Wires and electrodes inside the head intracranial recordings in the course of epilepsy surgery

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Epilepsy ~ a disorder of the brain that results in recurrent, unprovoked seizures

- ~ 5% of population will experience at least one seizure
- ~ 1% of population will have *recurrent seizures*

Why epilepsy surgery?

- ~ 25% of epileptic patients will have recurrent seizures despite modern anti-epileptic medication
- ~ 50% of them (~ 1/1000 of population) are possible candidates for epilepsy surgery

Indications for epilepsy surgery

- poorly controlled seizures after medication trials
- seizures are *disabling* for the patient
- well-defined focus of seizure onset (especially temporal lobe)
- epileptogenic zone in "*functionally silent*" regions (acceptable risk of post-operation deficits)
- a good understanding and strong desire from the patient

Preoperative studies

- history and clinical picture of seizures
- MRI (sclerosis, tumour, etc.)
- video/EEG monitoring with
 - scalp electrodes
 - intracranial electrodes
- neuropsychological tests
- psychiatric examination
- WADA (intracarotid amobarbital test)
- SPECT, PET, MEG, fMRI

Video-EEG setup in Kuopio University Hospital



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Indications for intracranial recordings

- exact localization of the epileptogenic zone is required to plan a precise surgical resection for treatment
- exact localization of functional cortex is required to plan a safe resection

Epileptogenic zone

the area necessary and sufficient for initiating seizures

whose removal or disconnection is necessary for abolition of seizures

Lüders HO, Engel J Jr, Munari C. *General principles.* In: Engel J Jr, ed. *Surgical treatment of the epilepsies*. 2nd ed. New York: Raven Press, 1993:137-53.

Intracranial electrodes - Strip electrodes

- 4 to 8 electrode contacts
- flexible strips with embedded stainless steel or platinum contact disks
- *implanted* surgically into the subdural space through a small hole drilled through the skull under general anesthesia



Intracranial electrodes - Grid electrodes

parallel rows of electrode contacts (e.g. 5 x 8)

requires craniotomy to be implanted surgically into the subdural space

Intracranial electrodes - Depth electrodes

- tubular probes carrying usually 10 12 electrode contacts
- penetrate the brain
- insertion is done stereotactically through small holes targeted to the locations of interest in the deep structures of the brain

Visualization of intracranial electrode locations

- needed for the planning of surgical resection
- it is necessary to know exactly the locations of the electrodes with respect to precise anatomical structures
- needed for the correct interpretation of EEG data

Orthogonal X-ray images of subdural electrodes do not provide accurate information of electrode locations with respect to the brain





Segmentation of cortical surface from preoperative MR images



Localising the electrodes from postoperative CT images







Combining the information



Subdural strip electrodes on the reconstruction of cortical surface

Combining the information



A subdural grid electrode on the reconstruction of cortical surface



Depth electrodes with tip contacts in temporomesial structures

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#### Seizure onset in the right hippocampal complex (OHC1 and OHC2 contacts)

# **Cortical stimulation**

- electrical stimulation of the cortical surface through a subdural grid electrode
- used to locate motor, sensory and language areas (with muscle contractions, paresthesias, or speech arrest respectively)
- also tests the cortical excitability near the epileptic focus (aftercharges)

# **Example of a cortical stimulation**



results are coded with colour-filled circles, e.g.

OFP5, OFP6 ~ 6 mA: protruding upper lip, loose of tongue muscle control

# **Deep brain stimulation (DBS)**

- surgery at sites deep within the brain utilizing a stereotactic frame and stereotactic coordinates
- implanting a DBS electrode in thalamus or basal ganglia for treatment of movement disorders like Parkinson's disease, pain, epilepsy, etc.





Therapeutic Effect: Stimulus Polarity ~ Cathode Stimulus Pulse Amplitude ~ 3 V Stimulus Pulse Duration ~ 0.1 ms Stimulus Frequency ~ 150 Hz

# MRI and X-ray showing DBS electrodes in thalamus



### **Cognitive neuroscience**

studies performed during evaluation for epilepsy surgery represent a valuable resource for scientific research

*Engel J Jr. Research on the human brain in an epilepsy surgery setting.* Epilepsy Res 1998;32:1-11

moral obligation ?

# A study on preattentive deviance detection

- we recorded event-related potentials to nonattended auditory stimuli in candidates for epilepsy surgery
- we used depth electrodes aimed at the amygdalohippocampal area
- we found significant differences between responses to frequent and infrequent (or deviant) stimuli

#### Temporomesial responses to standard and deviant tones



#### Responses to deviant stimuli recorded in one subject.

A coronal CT reconstruction demonstrates the temporo-mesial locations of the tips of the depth electrodes.



45 µV

# **Summary**

- invasive recordings are (still) needed in the course of epilepsy surgery
- accurate visualization of implanted electrodes with respect to relevant brain structures is of paramount importance
- implanted electrodes should be used for research both on epilepsy and normal functions of the brain

# Improving the accuracy of grid recordings

# present

# future



