Stereotactic Electroencephalography Is a Safe Procedure, Including for Insular Implantations

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BACKGROUND: **In some cases of drug-resistant focal epilepsy, noninvasive presurgical investigation may be insufficient to identify the ictal onset zone and the eloquent cortical areas. In such situations, invasive investigations are proposed using either stereotactic electroencephalography (SEEG) or subdural grid electrodes. Meta-analysis suggests that SEEG is safer than subdural grid electrodes, but insular implantation of SEEG electrodes has been thought to carry an additional risk of intraparenchymal hemorrhagic complications. Our objectives were to determine whether an insular SEEG trajectory is a risk factor for intracranial hematoma and to report the global safety of the procedure and provide some guidelines to prevent and detect complications.**

METHODS: **In a retrospective analysis of a surgical series of 525 consecutive procedures between 1995 and 2015, all electrodes were classified according to their insular or extrainsular trajectory. All complications were classified as major or minor according to their potential consequences regarding patient neurologic status.**

RESULTS: **Four intraparenchymal hematomas, all related to extrainsular electrodes (4/4974; 0.08%) were reported; no hematoma was found along insular electrodes (0/1042; 0%). There were 8 major complications (1.52%): 7 intracranial hematomas (1.33%) and 1 case of meningitis. Two patients had long-term neurologic impairment (0.38%), and 1 death (not directly related to the procedure) occurred (0.19%). Eleven minor complications (2.09%) were encountered, including broken electrode (1.52%), acute pneumocephalus (0.38%), and local cutaneous infection (0.19%).**

CONCLUSIONS: **SEEG is a safe procedure. Insular trajectories cannot be considered an additional risk of intracranial bleeding.**

INTRODUCTION

In some cases of drug-resistant focal epilepsy, phase 1 noninvasive presurgical investigation may be insufficient to clearly identify the ictal onset zone and the eloquent cortical areas. In such situations, phase 2 invasive investigation, including intracranial electroencephalography (EEG) recordings, may be proposed.[1] Implantation of subdural grid electrodes is a very popular technique that has been considered as a reference technique.[2] This technique is suitable for providing superficial hemispheric cortical recordings; however, interhemispheric or temporomesial electrode placement can be difficult and can lead to adverse effects.[3] Moreover, this invasive technique cannot record the bottom of sulci or the insula and may lead to complications, such as infections, intracranial hemorrhages, and elevation of intracranial pressure, which are encountered in 1%–4% of cases.[4]

Stereotactic electroencephalography (SEEG) is another way to obtain intracranial EEG. This technique, which uses depth electrodes, was developed in the second half of the 20th century in Western Europe and offers the possibility to accurately explore mesial structures, deep sulci, and insula and is becoming increasingly popular worldwide. A recent meta-analysis[5] provides strong data regarding the safety of SEEG based on a systematic review of all published complications.[6-35] However, published data related to the possible risk factors for complications are lacking.

Key words
- Drug-resistant
- Epilepsy
- Epilepsy surgery
- Focal epilepsy
- Postoperative complications
- Stereotactic surgery

Abbreviations and Acronyms
CT: Computed tomography
EEG: Electroencephalography
MRI: Magnetic resonance imaging
SEEG: Stereotactic electroencephalography

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In patients with drug-resistant epilepsy in whom phase 2 investigation is necessary, the implication of insula is a very common issue.[36] Seizures spreading between frontal or temporomesial regions and the insula are a common challenge, and SEEG is the only way to investigate these structures with a high temporal resolution. Moreover, insular seizures can have a clinical presentation very similar to frontal, parietal, or temporomesial seizures. Most SEEG investigations are performed because of a possible temporal or frontal localization of the epileptogenic zone and thus usually require the implantation of at least 1 electrode in the insula. This can lead to important therapeutic implications.[37] Historically, these insular electrodes were considered to be associated with a high vascular risk, owing to the proximity of the dense vasculature of the insulo-opercular region. Consequently, until 2000, this region was considered to be nonaccessible to SEEG electrodes.[38-40] Nevertheless, this risk is still mentioned in very recent publications,[5] although it is not supported by any scientific evidence,[16,17,21,22,29] as the safety of these particular electrodes has never been specifically studied. The primary objective of the present study was to determine whether an insular trajectory during SEEG is a risk factor for intracranial hematoma. A secondary objective was to provide safety data from 525 consecutive SEEG procedures to identify risk factors and to propose strategies for the prevention, detection, and management of complications.

MATERIALS AND METHODS

This study was a retrospective analysis of a surgical series based on the review of a prospectively filled database.

Patients

Between 1995 and 2015, 525 SEEG procedures were consecutively performed in 459 patients including children and adults in the Department of Neurosurgery of the Pierre Wertheimer Hospital for Neurology and Neurosurgery in Lyon, France. All patients had drug-resistant focal epilepsy and underwent a noninvasive (phase I) work-up to determine their eligibility to undergo SEEG. All patients underwent magnetic resonance imaging (MRI) and scalp EEG. Most cases benefited from a neuropsychological evaluation and fluorodeoxyglucose positron emission tomography. In a few selected patients, ictal and interictal single photon emission computed tomography, magnetoencephalography, Wada test, or functional MRI was also performed. SEEG was offered to patients fulfilling the following criteria: 1) conclusion of a phase I noninvasive investigation suggesting the possibility of a single epileptogenic zone, the extent of which could be delineated by SEEG and for which surgical resection could be performed with an appropriate benefit-to-risk ratio; 2) the suspected epileptogenic zone was extratemporal with fully concordant electroclinical findings in the absence of a well-delineated brain lesion (e.g., cavernoma or dysembryoplastic neuroepithelial tumor); and 3) the suspected epileptogenic zone was temporal in the case of normal MRI or of MRI abnormalities associated with discordant electroclinical or fluorodeoxyglucose positron emission tomography findings. Potential factors affecting the risk of hematoma were prospectively entered in the database, including sex, age, previous neurosurgery, previous SEEG, total number of implanted electrodes, number of insular electrodes, type of trajectory (oblique or orthogonal), perioperative angiography (vs. preoperative magnetic resonance imaging), type of surgical planning (manual or software), and years of expertise of the operating surgeon (M.G.).

SEEG Procedure

Of 525 SEEG procedures, 467 were performed according to the Talairach orthogonal methodology. The stereotactic frame (Talairach frame) is set up under general anesthesia. Stereotactic digital subtraction angiography, including selective catheterization of the relevant common carotid arteries, is then performed. Both digital subtraction angiography and MRI are then coregistered so that avascular trajectories reaching the anatomic targets can be found. Digital subtraction angiography is used as reference for the stereotactic space so that maximal vascular safety is favored over accuracy of brain targeting. Twist drill holes are then created with a 2.1-mm drill bit in the skull for each trajectory. The dura mater is perforated by means of low-current monopolar coagulation. An anchor bolt is screwed into each hole, through which the electrode is implanted. The anchor bolts (Dixi Medical, Besancon, France) have an external diameter of 2.45 mm. Each electrode (Dixi Medical) has 5–18 contacts. Dimensions of each contact are 2 mm in length and 0.8 mm in diameter, and the intercontact spacing is 1.5 mm. Positioning of each electrode is controlled by perioperative x-rays. Usually, 10–15 electrodes are implanted in a single patient, unilaterally or bilaterally. Details of the technique with illustrations are presented in a previous publication.[41]

In 58 patients, oblique (instead of strictly orthogonal) trajectories were required. For all patients, the calculation of trajectories was performed using a computer-assisted robot (neuromate; Renishaw; Gloucestershire, United Kingdom) and its related software (VoXim; IVS Technology GmbH, Chemnitz, Germany). The rest of the procedure was similar to the above-described procedure. The patients received routine prophylaxis with 3 g cefuroxime (only during surgery, not during the recording period). All procedures were performed by the same surgeon (M.G.). All patients underwent postoperative imaging within 24 hours after SEEG (computed tomography [CT] scan up to 2006 and MRI 2006 and beyond). The exact location of each electrode contact and determination of whether they were insular or not were based on this postoperative imaging.

Indications for Insular Exploration

Insular implantations were performed in cases in which an insular ictal onset zone was suspected or when the insula was suspected to be involved within the epileptic network. For each of these patient, 0–5 electrodes were implanted in the insula.

Classification of Complications

All complications were prospectively collected and registered in a database dedicated to the follow-up of epilepsy surgeries. In cases of intracranial hematoma, we determined whether or not this was related to an operculoinsular trajectory. Complications were then divided into 2 categories: major and minor complications. A complication was classified as major when considered at risk to lead to a permanent neurologic impairment or death.