



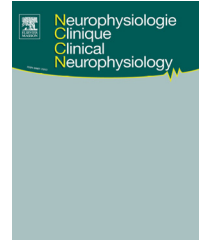
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COMPREHENSIVE REVIEW

Surgical technique

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Summary In SEEG, as for any surgical procedure, the benefit/risk ratio is a key-point. This implies rigorous clinical practice in terms of indication, information delivered to the patient, and surgical technique. Numerous technical options may be used to achieve this goal. All are valuable, as long as they are executed with rigor and consistency. Intracranial bleeding represents the main risk of the procedure (1–4% of cases). The procedure also carries a risk of infection (0.8%), death (total of 6 reported cases in all the literature, <0.002%), and of minor

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and transient side effects. SEEG is performed under general anesthesia. MRI is the gold standard morphological imaging, used for targeting and for trajectory calculations. It is strictly necessary to use some form of vascular imaging to minimize the peroperative bleeding risk. SEEG can be performed on a frame-based, or frameless, basis, using stereotactic instrumentation, or a neurosurgical robot. Literature does not provide any data in favour of one of these techniques compared to the other. The minimal acceptable bone thickness is considered to be 2 mm. Postoperatively, as soon as any non-preexisting neurological deficit is noticed, neuroimaging must immediately be performed. It is recommended to perform a postoperative imaging during the 24 hours after implantation. The numerous current possibilities, in terms of imaging and technology, give rise to many possible stereotactic strategies for performing SEEG implantation. None of these strategies can be considered as superior to the other. The guarantee of the best possible result is provided by the care with which these procedures are done.

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Introduction

In SEEG, as for any surgical procedure, the benefit/risk ratio is a key-point. This implies rigorous clinical practice in terms of indication, information delivered to the patient, and surgical technique. The basic principles of SEEG are simple: the method consists of stereotactically reaching pre-defined cerebral targets (previously defined through multi-disciplinary team discussion), while avoiding any vascular lesions, since postoperative hematoma is by far the worst complication [13,20].

Numerous technical options may be used to achieve this goal. All are valuable, as long as they are executed with rigor and consistency.

General data: what should be avoided

While post-implantation intracranial hematoma may be considered as the most severe complication of SEEG, intracranial bleeding is not the only procedural morbidity that can be encountered [4,43,44]. The various adverse events reported for patients undergoing SEEG can be summarized as follows (Tables 1 and 2).

Major adverse events

In two large series of respectively 500 [6] and 525 [5] procedures with a total of 6496 and 6016 implanted electrodes, the major complication rate was respectively 2.4% and 1.52%.

Intracranial bleeding represents the main risk of the procedure. It occurs in 1 to 4% of the cases [5,6,24,27,36]. It can be located extradurally, subdurally, or intracerebrally.

Bleeding may occur during insertion of the intracranial electrodes when there is contact between a vessel and the electrode (Fig. 1). Intracranial bleeding may also occur when electrodes are removed, as this may cause friction between the electrode and the vessel if they are too close. The hemorrhagic risk calculated per electrode was estimated to be

0.18% (with an intraoperative cerebral angiography procedure) and 0.70% (with an MRI angiography procedure) in recent series [6]. Intracerebral hematomas may be symptomatic or asymptomatic depending on their location and half of them require surgery (craniotomy, evacuation of the clot, external CSF drainage). This can lead to a permanent neurological impairment in one third of cases, and even to death [7].

The procedure carries a risk of infection, either superficial, or deep-seated: in a recent meta-analysis [27], 28 infectious complications were reported (prevalence 0.8%), mainly meningitis and brain abscesses.

At least six deaths have been reported in the whole of the published literature on SEEG (over 2500 reported patients). One occurred as the consequence of severe hyponatremia with massive brain edema [6] and a second was due to an atypical delayed intracranial hematoma, which occurred 8 days after the implantation procedure [12]. Two were attributed to intracranial hematoma [20,35] and two other were reported as a complication of ventriculography performed as part of the surgical planning [31].

Permanent neurologic deficits have been reported in the literature [28] with an overall prevalence of 0.6%. These can be due to hemorrhagic complications, or brain edema especially when the electrode trajectory is in a functional area.

Minor adverse events

Not infrequent minor and transient side effects are observed during SEEG.

In the first few days after SEEG implantation, the following effects have been reported:

- masticatory pain, caused by electrodes that pass through the temporal muscles and the masseters. This essentially concerns electrodes which explore the temporal pole during orthogonal implantations;

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