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**

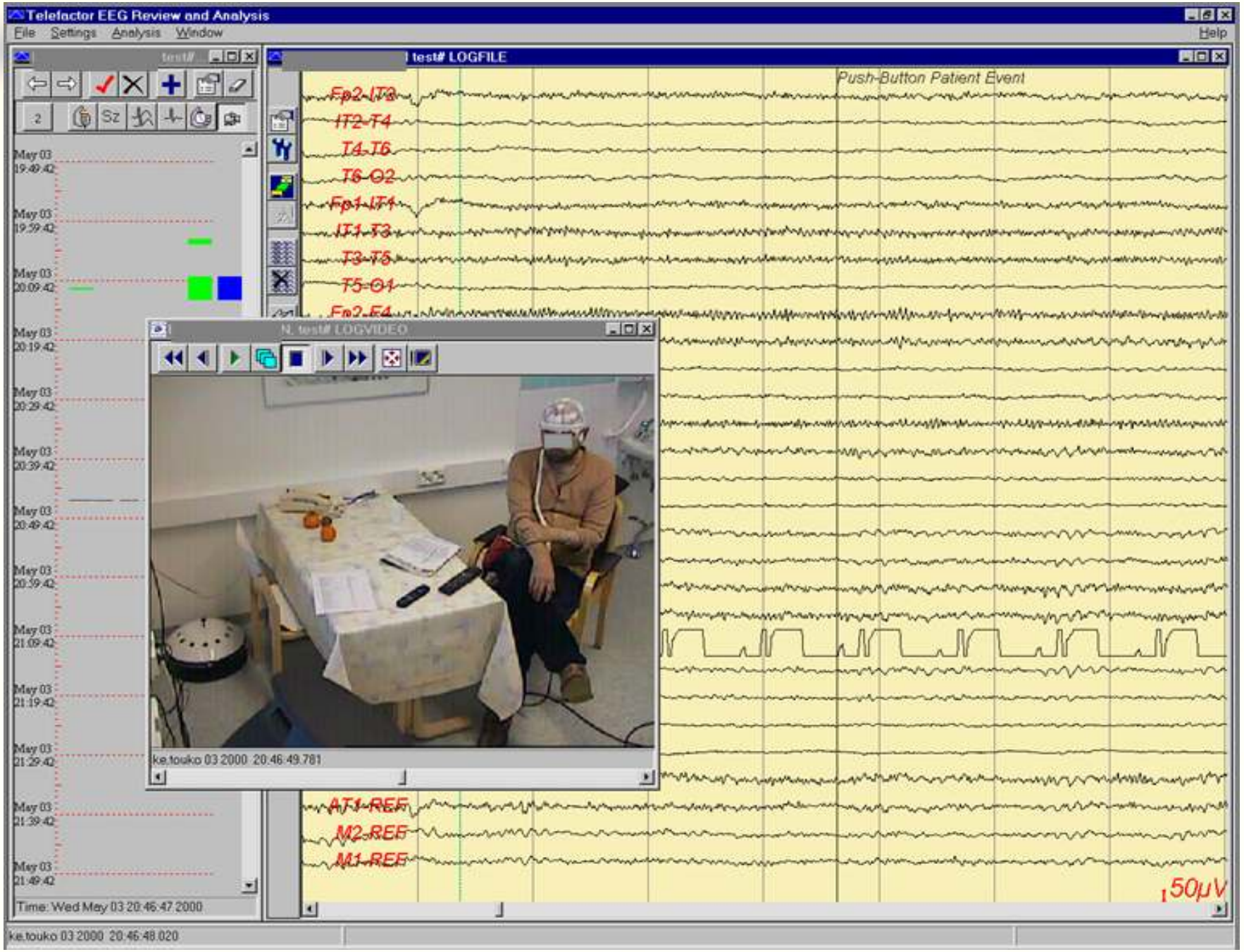
Indications for epilepsy surgery

- 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


Telefactor EEG Review and Analysis
File Settings Analysis Window Help
test# LOGFILE
Push-Button Patient Event
Fp2-LT3
LT2-T4
T4-T6
T6-O2
Fp1-LT4
LT1-T3
T3-T5
T5-O1
Fp2-F4
N. test# LOGVIDEO
ke.touko 03 2000 20:46:49.781
AT1-REF
M2-REF
M1-REF
50µV
Time: Wed May 03 20:46:47 2000
ke.touko 03 2000 20:46:48.020

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***

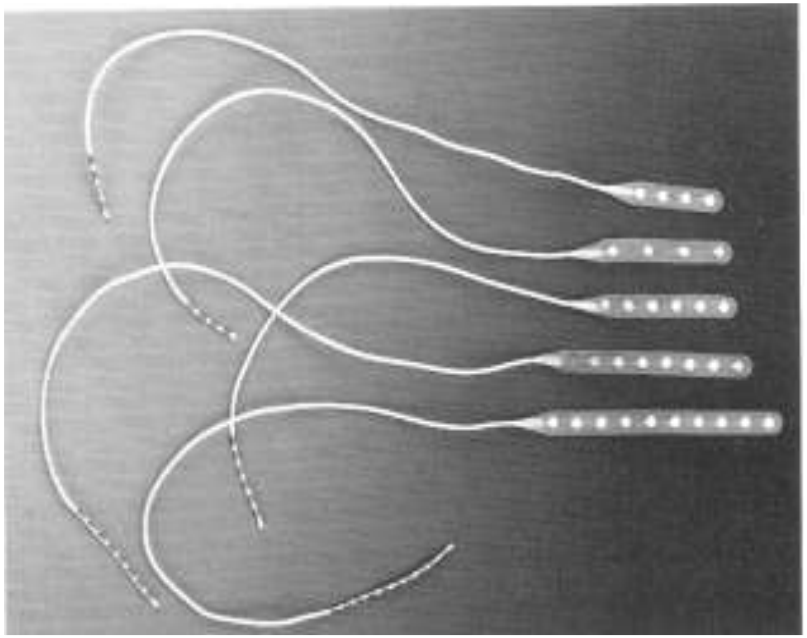
Epileptogenic zone

- **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.

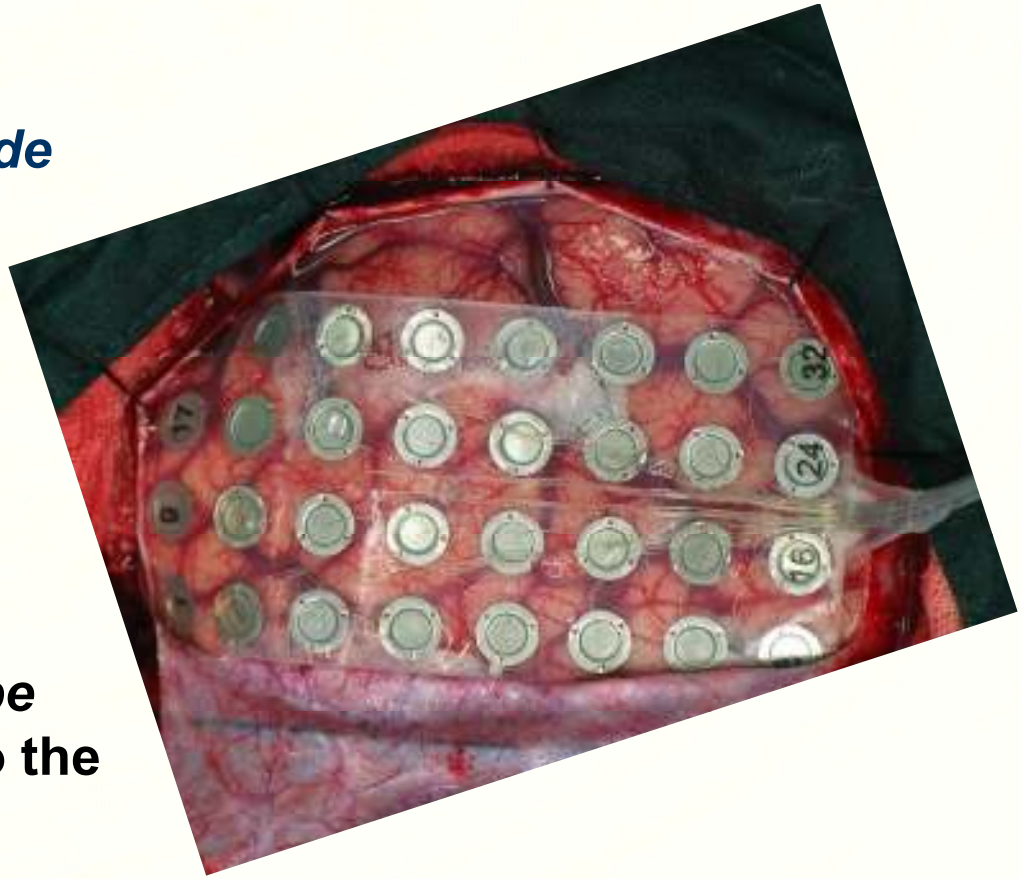
Intracranial electrodes - Strip electrodes

- *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

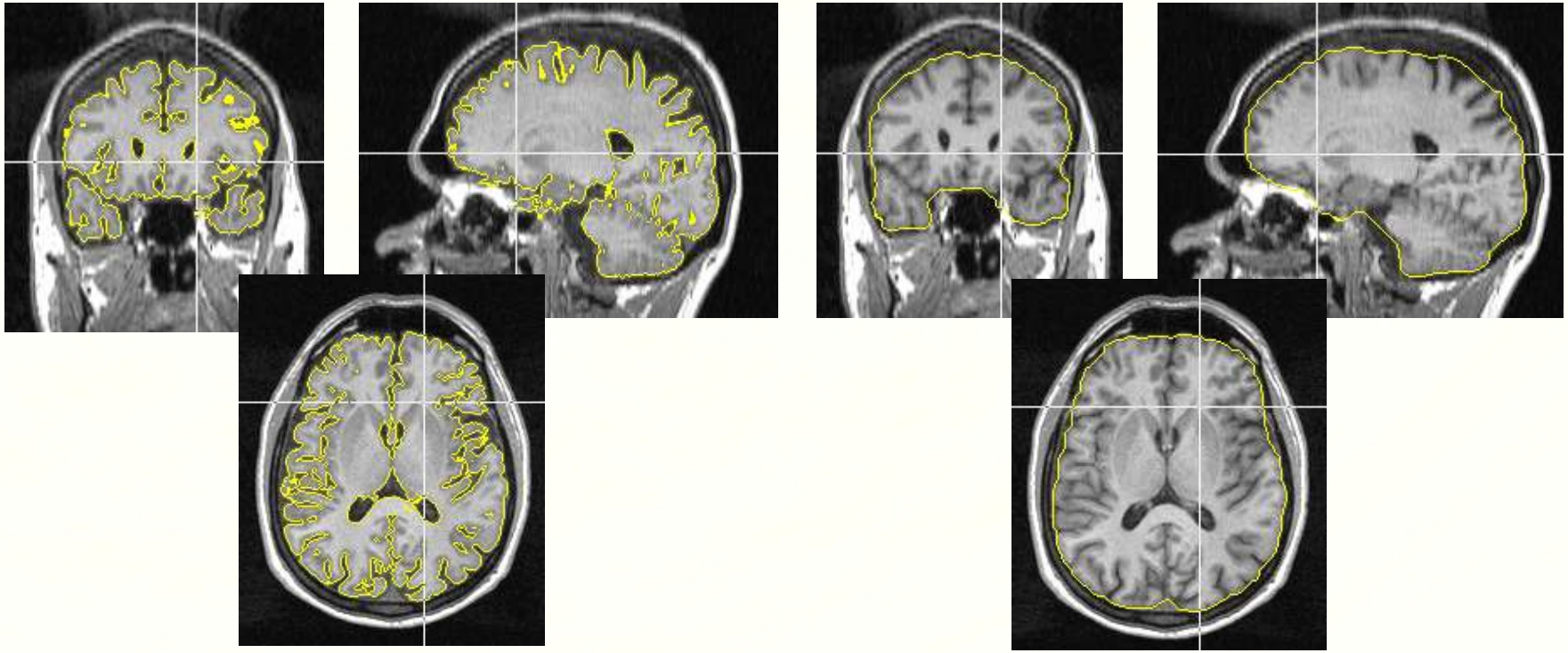
- *needed for the planning of surgical resection*

~ *it is necessary to know exactly the locations of the electrodes with respect to precise anatomical structures*

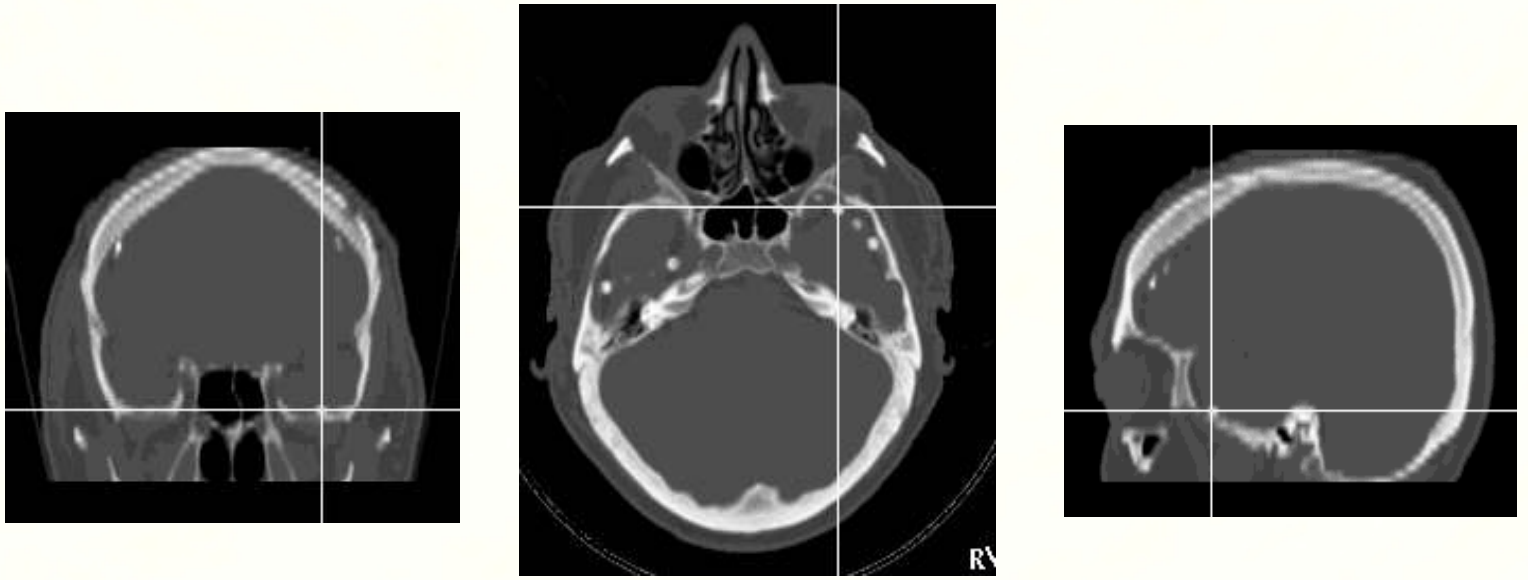
- *needed for the correct interpretation of EEG data*

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

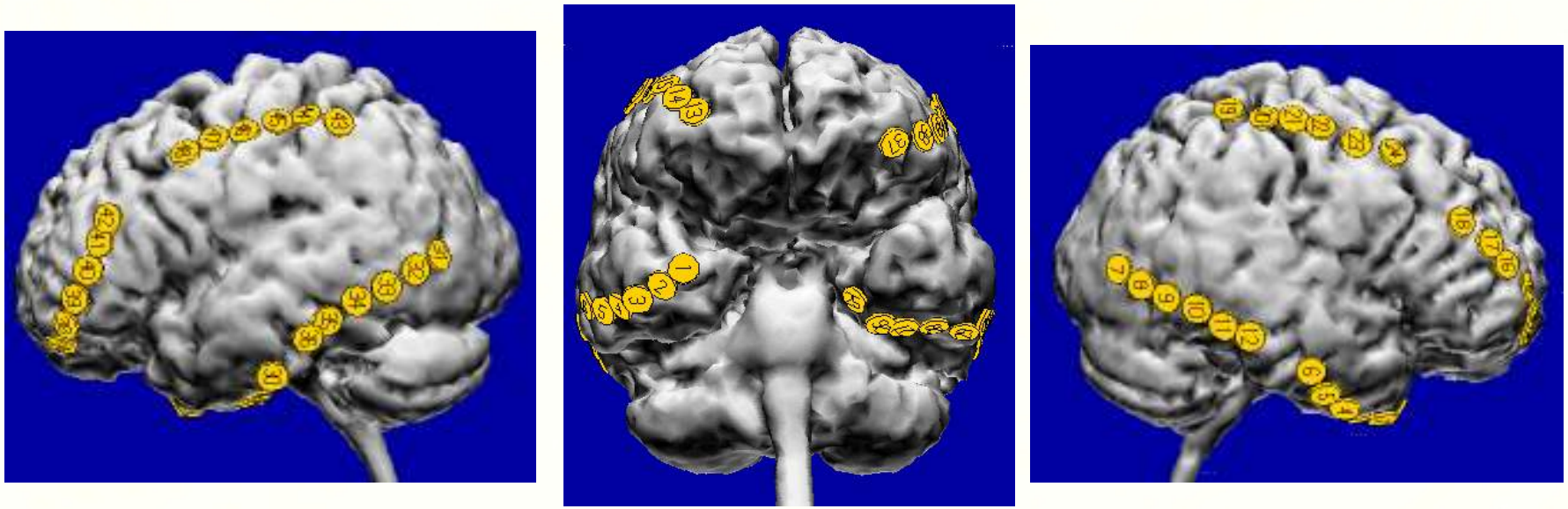
Segmentation of cortical surface from preoperative MR images



Localising the electrodes from postoperative CT images

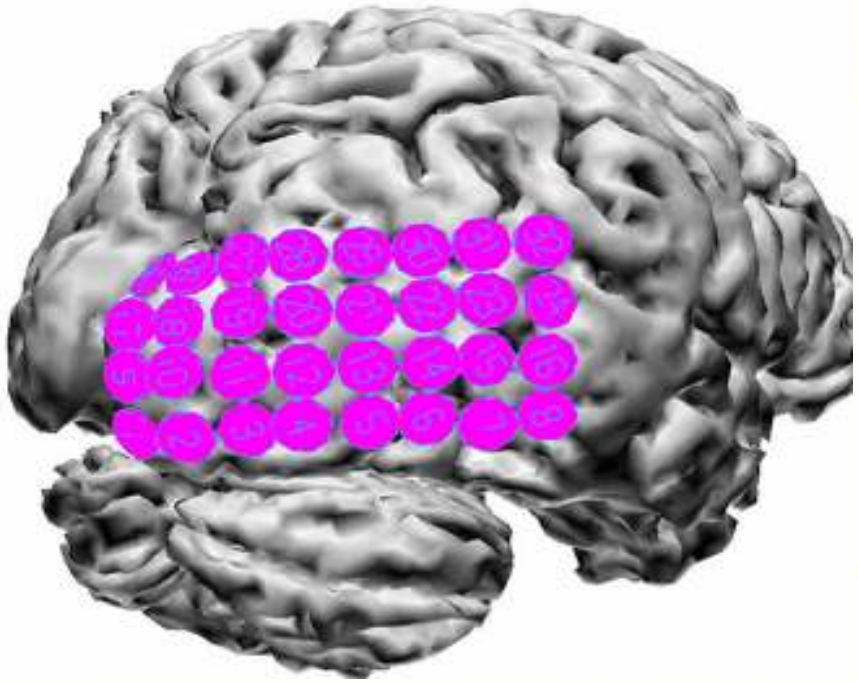


Combining the information

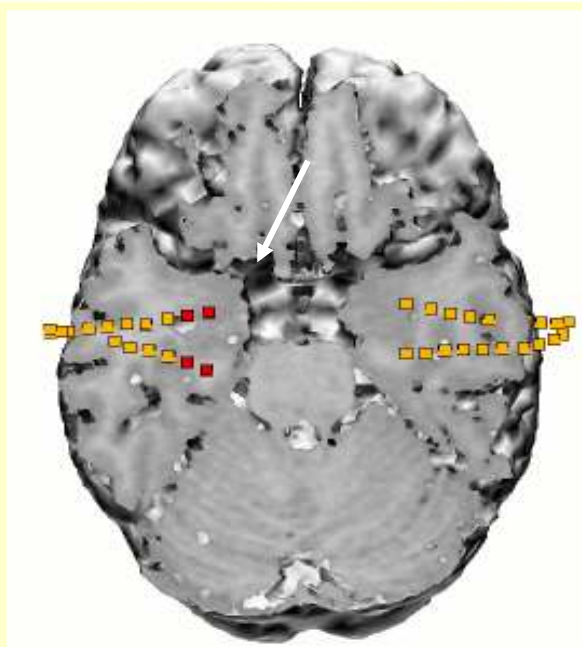


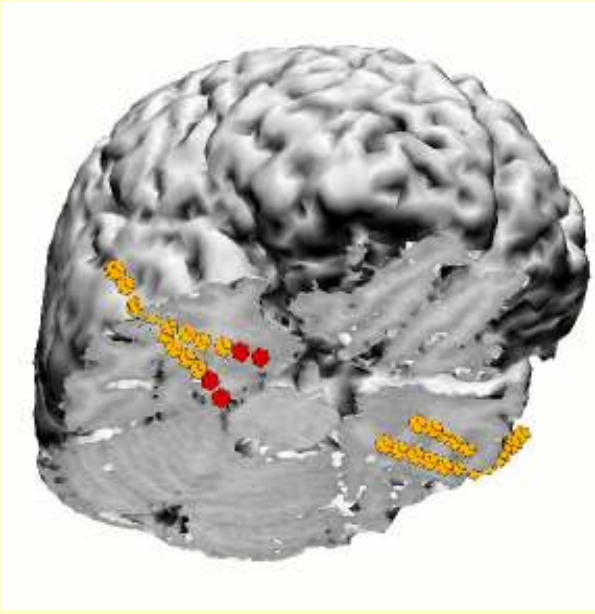
Subdural strip electrodes on the reconstruction of cortical surface

Combining the information

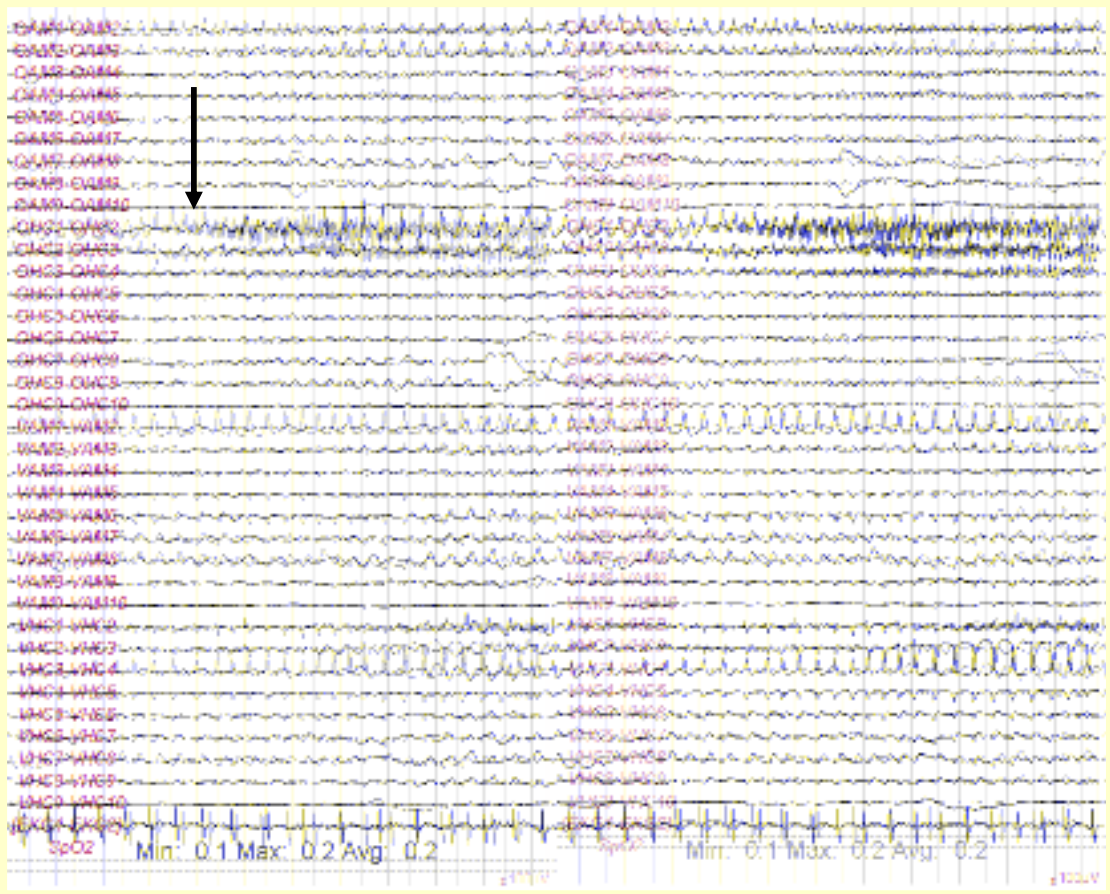


A subdural grid electrode on the reconstruction of cortical surface





Depth electrodes with tip contacts in temporo-mesial structures



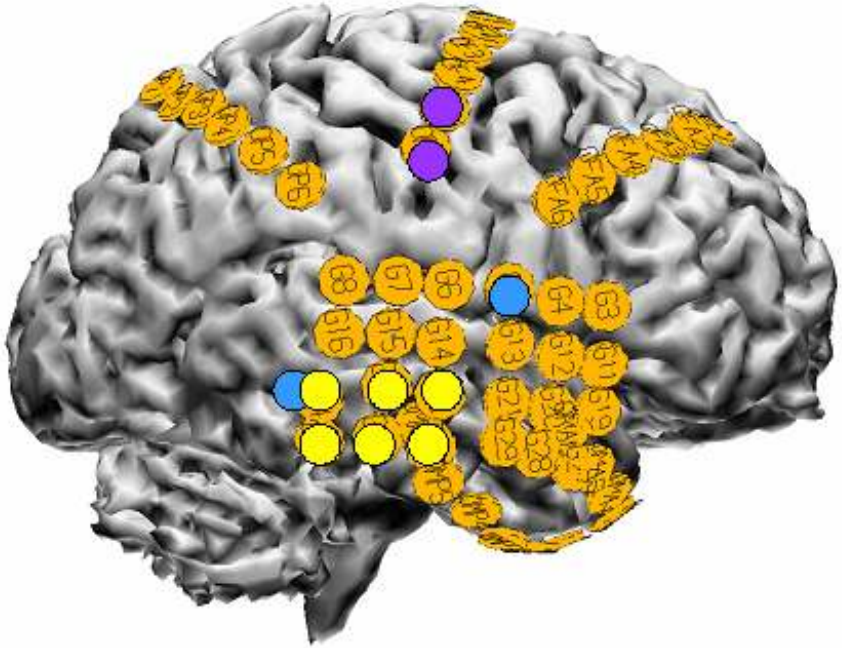
Seizure onset in the right hippocampal complex

(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.

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

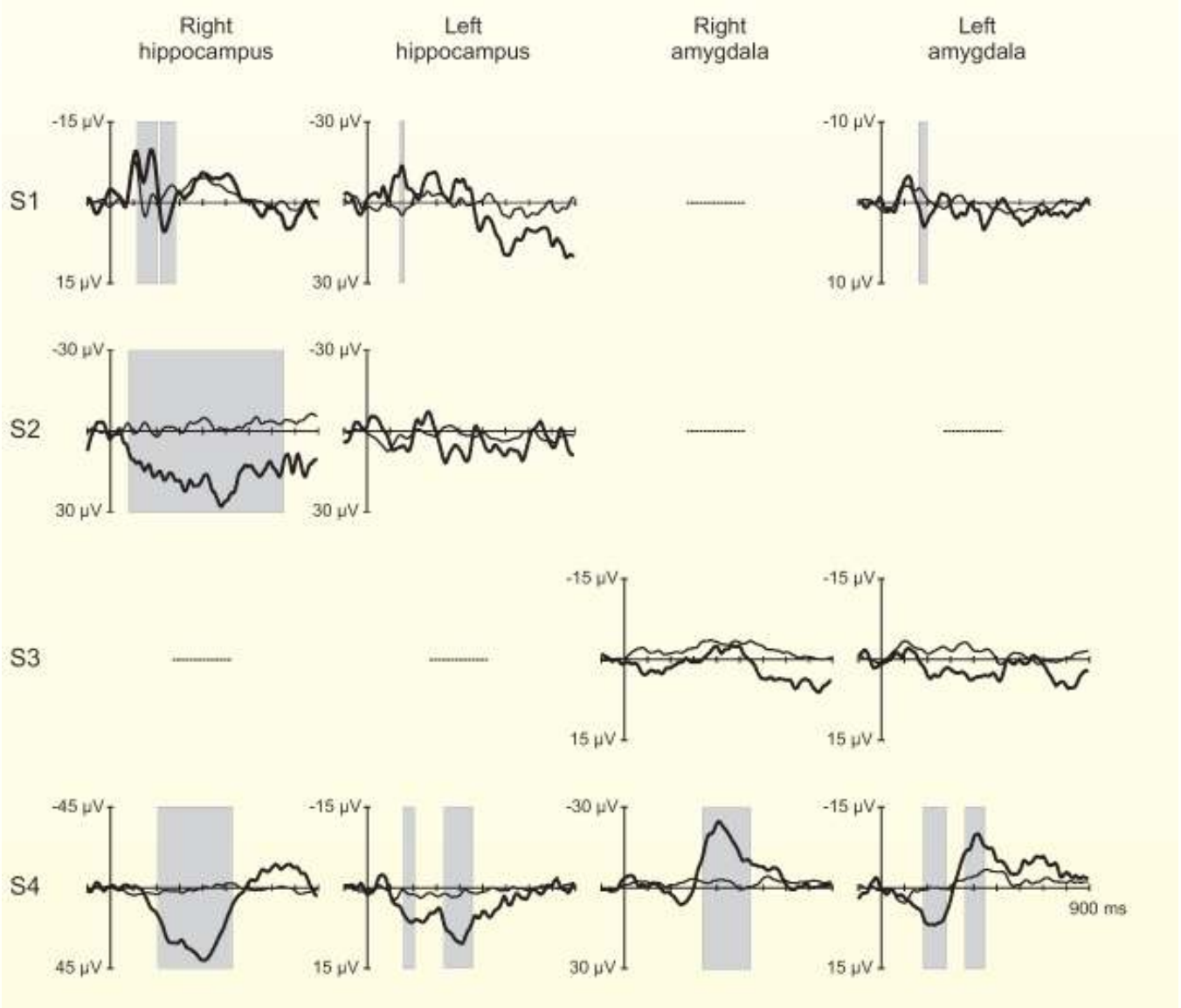
- we recorded *event-related potentials to non-attended auditory stimuli* in candidates for epilepsy surgery
- we used *depth electrodes aimed at the amygdalo-hippocampal area*
- we found *significant differences between responses to frequent and infrequent (or deviant) stimuli*

Temporomesial responses to standard and deviant tones

standard ~
thin line

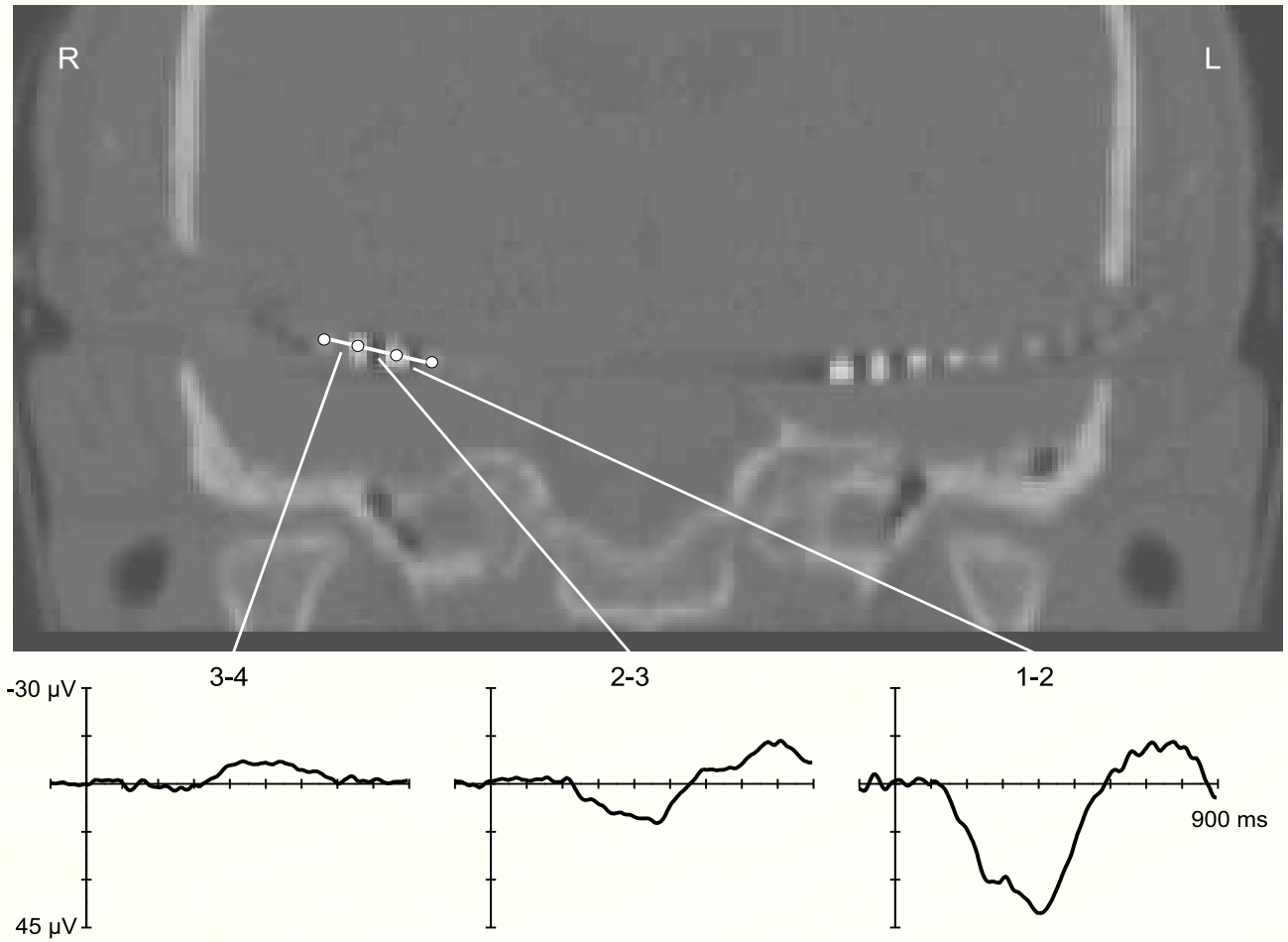
deviant ~
thick line

grey bars ~
$p < 0.05$



Responses to deviant stimuli recorded in one subject.

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

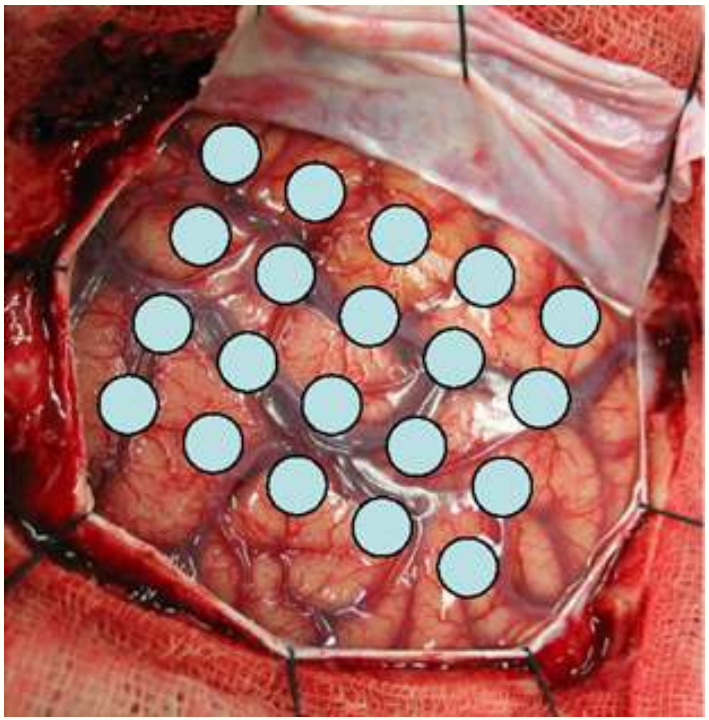


Summary

- *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