Functional Imaging in Epilepsy Surgery

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1st EPODES course on Epilepsy Surgery, Brno, Czech Republic
Patients with an intractable localization-related seizure disorder and normal MRI, i.e. with nonlesional focal epilepsy, may be considered for surgical treatment.

However, in these patients it is difficult to localize the epileptogenic zone, and epilepsy surgery results are less favorable.

This is the main reason for increasing use of functional imaging methods in epilepsy surgery candidates.

In addition FI is the key technique to determine whether it will be possible to resect the epileptogenic zone without inducing relevant new neurological or neuropsychological deficits.
Functional imaging techniques

- **Interictal** and ictal **PET**
- Interictal and ictal **SPECT, SISCOM**
- **fMRI** (incl. continuous EEG/fMRI and ictal fMRI)

These techniques must be carried out as a part of a multimodal preoperative evaluation process (incl. interictal and ictal video-EEG, MRI, neuropsychological testing, and event. intracranial EEG recordings).

The aim is then to assess whether all data point to the same abnormal areas and to combine all available data to delineate the spatial relations between epileptogenic, irritative and functional-deficit zones!
the first functional nmg technique applied to presurgical evaluation of intractable epilepsies in late 1970s, using FDG (= still most widely used PET tracer in epilepsy studies).

Interictal FDG-PET can detect a local glucose ↓ metabolism within epileptic focus (functional-deficit zone, which is usually exceeding epileptogenic zone!)
Sensitivity of FDG-PET
differs according to the location of the epileptic focus and to the nature of underlying lesion.

Mean value in all types of partial epilepsies – **70-80%**
Mean value in pts with normal brain MRI – **61-77%**

**TLE** – **85-100%**
**FLE** – **36-96%**

Glucose hypometabolism is ipsilateral to the epileptogenic area in a vast majority of patients.
Lateralizing value of PET is higher than that of MRI!
FDG-PET and localization of the EZ

The presence of a temporal hypometabolism makes invasive recordings unnecessary in deciding whether or not to perform a conventional AMTR in a patient presenting with all criteria of medial TLE (history, seizure phenomenology, HS in MRI, neuropsychology).

A focal hypometabolism limited to the temporal lobe predicts a good outcome of AMTR, even in nonlesional TLE patients = MRI-negative, PET-positive TLE.
• **Coregistration of PET and MRI data**

Structural lesion in mesiofrontal ctx

MRI-negative epilepsy

• **Ictal PET is extremely rare**

*PET is not adapted to ictal studies except for szs that can be provoked during data acquisition, provided they do not induce head movements.*
SPECT

is the most appropriate ictal imaging method for identifying the seizure onset zone in epilepsy surgery candidates. Ictal SPECT studies are superior to interictal images!

- Interictal imaging = hypoperfusion
  (sensitivity 45-70%)

- Ictal imaging = hyperperfusion
  (sensitivity ~ 90%, specificity ~ 80%)

R L

RT 8 s
SISCOM in right MTLE/HS
(RT injected 6 seconds after seizure onset)

Fem. aged 30 years, disease duration 24 years.
Frequent complex partial seizures of temporal type.
AMTR l.dx., histopatholog. analysis verified HS.
Outcome - Engel Ib (2.5 years after the surgery).
SISCOM in lesional epilepsies

RT injected 15 seconds after sz onset.

Pt. with lesional lateral TLE (subtle hyperintense lesion in the depth of right superior temporal sulcus). Histopathological analysis revealed DNET with cortical dysplasia. Outcome – Engel Ib (2.5 years after the surgery).
SISCOM in nonlesional epilepsies

RT injected 3 seconds after seizure onset. Seizure duration 25 seconds.

Pt. with frequent SPS – laryngeal constriction, sensory and motor symptoms on the right mouth corner, tonic posture of right UL (25/d). 2 sGTCS/m. Histopathol. FCD IA. Engel Ib.

Multifocal SISCOM finding is frequent
It can reflect spread of ictal activity (which focus is primary?)

Left TLE
Ictal semiology:
No warning, loss of consciousness, bilateral hand and perioral automatisms, nonversive head turning to the left side, RT INJECTION → clonic jerks of right mouth corner and then of right side of face, eyes version to the right, sGTCS.
Multifocal SISCOM finding is frequent
It can reflect spread of ictal activity (which focus is primary?)

Pt. with posttraumatic lesion in right temporo-parieto-occipital region, seizure history from the age of 12 years, CPS with initial visuo-spatial illusion, subsequently infra- (temporal automatisms) or suprasylvian spreading (eyes and head version to the left side) and occasional sec. generalization. Histopathology: posttraumatic changes.
SISCOM (ictal versus postictal injection)

ICTAL

Lesional left-sided MTLE

POSTICTAL

RT injected 10 seconds after sz onset.  RT injected 30 minutes after seizure
Indications for SISCOM

- Pts with intractable focal epilepsy and normal MRI scan
- Pts with multilobar pathology
- Pts with the presence of a discordant noninvasive presurgical evaluations
- Pts with surgical failures, considered for re-operation

To determine the strategy for placement of subdural and depth electrodes for chronic intracranial EEG monitoring.
Functional MRI

Major applications in epilepsy:
1/ determination of eloquent cortical areas
2/ localization of paroxysmal and ictal phenomena

Ad 1/ a) Lateralization and localization of language

Atypical representation of speech area in a right-hander

Broca speech area

Sensory speech area (Wernicke)

VFT

Story listening
b) Sensorimotor system

Primary motor cortex (hand)

Primary visual cortex

Primary auditory cortex

Centrum pro epilepsie Brno
c) Memory

Bilateral mesiotemporal activation in memory task
(subject data, visual scenes memory task, p< 0.05 corr)

Verbal memory (group data, verbal encoding task, p< 0.001 uncorr)
Ad 2/ **Functional MRI** in the evaluation of the irritative zone *(mapping of spontaneous interictal epileptiform EEG activity)*

- **EEG-triggered fMRI** (spikes-triggered fMRI) — acquisition of single MRI scans was triggered manually by a neurophysiologist monitoring the EEG closely (Warach et al, 1996; Lemieux et al, 1997; Seeck et al, 1998; Krakow et al, 1999, 2000, 2001; Patel et al, 1999; Lazeyras et al, 2000)

EEG/fMRI

Generalized IEDs

Focal IEDs

EEG/fMRI provides additional information about the epileptic source in the presurgical work-up of complex cases

Ad 2/ **Functional MRI** in the localization of the epileptogenic zone?

- **Ictal fMRI**
  

Case-reports; analogy of ictal SPECT with different temporal resolution

Do data obtained from different neuroimaging techniques point to the same abnormal area?
Conclusions

• Functional imaging is a valuable tool in the present-date presurgical evaluation of patients.

• All described techniques (interictal PET, SISCOM, and EEG/fMRI) may contribute importantly to the localization of the epileptic source in many specific (nonlesional) patients.

• The epileptogenic zone (EZ) is a theoretical concept (none of the currently available tests permits direct measurement and precise delineation of the EZ). It seems very likely that new diagnostic techniques with a capacity to directly define EZ will be developed in the field of functional neuroimaging (imaging the distribution of neurotransmitters and receptors involved in the pathogenesis of epilepsy?, data driven fMRI methods?, continuous EEG/functional MRSI?, …).