

Quadrimodal localisation of epileptic focus using simultaneous EEG, MRI and PET imaging

Frédéric Grouiller¹, Suzanne Heinzer², Bénédicte Delattre^{1,2}, François Lazeyras¹, Giannarita Iannotti^{3,4}, Laurent Spinelli³, Francesca Pittau⁵, Margitta Seeck³, Osman Ratib¹, Maria Isabel Vargas¹, Valentina Garibotto¹, and Serge Vulliémot³

¹Department of Radiology and Medical Informatics, Geneva University Hospital, Geneva, Switzerland, ²Philips AG Healthcare, Zürich, Switzerland, ³EEG and Epilepsy Unit, Department of Neurology, Geneva University Hospital, Geneva, Switzerland, ⁴Functional Brain Mapping Laboratory, University of Geneva, Geneva, Switzerland

Target audience: neuroscientists, engineers, neuroradiologists and epileptologists.

Purpose: In patients suffering from pharmaco-resistant focal epilepsy, resection of the epileptic focus can lead to seizure-freedom or significant improvement in cases where the epileptic focus can be established. The localisation of the epileptic focus relies on structural and functional brain imaging and multimodal concordance is associated with a better post-operative outcome. The existence of epileptogenic lesions detectable on structural MRI and the presence of focal hypometabolism on FDG-PET, especially after fusion with MRI are widely accepted localising findings. In addition other tools for localising epileptic activity, such as EEG-based electric source imaging (ESI) and simultaneous EEG and functional MRI (EEG-fMRI) are increasingly used. We here report the feasibility to record in a single session combined EEG-PET, MRI, EEG-fMRI and ESI using high-density EEG and a PET-MRI hybrid scanner.

Methods: Ten patients (mean age = 34 y.o., range = 10-56 y.o.) with pharmaco-resistant epilepsy benefitted from this multimodal recording. EEG was recorded at 1kHz using an MR-compatible high-density (256 electrodes) EEG system (Electrical Geodesics Inc., Eugene, Oregon). PET and MRI images were acquired using a hybrid PET/MR scanner (Philips Ingenuity TF PET/MR). This device consists of the Ingenuity Time-of-Flight PET and the Achieva 3T X-series MRI linked through a single patient table, allowing for MRI and PET imaging in the same session.

Data acquisition:

(1) EEG-fMRI: After installation of the 256 electrodes cap, simultaneous EEG-fMRI was recorded during 20 minutes while the patient was at rest with eyes closed. The EEG acquisition was synchronized to the MRI clock to facilitate removal of gradient artefacts. Six hundred functional images were acquired using T₂*-weighted single-shot gradient echo echo-planar images with the 8channels head coil (TR=1984ms, TE=30ms, voxel size=1.78x1.78x3mm³, 32 slices).

(2) FDG-PET with EEG monitoring: The PET-FDG tracer was injected intravenously. During the 30 minute of tracer uptake, the patient was at rest under EEG monitoring in order to document potential subclinical epileptic seizures that could cause false normalization of the interictal metabolism. At the end of the uptake, the EEG cap was removed to allow for a full epilepsy imaging protocol (some sequences are not compatible with the EEG cap) and improve comfort. A fifteen minutes PET scan was recorded.

(3) A full MRI clinical protocol for epilepsy including 3D-T1, 3D FLAIR, coronal T2, DTI, ASL and attenuation correction (atMR) were finally acquired in coregistration with the PET acquisition.

Analysis:

(1) EEG-fMRI: EEG was corrected for gradient and pulse-related artifacts using moving averaged template subtraction method. An experienced neurophysiologist manually detected interictal epileptiform discharges (IEDs). If few or no spikes were found during the 20 minutes of simultaneous recording, the presence of the patient-specific epileptic topographic map used for ESI was quantified by means of correlation-based fitting¹. The IEDs timing or the time course of the topography-based correlation was then convolved with the canonical hemodynamic response function and used as a regressor for the fMRI analysis. Haemodynamic changes correlated to interictal epileptiform discharges or to the presence of epileptic-specific EEG topography were detected.

(2) PET: high-resolution Time-of-Flight reconstruction was performed using the coregistered MR-based attenuation correction (atMR)². Visual interpretation and voxel-based analysis were used to identify areas of hypometabolism.

(3) Visual detection of MR structural abnormalities.

(4) EEG acquired at rest during PET-FDG tracer uptake was used for Electric Source Imaging (ESI)³. ESI was performed after spike detection and averaging using the individual head model derived from the 3D T1 and a linear distributed inverse solution.

Results: The whole multimodal recording could be performed in two hours of scanner time. This single-session quadrimodal imaging provided reliable interictal clinical data with good patient comfort. In all patients, we obtained concordant results of at least two modalities that were also concordant with electro-clinical ictal semiology.

Discussion & Conclusion: The whole multimodal recording could be performed in a single session in less than two hours and it was well tolerated by the patients. This single-session was able to replace four separated exams usually performed during epilepsy presurgical evaluation. Furthermore, exposition to radiations was reduced compared to the use of PET-CT. Additional functional mapping of eloquent cortex (motor, language) could be added in individual cases with little duration increase. This multimodal imaging could help in localizing the epileptic focus, reduce the need of intracerebral EEG recording and improve the surgery outcome. This new procedure may improve significantly the workflow and decrease the cost of presurgical epilepsy evaluations.

References:

1. Grouiller F., Thornton R.C., Groening K. et al. With or without spikes: localization of focal epileptic activity by simultaneous electroencephalography and functional magnetic resonance imaging. *Brain*. 2011;134(Pt 10):2867-2886.
2. Garibotto, V., Heinzer S., Vulliémot S. et al. Clinical applications of hybrid PET-MRI. *Clin Nucl Med*. 2013;38(1):e13-18.
3. Brodbeck V., Spinelli L., Lascano A.M. et al. Electroencephalographic source imaging: a prospective study of 152 operated epileptic patients. *Brain*. 2011;134(Pt 10):2887-2897.

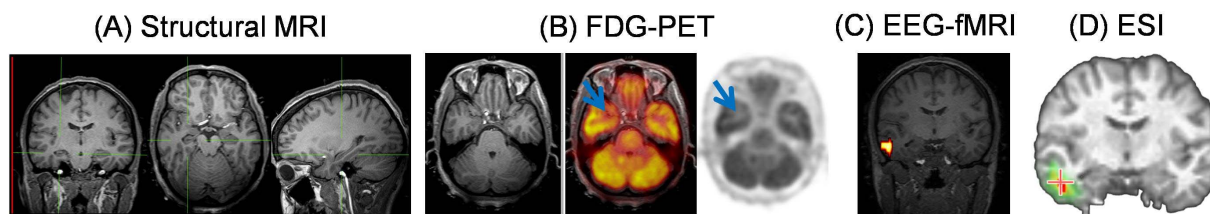


Figure 1: Quadrimodal results for a patient suffering from right temporal lobe epilepsy. (A) Right hippocampal sclerosis in structural MRI. (B) Right temporal hypometabolism in FDG-PET. (C) BOLD activation in right temporal lobe. (D) Electric source in right temporal lobe.