Focal lesion ablation

Less invasive, more effective? new treatment options in epilepsy surgery

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Focal lesion ablation in epilepsy

NO DISCLOSURES
Focal lesion ablation in epilepsy

IA
SEEG-guided RF-thermocoagulation of epileptogenic foci (2004 France/2016 NL)

IB
First results: our patient cohort with periventricular heterotopias

II
MR-guided stereotactic laser ablation of epileptogenic foci
SEEG-guided RF-thermocoagulation of epileptogenic foci

**SEEG-technique**
- stereotactic implantation of depth electrodes

(Bancaud et al; Electroencephalogr Clin Neurophysiol 1962;14:788)

-detailed detection of the spatiotemporal electrical distribution & correlation to semiology
SEEG-guided RF-thermocoagulation of epileptogenic foci

SEEG-technique: Talairach frame
SEEG-technique MUMC

3T double GD-MRI fusion with CT & 
Leksell frame

2008-2013: Stealth, Medtronic

2014-2018: Iplan, Brainlab
SEEG-technique: The MUMC version

- orthogonal and OBLIQUE trajectories

- postop CT+MRI / fusion with preop MRI
SEEG-technique MUMC: Dixi depth electrodes
SEEG-technique MUMC: Dixi depth electrodes
SEEG-technique MUMC: Dixi depth electrodes

Diameter 0.8 mm
Contact length 2mm

☐ Implantation procedure and accessories validated for over 30 years (more than 20 000 implanted electrodes)
☐ Platinum/iridium
☐ Adapted to the treatment of epilepsy thanks to thermocoagulation by radio frequency at the end of a SEEG for a diagnosis and therapeutic use
☐ MR Conditional
SEEG-technique Maastricht Planning trajectories
SEEG-guided RF-thermocoagulation of epileptogenic foci
SEEG-guided RF-thermocoagulation of epileptogenic foci
Postoperative CT
clinical onset
Methodology, outcome, safety and in vivo accuracy in traditional frame-based stereoelectroencephalography

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Stereotactic (monopolar) RF thermocoagulation

History

- Use of stereotactic surgery for RF waves: first report by Spiegel et al., Science 1947

- First paper (amygdalotomy for behavioral problems) with positive effect in epilepsy (Schwab et al., 1965)
Stereotactic (monopolar) RF-thermocoagulation

History

-Lesioning specific brain structures with

* oil wax injection (Narabayashi, 1963)
* isotope implants (Talairach, 1965)
* cooling (Heimburger, 1966)
Stereotactic (monopolar)RF-thermocoagulation

History

-proposal to treat drug-resistant TLE by (monopolar TC) lesioning amygdalo-hippocampal foci (Flanigin, Acta NCH, 1976)

-Sz outcome proved to be less favorable than resective surgery (Parrent, Can J Neurol Sci, 2000 & Patil, Stereot Funct Neurosurg, 1995)
SEEG-guided RF-thermocoagulation of epileptogenic foci

- **Diagnostic** method (SEEG) turned into **therapeutic** method due to application of RF-thermal energy = new approach
  (Guenot, 2004; Catenoix, 2008; Guenot, 2011; Cossu, 2014; Catenoix, 2015; Cossu, 2015; Bourdillon, 2016; Bourdillon, 2017)

- therapeutic alternative for drug-resistant non-resective partial epilepsies
SEEG-guided RF-thermocoagulation of epileptogenic foci

Lesions
Periventricular Nodular Heterotopia (PNH)
Mild Malformations of Cortical Development (mMCD)
Hypothalamic Hamartoma (HH)
Focal Cortical Dysplasia (FCD)
Hippocampal sclerosis (HS)
SEEG-guided RF-thermocoagulation of epileptogenic foci

*Excellent indication:
- (deep seated) Heterotopia.

*Potential good indication: HH, MCD and HS

*Discussion: other lesions (incl FCD), MRI-negative.

Indication for good Sz-outcome: LAFA and Sz-reproduction
SEEG-guided RF-thermocoagulation of epileptogenic foci
SEEG-guided RF-thermocoagulation of epileptogenic foci

**pulsed RadioFrequency-technique for tissue ablation:**

- RF power generator $\Rightarrow$ RF energy. Frequency range 400-500 kHz, 50V, 120mA, 30 sec.

$\Rightarrow$ abrupt current decrease, indicates tissue coagulation

$\Rightarrow$ temperature raise between 78-82° C; lesion <10-30 seconds

- RF is pulsed to prevent coagulum formation on electrode(tip)
SEEG-guided RF-thermocoagulation of epileptogenic foci
SEEG-guided RF-thermocoagulation of epileptogenic foci

- Lesions in areas showing low-amplitude fast pattern or spike-wave discharges at seizure-onset

- Targets first functionally tested using electrical stimulation (50Hz/0.5ms pulseduration/1-3mA/3s)

- Only targets without clinical response are selected for thermolesion; no RF-TC < 2mm from vessels
SEEG-guided RF-thermocoagulation of epileptogenic foci

- bipolar lesions (between 2 contiguous contacts) placed without anaesthesia (for clinical monitoring of the patient)

- thermocoagulation parameters: 50Hz / 50V / 30 seconds

- each thermocoagulation produces a 5-7mm diameter (sub)cortical lesion (100 mm³)

- inability to measure temperature in situ and to monitor ablation in real-time (in contrast to laser therapy)
SEEG-guided RF-thermocoagulation of epileptogenic foci

- after each coagulation => depth electrode recording => absence of focal epileptiform activity

- removal of electrodes same day after coagulation and discharge 24-48h later
SEEG-guided RF-thermocoagulation of epileptogenic foci

Post RF thermolesion MRI with lesions in right insula and frontal operculum (1-2M post RF)
SEEG-cohort Maastricht

Period 2008 – 2018
SEEG – diagnostic cohort
N = 116 patients (N= 90 adults / N= 26 children)

Period 2016 – 2018
SEEG – diagnostic & therapeutic cohort
N = 12 patients (only adults)
SEEG-guided RF-thermocoagulation of epileptogenic foci

The ACE-MUMC experience

Pilot-study (March 2016 - today)
-12 patients, all with Periventricular Nodular Heterotopia (PVNH), 16 RFTC’s
-all focal lesions, 9 uni- and 3 bilateral
SEEG-guided RF-thermocoagulation of epileptogenic foci

The ACE-MUMC experience

- oligo lesion: N = 5
- multiple PVNH’s: N = 7 (uni-& bilateral)
- PVNH in Seizure-Onset Zone (SOZ): N = 12
- in most Sz: SOZ visible in PVNH
SEEG-guided RF-thermocoagulation of epileptogenic foci

The ACE-MUMC experience

Follow-up: average 15 M (3-33 M) (N=12)

Mean: 7 depth electrodes (1-22)

Mean: 16 RFTC points (1-34)
SEEG-guided RF-thermocoagulation of epileptogenic foci

The ACE-MUMC experience

- complete lesioning of PVNH: N = 3

- complete lesioning:
  N = 1 => Sz free patient
  N = 1 => PNEA patient
  N = 1 => >80% Sz reduction patient

→ Incomplete lesioning in 5/6 Sz free patients!
SEEG-guided RF-thermocoagulation of epileptogenic foci

The ACE-MUMC experience

Seizure outcome
-Sz free: N=6 (50%)
->80% Sz reduction: N=2 (17%)
- >50% Sz reduction: N=1 (8%) *
- <50% Sz reduction: N=3 (25%)
- * developed psychogenic Sz’s (PNEA)
SEEG-guided RF-thermocoagulation of epileptogenic foci:

The ACE experience

Complications:
Permanent: N=0
Transient, minor: N=2

N=2: fever and headache 1 week after RFTC
Analysis: no etiological explanation
Spontaneous recovery after 3 days
SEEG-guided RF-thermocoagulation of epileptogenic foci:
The ACE experience

Discussion:
- several reports:
1. Overlying cortex “more important” than PVNH
2. Incomplete lesioning not “fruitful”

→ our experience: destruction “critical hub” in PVNH as part of epileptogenic network => can be sufficient
Bourdillon et al, Epilepsia 2017

• 162 patients, “mixed bag” (44 FCD, 5 heterotopia), no correlation outcome-pathology. Lesions/patiënt? 24 re-procedures
• 2 months: 25% sz-free, after 1 year 7%
• 2 months: 67% responders (>50% Sz-reduction), after 1 year 48%
• 58% of responders maintained their status during 5 yrs F/U
Bourdilon et al, Epilepsia 2017

• PPV of being responder < 2 months after RFTC and an Engel I/II after surgery = 93%

• => being a responder appears to be a reliable indicator for predicting Sz outcome
Bourdilon et al, Epilepsia 2017

• 1.1% permanent complications

• 2.4% transient complications
Catenoix, Neurosurgery, 2015

- 14 patients with MCD. Avg 25.8 lesions. 9 (64%) responders (>50% Sz-reduction), 6 Sz-free.
- Sz-begin with LAFA: 87% responder
- Sz reproduction after stimulation: all responders.
SEEG-guided RF-thermocoagulation of epileptogenic foci

• **Summary of advantages:**
  1. Target choice based on SEEG data
  2. Diagnostic electrodes = therapeutic ones
  3. Multiple electrodes means multiple possible lesion sites
SEEG-guided RF-thermocoagulation of epileptogenic foci

• Summary of advantages:
  4. real-time monitoring clinical & neurophysiological status of the patient
  5. No anesthesia
  6. Resective surgery after RFTC = possible
  7. Electrode explantation = possible without additional bleeding risk
SEEG-guided RF-thermocoagulation of epileptogenic foci: Future perspective
Robot-assisted implantations
MR-guided stereotactic laser ablation of epileptogenic foci

Indications

*Hypothalamic hamartoma:*
Congenital, non-neoplastic, heterotopia variant, gelastic epilepsy, pubertas precox, behavioral problems, prevalence 1:1,000,000.
MR-guided stereotactic laser ablation of epileptogenic foci

= MR-guided Laser Interstitial Thermal Therapy

= MRgLITT
MR-guided stereotactic laser ablation of epileptogenic foci

Indications
Hypothalamic hamartoma
MR-guided stereotactic laser ablation of epileptogenic foci

Hypothalamic hamartoma classification
MR-guided stereotactic laser ablation of epileptogenic foci

Indications

Hypothalamic hamartoma
MR-guided stereotactic laser ablation of epileptogenic foci

**Indications**

*Periventricular nodular heterotopia*

Congenital, 6th-24th week, neuronal migration disturbance, 5 PNH groups dependent on location
MR-guided stereotactic laser ablation of epileptogenic foci

**Indications**

*Periventricular nodular heterotopia*
MR-guided stereotactic laser ablation of epileptogenic foci

Indications

Periventricular nodular heterotopia
MR-guided stereotactic laser ablation of epileptogenic foci

Other Indications in literature

Focal cortical dysplasias

Tubers (TS)

MTS

LEAT
MR-guided stereotactic laser ablation of epileptogenic foci
percutaneous MRI-guided laser interstitial thermal therapy (MRgLITT)

Two major LITT platforms:
1. Visualase®, Medtronic
   FDA approved 2007; mid 2017 expected CE approval

2. NeuroBlate®, Monteris Medical, Minnesota
   FDA approved 2009
MR-guided stereotactic laser ablation of epileptogenic foci

Major components of the laser system:
1. 1.15W, 980nm diode laser

2. Disposable saline-cooled laser applicator probe with cooling catheter (diameter 1.65cm)

3. Computer workstation communicating with MRI
MR-guided stereotactic laser ablation of epileptogenic foci

Visualase

Computer-workstation
MR-guided stereotactic laser ablation of epileptogenic foci

- procedure under general anesthesia
- stereotactically guided twist drill burr-hole
- bone anchor placed in skull
- cooling catheter & laser probe is stereotactically inserted to the intended target area & locked
MR-guided stereotactic laser ablation of epileptogenic foci

- Patient transport to the MRI
- T2-imaging & probe tip placement confirmation
- Fast-spoiled gradient MRI images at temperature as baseline
- Circulation cooling system + test pulse: 3-4 W for 30-60 sec: exact location distal probe
MR-guided stereotactic laser ablation of epileptogenic foci

Ablation treatment doses: 10-15W for 30-60 sec until “damage zone” covers target

After completion: removal of catheter and anchor and stitching the small skin puncture site
MR-guided stereotactic laser ablation of epileptogenic foci

Physics: emitted photons $\Rightarrow$ absorbed by pathogenic tissue $\Rightarrow$ healthy tissue $\Rightarrow$ tissue heating

Irreversible cell damage $\Rightarrow$ 46-60 Celsius

Instantaneous coagulation necrosis $\Rightarrow$ >60 Celsius

Sharp temp. fall off at border of the coagulation zone $\Rightarrow$ sharp margin between viable/nonviable tissue
MR-guided stereotactic laser ablation of epileptogenic foci

Laser light heats and destroys target area. Temperature maps show the physician the extent of the tissue being destroyed, minimizing risk of potential damage to surrounding healthy tissue.
MR-guided stereotactactic laser ablation of epileptogenic foci

Review by LaRiviere et al. Frontiers in Surgery; 2016; 3: 64

1963: first described by Narabayashi, Tokyo

1995: first CT-guided stereot. RF amyg. hippocampotomy: highly variable results regarding Sz outcome in following series (2-75% Engel I)

MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al.
Frontiers in Surgery; 2016; 3: 64

1990: first report on LITT = Laser Interstitial Thermo Therapy in tumors

1991: first report on MRI thermometry in tumors
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al. Frontiers in Surgery; 2016; 3:64

1996: first report on “water proton resonance frequency shift MRTI” = technique for modern laser ablation systems

Start MRI-guidedLITT = MRgLITT
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al.
Frontiers in Surgery;2016;3:64

2007: first commercially available MRgLITT system → Visualase, Medtronic

2008: first human application in patient with metastases
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al.
Frontiers in Surgery; 2016; 3: 64

2012: first Visualase report in epilepsy: 5 pediatric patients by Dr Curry, Houston

2xHypothalamic hamartoma/1xFCD/1xtub.sclerosis/1x MTS
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al. Frontiers in Surgery; 2016; 3: 64

Indications: hypothalamic hamartoma / mTLE (HS) / FCD / PNH / LEAT / Tub. sclerosis

Only small case series with short follow up (<24 months)
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al.
Frontiers in Surgery; 2016; 3: 64

-Curry 2013; 14 HH’s: 86% Engel I; mean 9 months follow up
1 transient complication (memory!!)
-Willie 2014; 13 SLAH: 54% Engel I, F/U 5-26 months; potentially improving neuropsychological outcome
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al.
Frontiers in Surgery; 2016; 3: 64

2014: reports on MRgLITT in PNH’s: 2 patients; both Sz free; 1 after AED adjustment + 1 after ATL
2015: report on MRgLITT in 9 FCD’s: outcome substantially worse compared to open resection
MR-guided stereotactic laser ablation of epileptogenic foci

Complications:
13% of all => transient neurologic def. (paresis/hemianopia/dysphagia
3% permanent neurolog.complications
2.5% intracerebral hemorrhage
2.5% infections
MR-guided stereotactic laser ablation of epileptogenic foci

Review by LaRiviere et al. Frontiers in Surgery; 2016; 3:64

Conclusion: MRIgLITT is in its infancy in epilepsy & evidence is limited

Only small series - variable inclusion criteria - mixed pathology - short F/U - no prospective trials yet => predisposing to selection bias
SEEG-RFTC or MRgLITT in HH?

Perhaps:


Stereoelectroencephalography-Guided Radiofrequency Thermocoagulation for Hypothalamic Hamartomas: Preliminary Evidence.

Wei PH¹, An Y¹, Fan XT¹, Wang YH¹, Yang YF¹, Ren LK², Shan YZ³, Zhao GG⁴.

China