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COMPREHENSIVE REVIEW

Electrophysiological technical procedures

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Summary The reliability of the interpretation of SEEG data depends entirely on the technical quality of the acquisition recording. Digitalization of data and the development of computer technology, over the last 20 years have transformed electrophysiological procedures. Recording equipment must be able to record concomitantly clinical events and brain electrical activity. Recording is carried out during wakefulness and sleep and with use of various activation methods (hyperventilation, intermittent photic stimulation). Intracerebral electrical stimulations (with low and high frequency) and the acquisition of evoked potentials complete the SEEG exploration. This chapter will discuss the characteristics of video-EEG recording equipment, procedures for acquisition and creation of SEEG montages, technical recording and activations, procedures of intracerebral electrical stimulations and the acquisition of evoked potentials.
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Introduction

While the methodology of stereoencephalography (SEEG) as elaborated by Jean Bancaud and Jean Talairach [2—4] remains the base for current practice, video-EEG monitoring of epileptic patients has been greatly improved during the last 20 years by the development of computer-based technology. Concomitantly recorded clinical events and brain electrical activity are permanently stored and can be reviewed freely [26,32,36].

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Through the benefits of computerized technology, montage reformatting, filters and gain settings can be changed during the reviewing session, allowing for greater flexibility in reading the EEG. It is recommended to view the recording first without filtering [12]. However, the reliability of the interpretation of the SEEG data depends a great deal on the technical quality of the acquisition recording. Possible sources of artifact in the background activity must be quickly recognized during the SEEG session so that they can be eliminated as soon as possible after acquisition. The referential electrode is chosen from among leads considered to be ''neutral'' with respect to the intra-cortical leads.

Simultaneous video recording of the patient and EEG devices must therefore provide specific characteristics, in particular in terms of resolution, sampling and acquisition filters. Recording is carried out during wakefulness and sleep and with various activation methods. Intracerebral electrical stimulations and the acquisition of evoked potentials complete the SEEG exploration and provide essential data for analysis of the epileptogenic network and for functional mapping.

This chapter will discuss:

- characteristics of video-EEG recording equipment;
- procedures for acquisition and creation of SEEG montages;
- technical recording and activation procedures;
- procedures of intracerebral electrical stimulations;
- acquisition of evoked potentials.

Characteristics of EEG-video recording equipment

The acquisition system must have at least 128 channels and ideally 256 channels. A minimum of 128 channels is recommended for intracranial investigation by SEEG [35]. When the procedure exploration involves the implantation of lengthy electrodes with many recording contacts, especially in the case of a frontal implantation, or when a large number of depth electrodes is implanted, the total number of contacts will likely exceed the 128 existing recording channels and consequently some leads cannot be simultaneously recorded. In this case, contacts are selected according to their site in the brain and the aspect of recorded intracerebral electrical activity. It is possible to eliminate the less informative contacts, such as those located in the white matter. Ideally, 256 channels should be preferred in order to record all the contacts of all implanted electrodes without having to choose.

The concept of SEEG implies simultaneous and synchronized video-recording relating electrical brain activity to the clinical state of the patient. Most epilepsy surgery centers use intracranial EEG equipment that allows simultaneous recording of electrical brain activity and clinical symptomatology, thus facilitating the establishment of reliable anatomo-electro-clinical correlations between electrical changes and seizure symptoms [35].

The reviewing of synchronized data is essential for better understanding of the epileptogenic zone and propagation [5]. Video equipment is used to analyze detailed and global seizure semiology. Mobile cameras placed in the recording room must be synchronized with the EEG recording software. The video should have a wide angle filming the patient as a whole, as well as a close-up on the face and/or the area affected by the seizures [21].

Seizure semiology is analyzed in detail, as this reflects the dynamic spread of the seizure. Individual elements and overall aspect of semiology provide crucial information to the likely brain networks involved [5]. As nocturnal sleep tends to activate seizures, especially in children, it is essential to analyze this carefully. Detailed analysis of seizure semiology, including features not reported by the patient or his family [1,38] is a key element in evaluation. Video equipment must be suitable for viewing in dim lighting conditions and include infrared cameras [1]. However, video-recording should not preclude direct observation during and after the seizure with appropriate peri- and post-ictal examination.

Procedures for acquisition and creation of SEEG montages

Seizure onset is very often characterized by a low voltage fast discharge, and therefore high frequency rhythms have to be recorded in the correct way. According to Shannon's theorem, the sampling of the signal must be twice greater than the highest of interest [34]. It is necessary to filter for frequencies above the Nyquist limit (corresponding to half of the sampling frequency). To correctly analyze the onset of a seizure, sampling frequency must be at least 256 Hz, and ideally 512 Hz. In addition, numerous studies recommend careful analysis of interictal high frequency activity (80—250 Hz) (ripples) or very high frequencies (250—500 Hz) (fast ripples) [15,16,43]. It is thus important that the signal be acquired with sufficient high frequency in order to study these rapid oscillations, at least at 512 Hz, or even 1024 Hz, at least during a part of SEEG exploration including sleep.

Use of filters should be applied with caution. In particular, it is preferable not to filter the signal at 50 Hz (or 60 Hz) during acquisition. Indeed, the presence of 50 or 60 Hz activity can suggest an electrode dysfunction or high impedances [30] and as such is useful information. Such filters should be reserved for reviewing the SEEG recording. During intracranial EEG, as for surface EEG, recording is carried out in a bipolar manner between an ''active'' electrode and a so-called ''inactive'' (reference) electrode. The placement of the reference electrode is therefore fundamental: in scalp EEG it is difficult to find an inactive electrode, whereas this is easier in intracranial EEG. Indeed, leads that are located in the white matter capture very few signals compared to the intra-cortical leads and can therefore be considered as practically ''inactive''.

The contacts that are located in the bone (tissue of lower conductivity), can also be used as reference. Nevertheless, care must be taken because these leads may be in contact with the cortex (and thus influenced by electrocorticographic activity) or with skin (and thus display artefacts due to electromyographic activity). When any contact is located in white matter or in bone, it will be recommended to choose a scalp EEG electrode as reference, for example the vertex electrode, because the scalp EEG signal is of much lower amplitude than the intracranial signal.

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