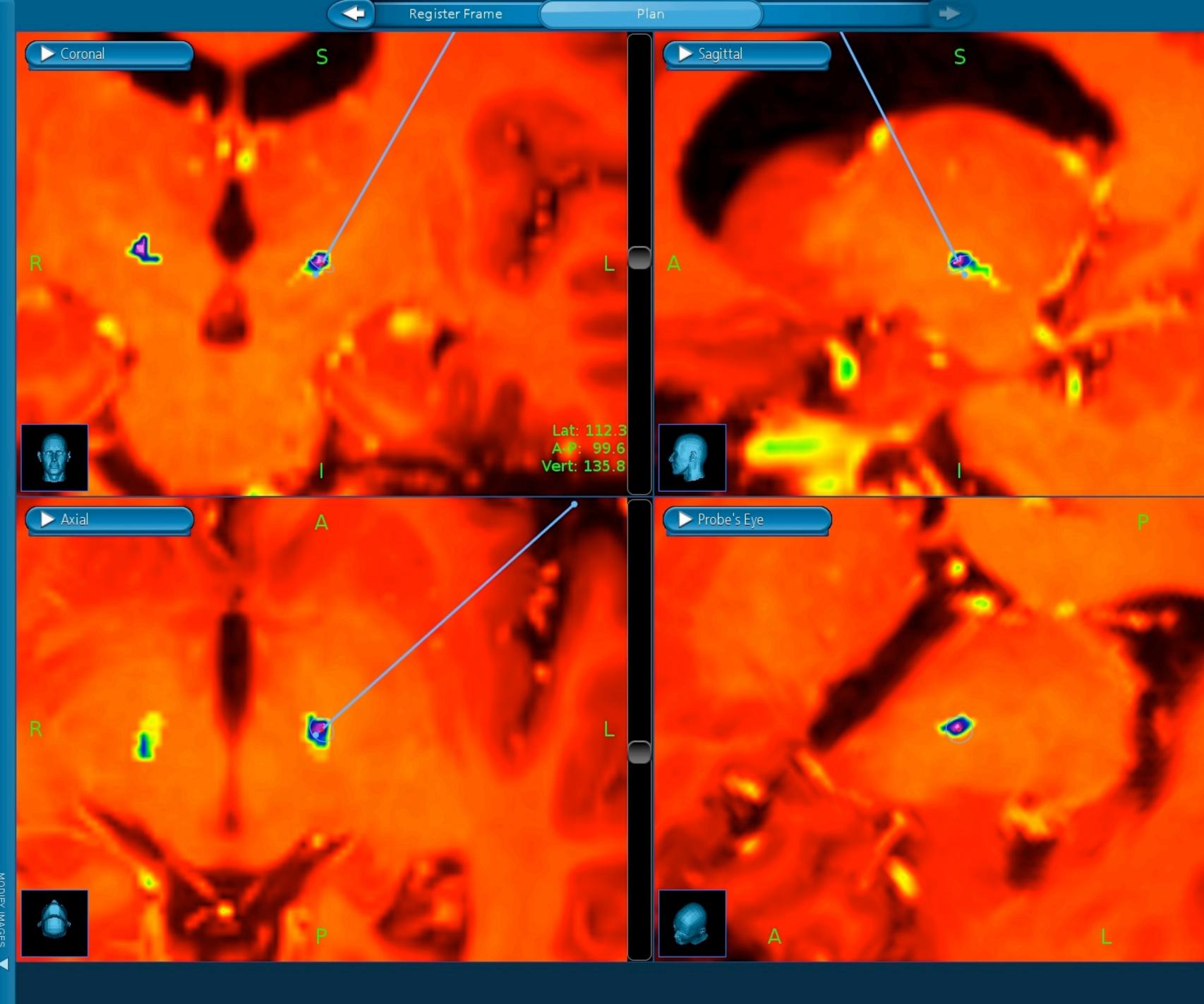


TARGETS IN MOVEMENT DISORDERS

- 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

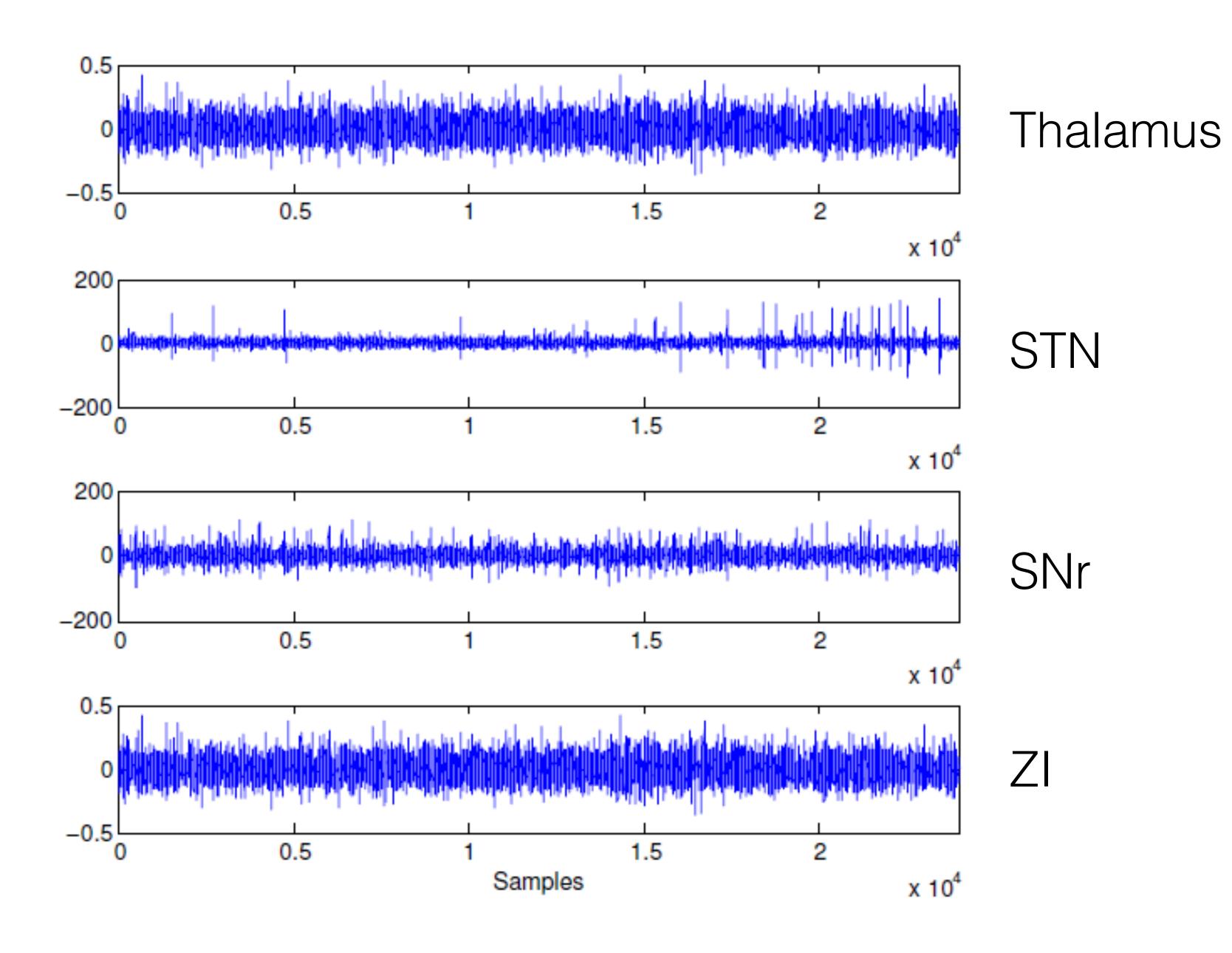




CONTROL

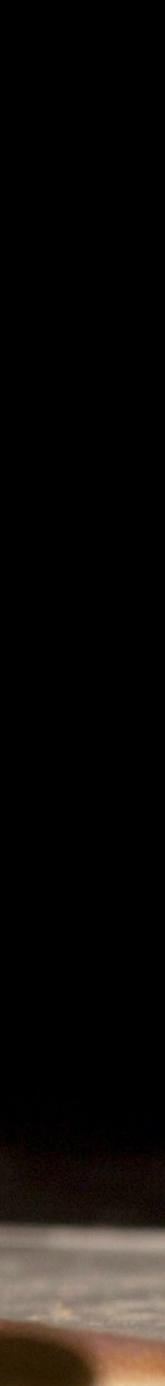
INTRAOPERATIVE MAPPING

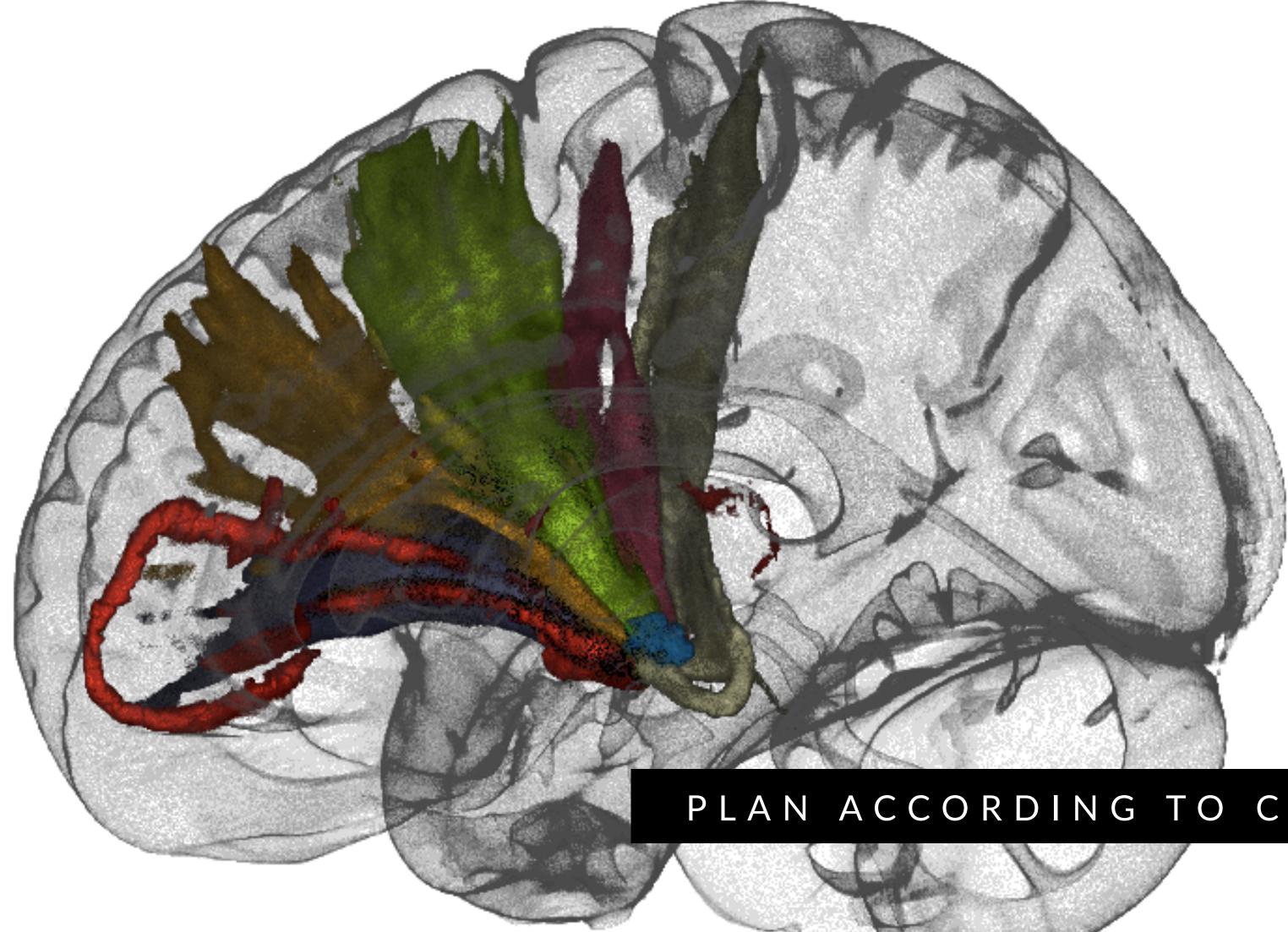
The patient is usually awake



GRADINARU ET AL 2009 SCIENCE





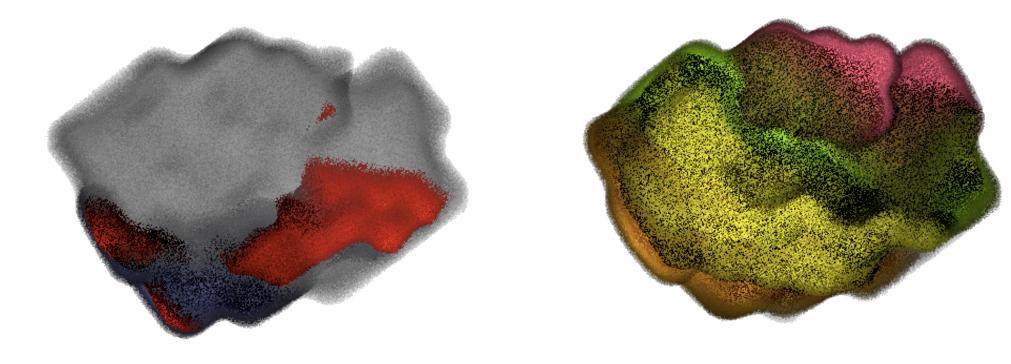


PLAN ACCORDING TO CONNECTIVITY MAPS



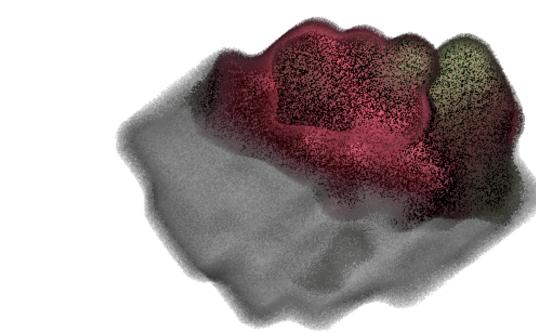


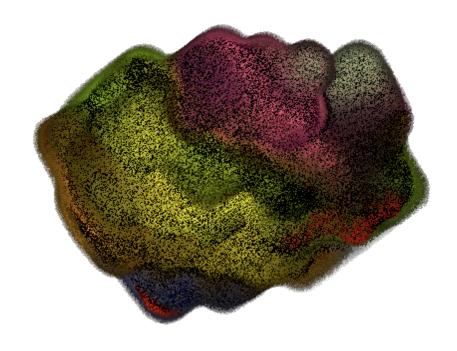
FUNKCIONAL CONNECTIVITIES OF THE STN



LIMBIC-ASSOCIATIVE MOTOR REGIONS SENSORY-MOTOR

OFC, HIPPOCAMPUS, AMYG, ACC, DLPFC PRESMA, SMA, PREOMOTOR, M1

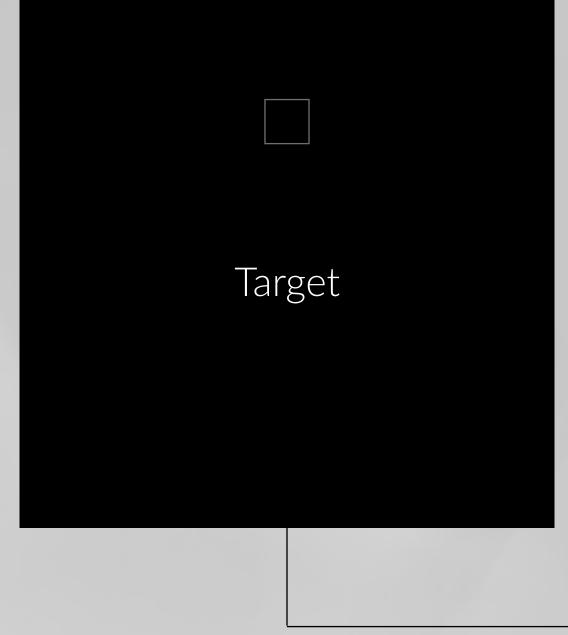




STN

M1, S1

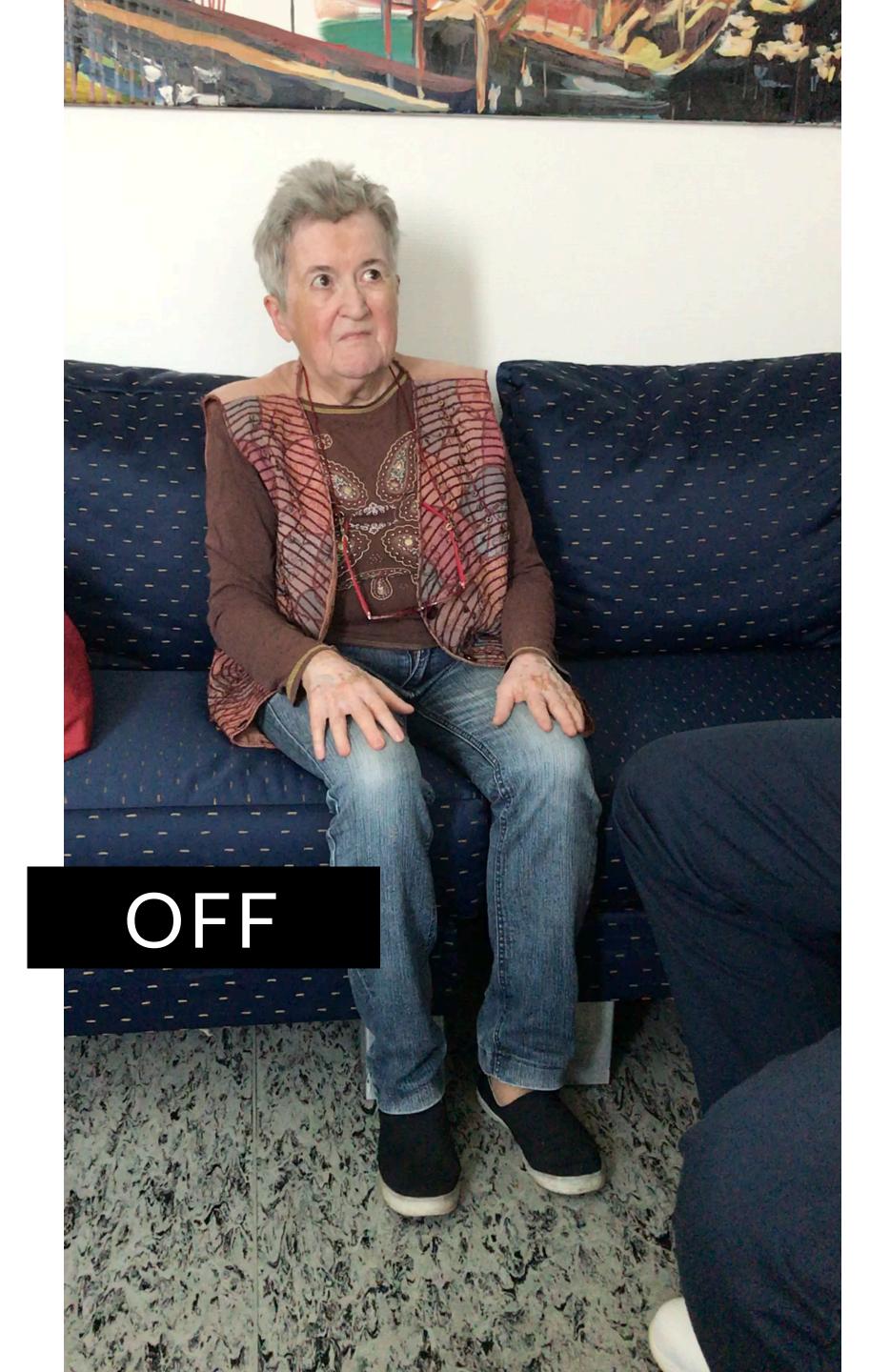
L. HALÁSZ ET AL





CONNECTIVITY MAPS















INTRATHECAL DRUG DELIVERY



WHAT IS SPASTICITY?

 Spasticity is a disorder of the sensorimotor control muscles (EU-SPAZM Group, 2005)

resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of

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, reactions, brisk tendon reflexes, extensor plantar postural responses)

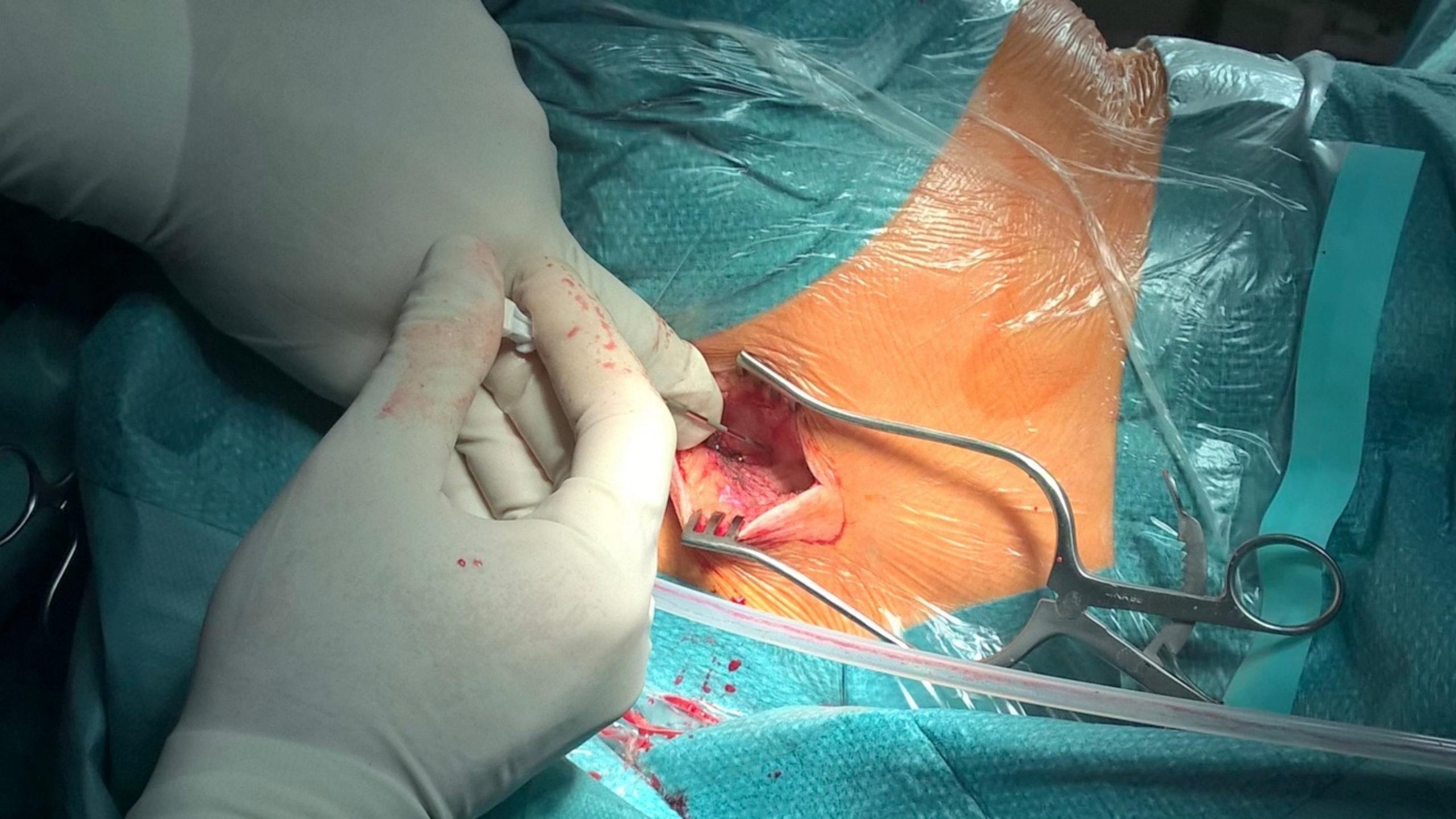
spazms, clonus, asssosiated reactions, poz. support responses, NEG: weakness, reduced dexterity, reduced

COMPLEX THERAPEUTIC OPTIONS

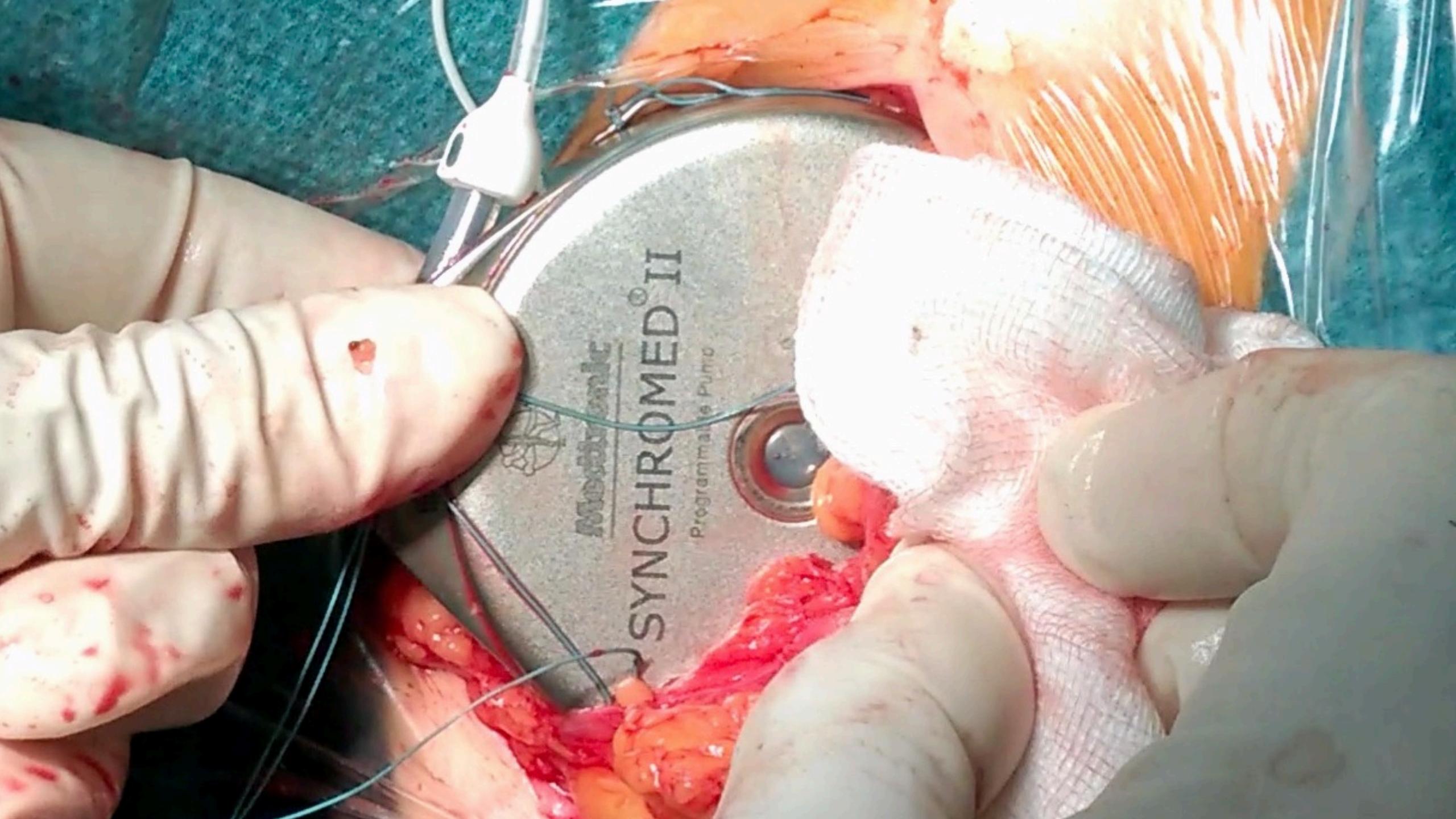
- Physiotherapy
- Oral drug therapy
- Focal botulinum toxin therapy
- Orthopedic deformity correction
- Neuroablative procedures
- Intrathecal Baclofen therapy

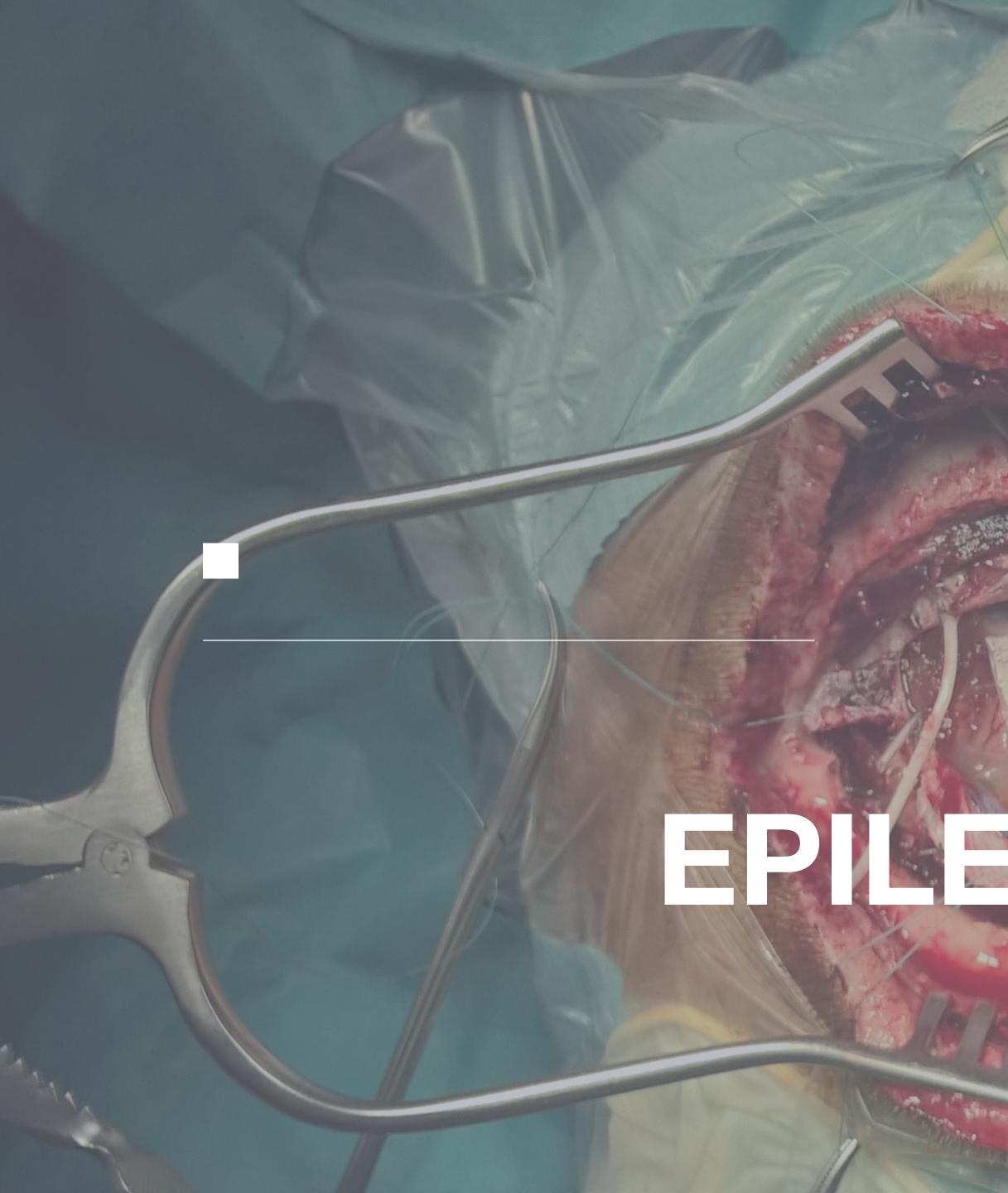












EPILEPSY SURGERY



EPILEPSYON NETWORK

IDENTIFY THE SEIZURE ONSET ZONE

REMOVE THE EPILEPTOGENIC ZONE WITHOUT DOING ANY SEVERE NEUROLOGICAL DEFICIT





- Standard surgeries: lobectomies, selective amygdalohipocampectomy
 - Extratemporal resections
 - Hemispherotomy
 - Callosocomissurotomy

SURGICAL PROCEDURES

- Lesionectomy
 - Topectomy

MST



MULTIMODAL APPROACH







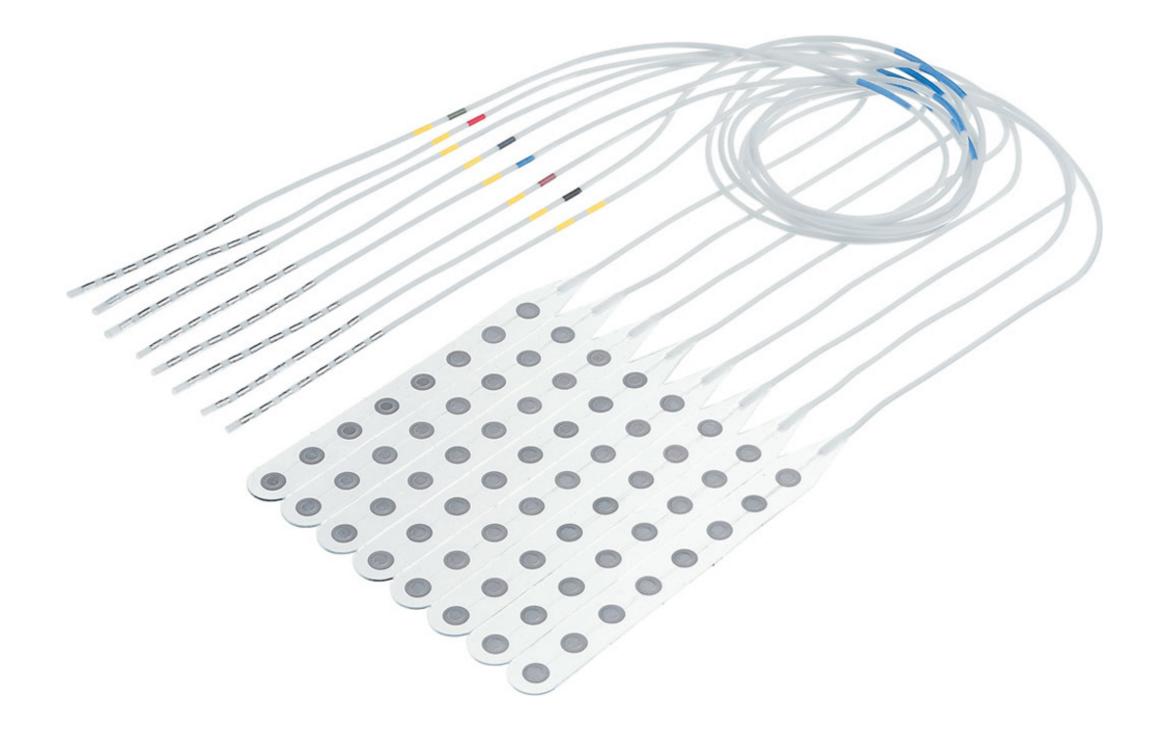


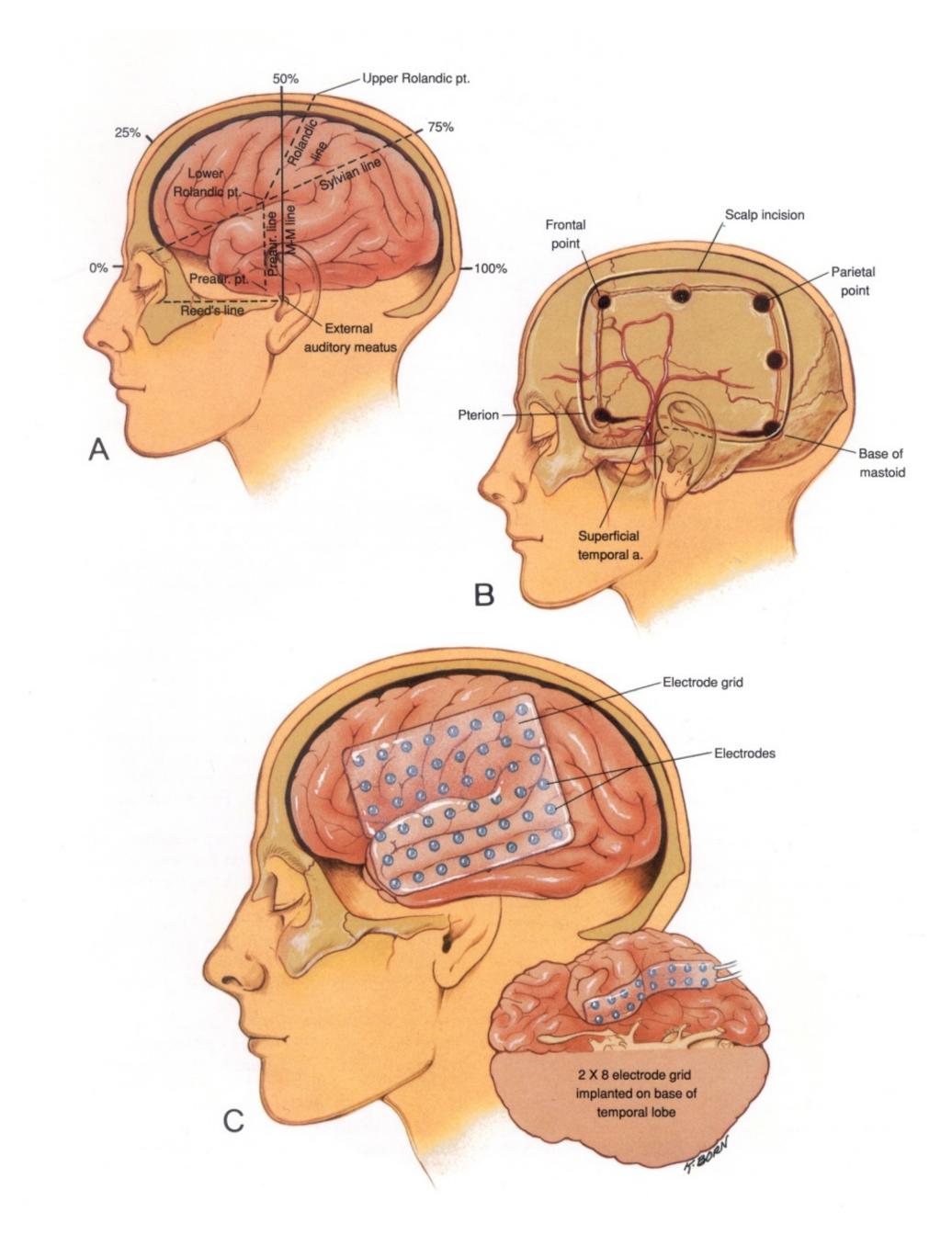
HISTORY SEMIOLOGY EEG MRI NEUROPSYCHOLOGY FMRI, DTI, PET - CT/MR, SPECT, ASL, MAP07

NON-INVASIVE



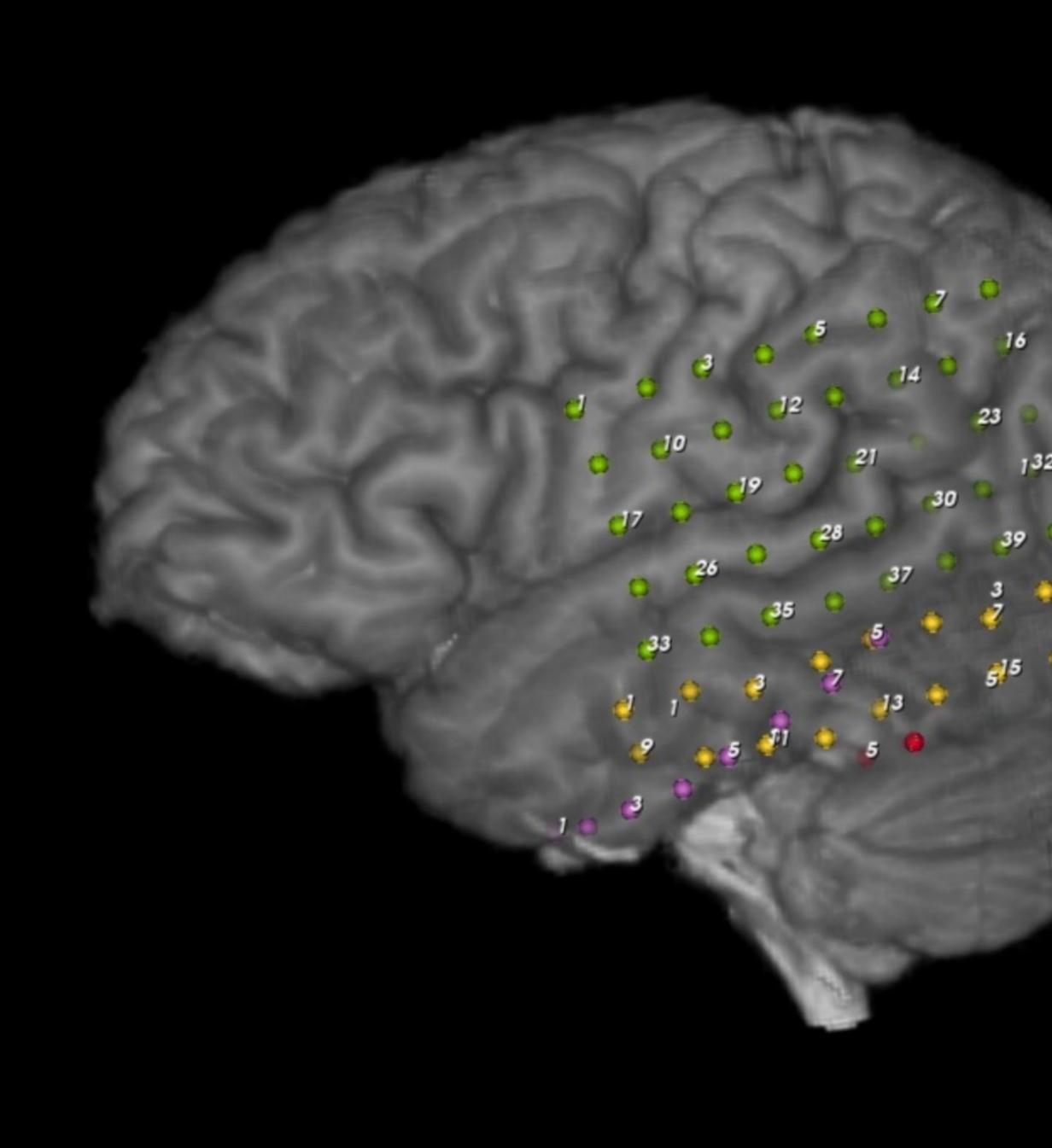


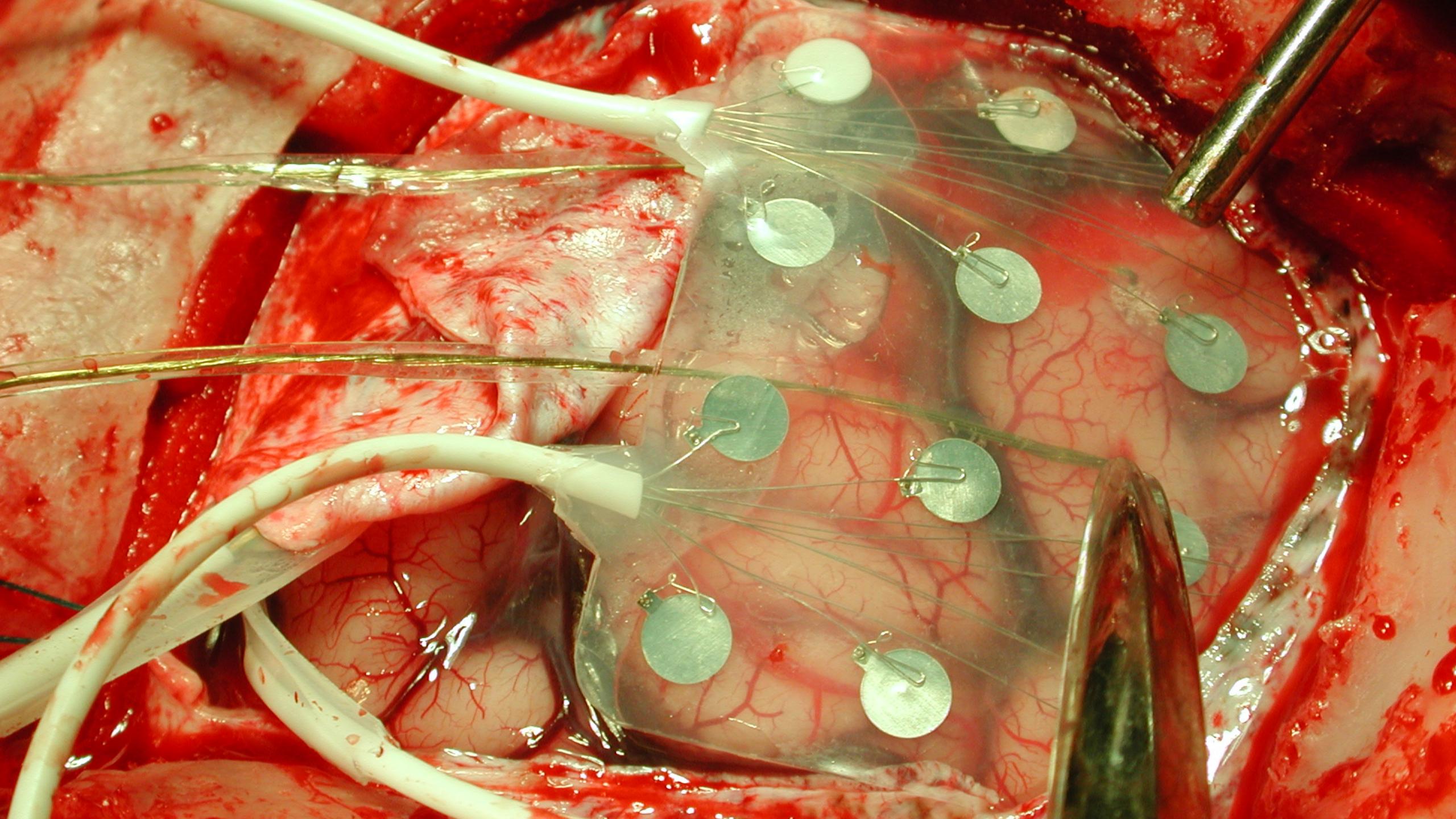




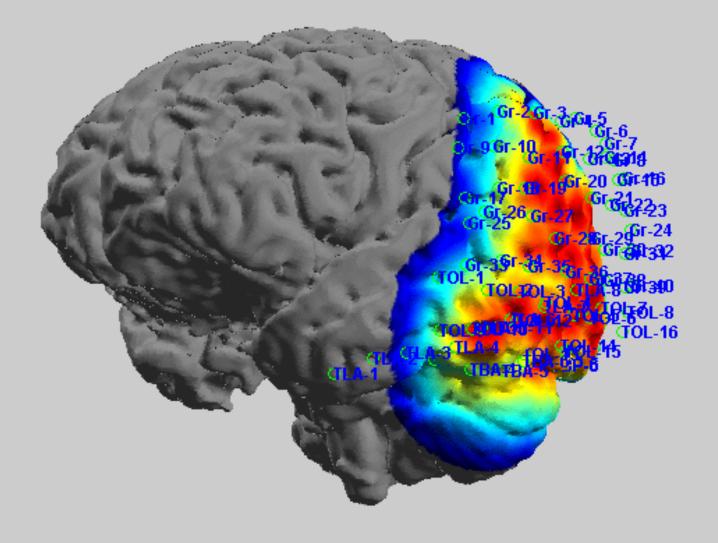
INVASIVE MONITORING

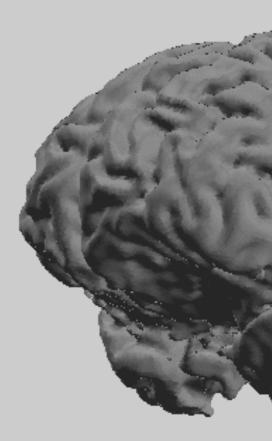
SUBDURAL ELECTRODES LOCALIZATION OF ELECTRODES

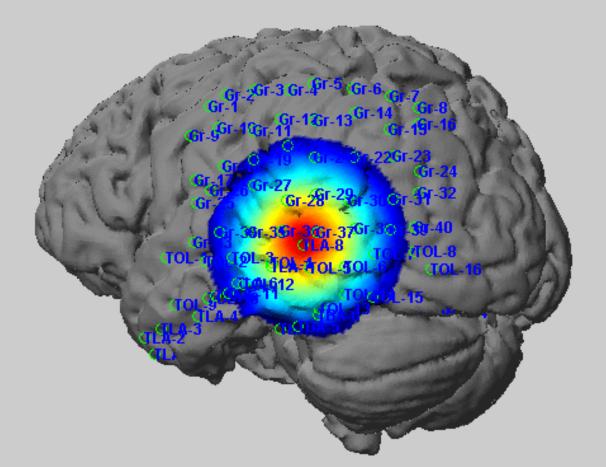




Spike map



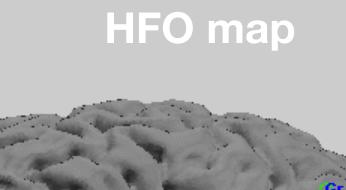


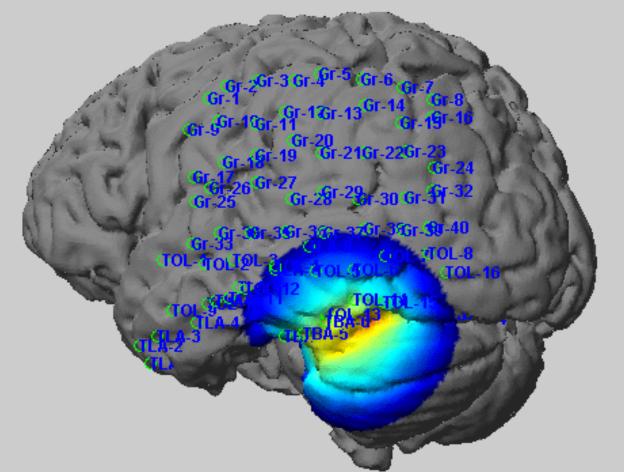




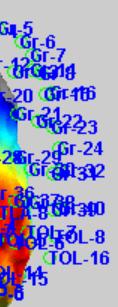
CCEP map

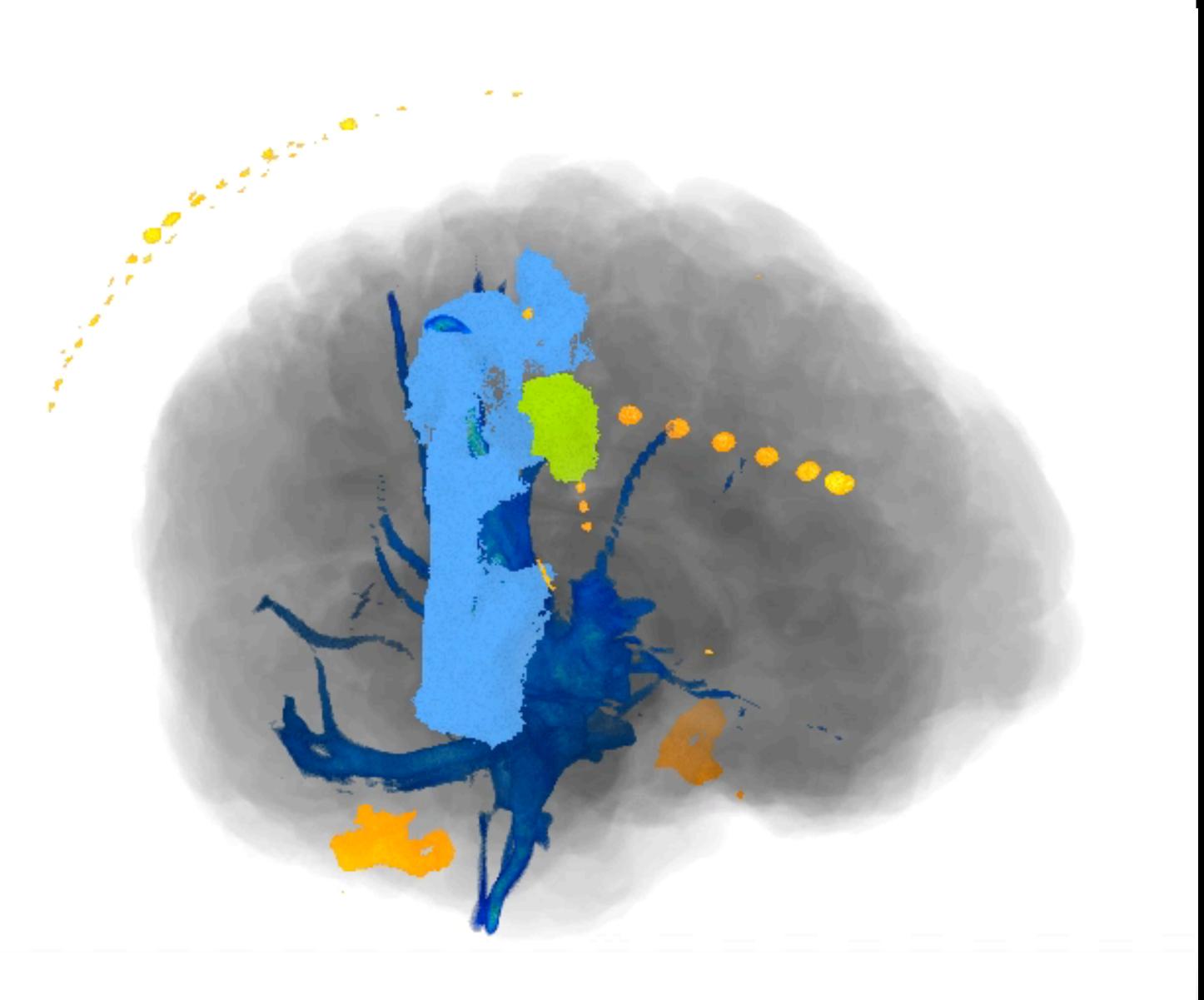
Gr. 10 Gr. 6 Gr. 10 Gr. 6 Gr. 9 10 C. 20 Gr. 46 Gr. 9 10 C. 20 Gr. 47 Gr. 47



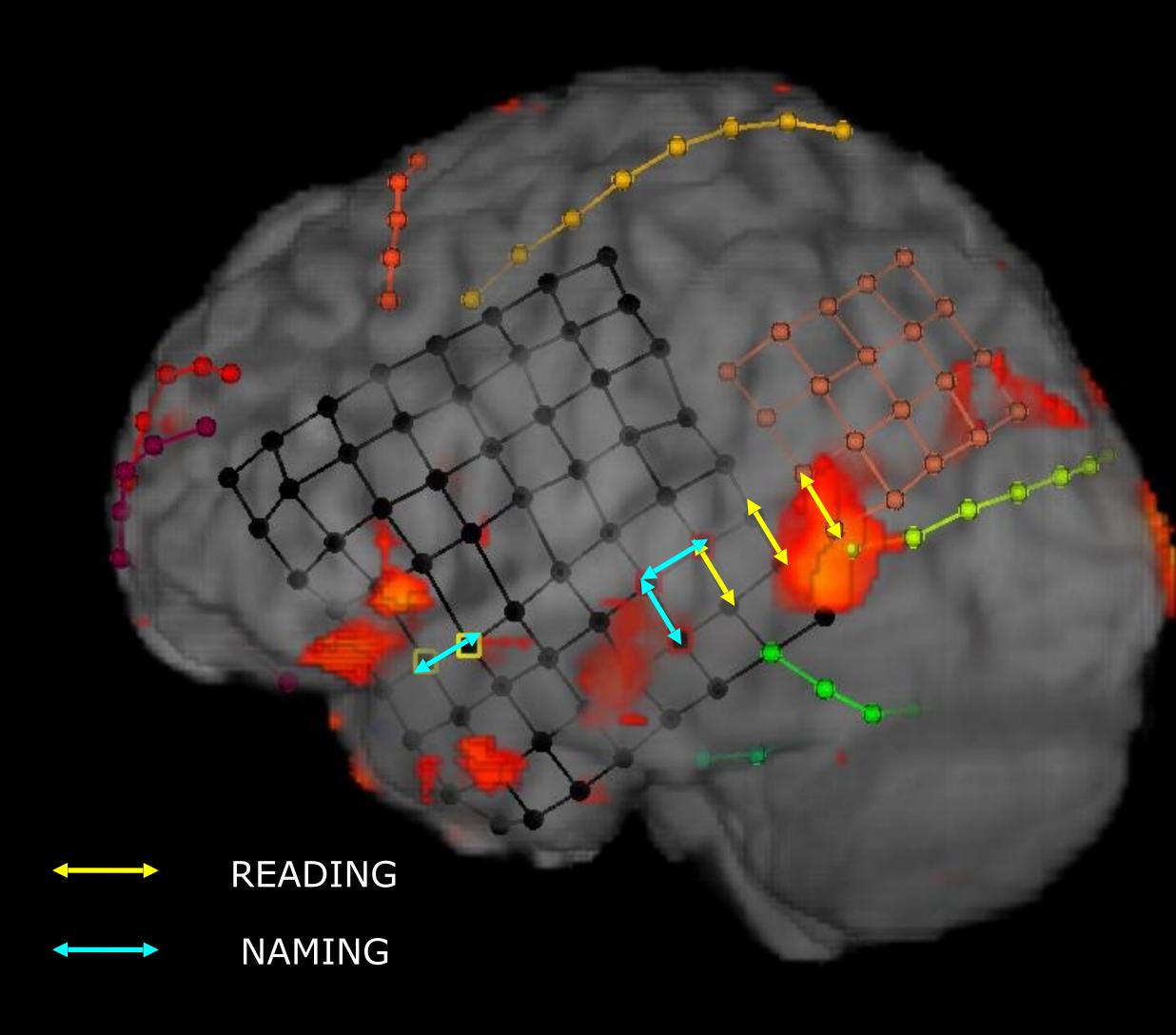


2. SEIZURES

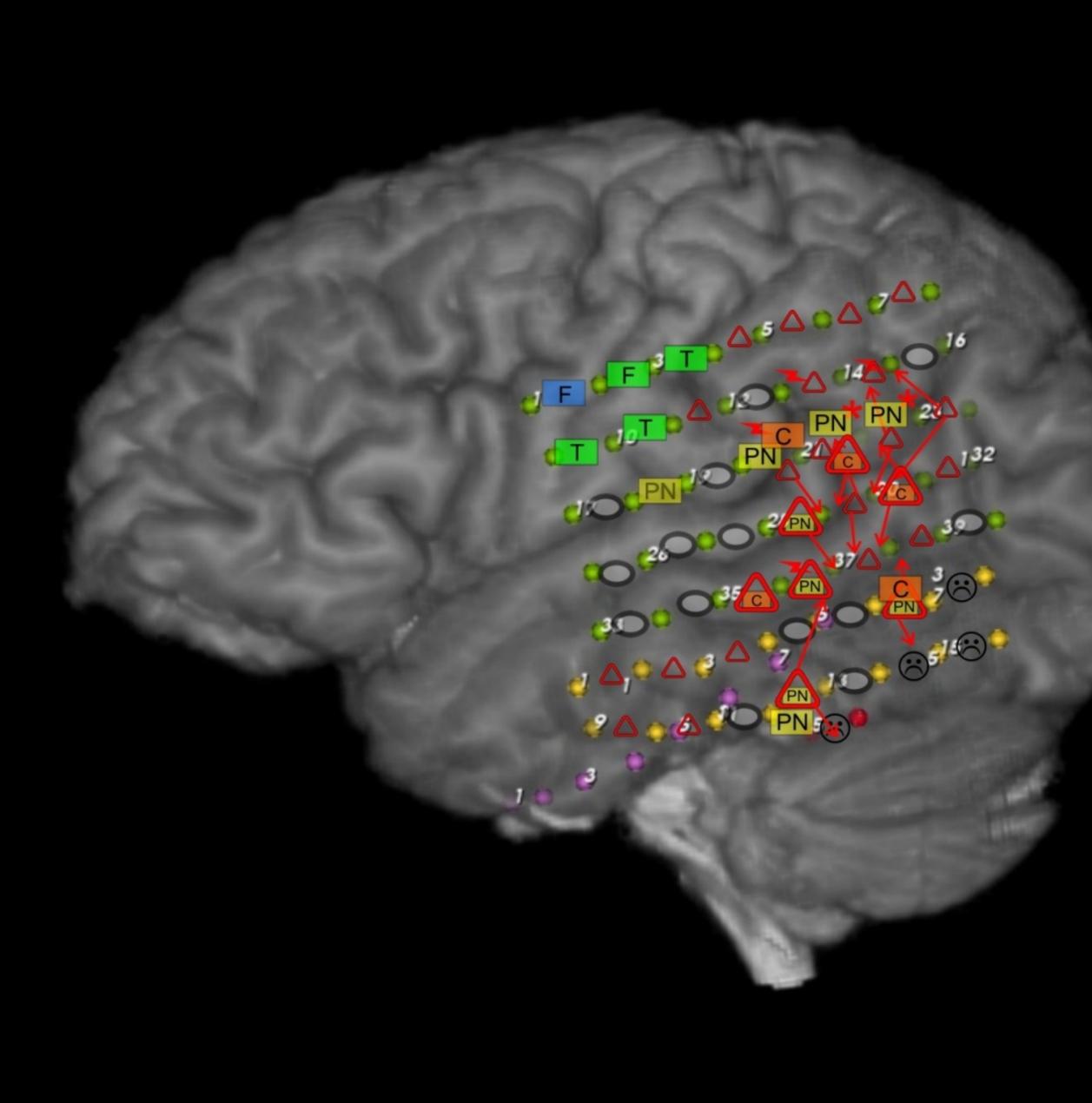




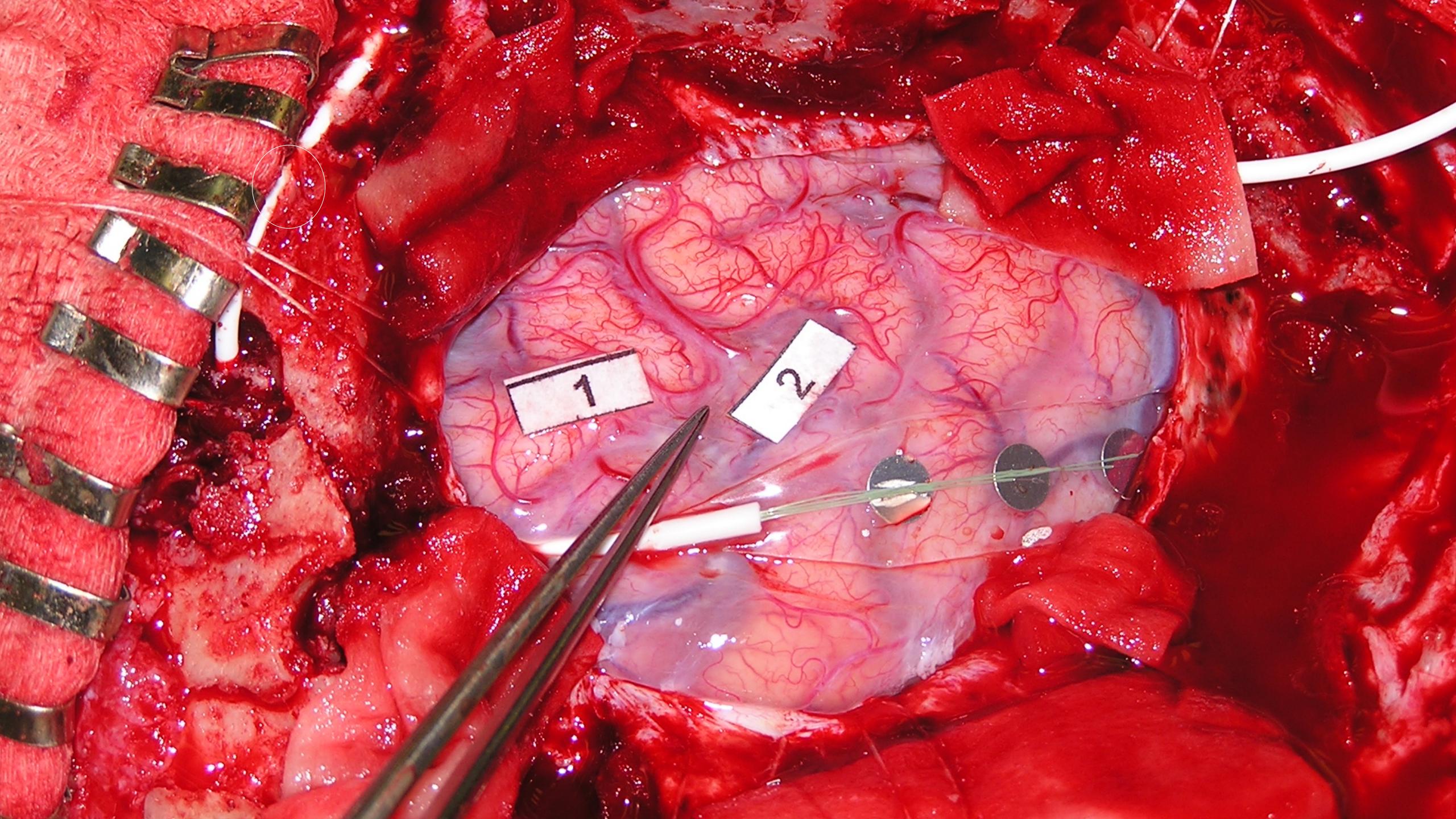
INTEGRATIVE APPROACH

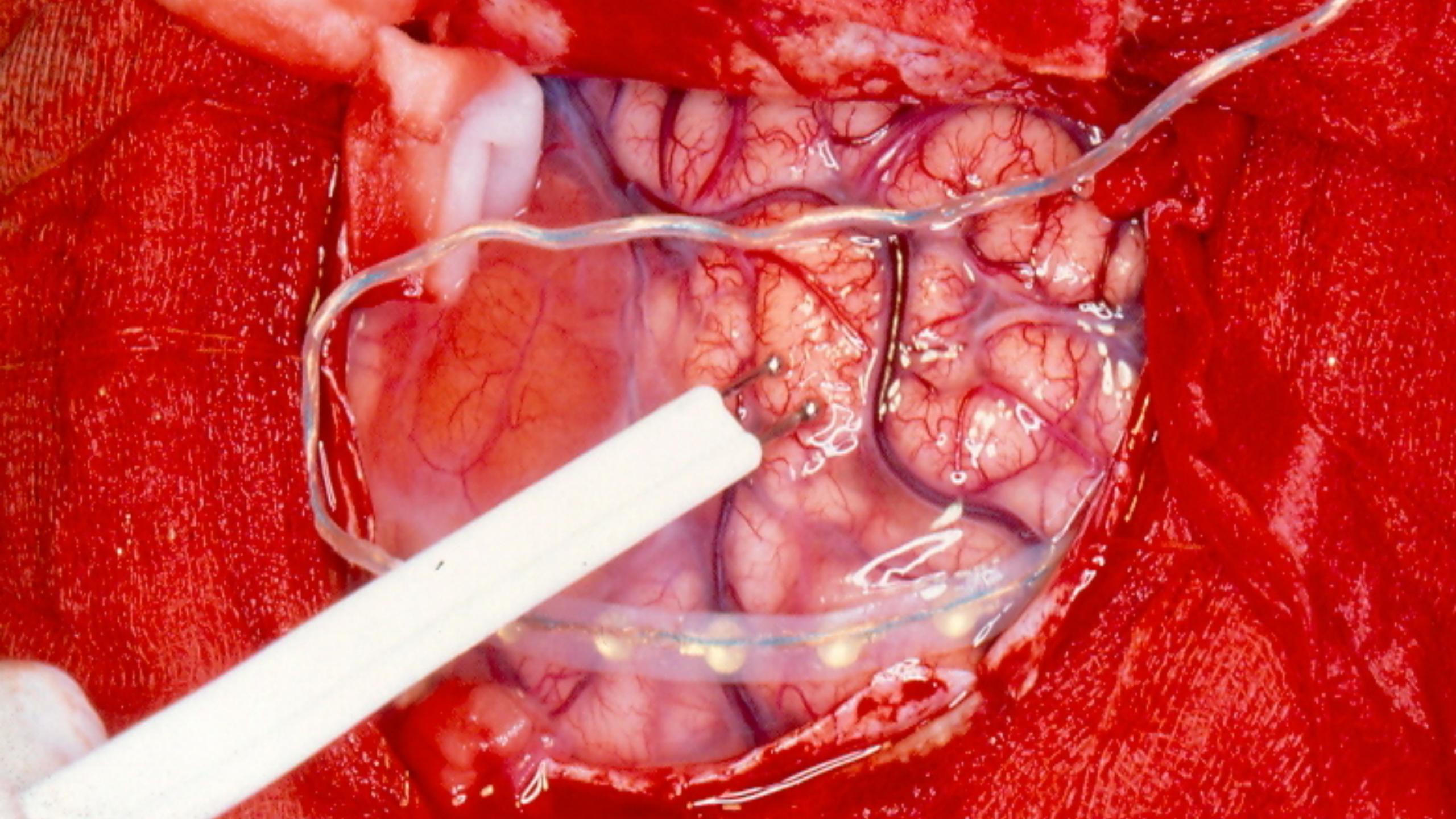


INTEGRATIVE APPROACH



INTEGRATIVE APPROACH





INTRAOPERATIVE STIMULATION

